

NEBRASKA GEOLOGICAL SURVEY

G. E. CONDRA, STATE GEOLOGIST

Bulletin I, Second Series

The Stratigraphy
of the Pennsylvanian System
in Nebraska

By G. E. CONDRA



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PREFACE

This volume is a report on the oldest and probably the most important system of rocks in Nebraska. It is based on several years of field study in which it was found necessary to extend the investigation into Iowa, Missouri, and Kansas in order to determine the correlation of strata.

The report is in line with publications which have been made in Missouri, Iowa, and Kansas, and on which other states are working, the purpose being academic rather than economic. It should contribute somewhat to the content of knowledge in geology, and is intended to serve as a basis for future Nebraska research relating to paleozoology, paleobotany, and the clay, stone, and water resources of the Pennsylvanian formations.

Although this volume is on stratigraphy, describing in detail the small units of the formations, it may have some direct economic bearing in the stone and clay resources, and in showing, to some extent, where to prospect for oil and gas.

Reports, some educational, others on the economic relations of the Pennsylvanian beds, are in preparation for publication under the titles: Faunal Studies (five bulletins), Stone Resources, Clay Resources, Coal Deposits, and The Oil and Gas Possibilities of Nebraska.

This volume is issued under the Second Series, because all of the earlier reports of the Geological Survey are out of print, and because, under the reorganization of the Survey, due to legislative enactment, it is planned to publish on some of the subjects which have been covered in the earlier volumes.

ACKNOWLEDGMENTS

The writings of many geologists have been consulted and acknowledged in the preparation of this report. Among those whose publications have contributed most are: G. I. Adams, H. F. Bain, J. W. Beede, G. C. Broadhead, C. H. Girty, C. N. Gould, F. C. Greene, Erasmus Haworth, Henry Hinds, C. R. Keyes, Raymond C. Moore, Chas. S. Prosser, G. L. Smith, J. L. Tilton, J. E. Todd, J. A. Udden, and David White.

The author is indebted to many for assistance. Professors N. A. Bengtson, Carl O. Dunbar, and R. J. Scarborough rendered helpful service in the survey and correlation of the unit subdivisions. E. L. Edwards, Von Russom, Glen Ruby, Richard Hughes, Elmer Ulstrom, M. E. Upson, and L. W. Hewitt assisted in the field work. Allen Tillotson, Elmo Adams, M. E. Upson, and S. W. Brock did the drafting. A. J. Luebs and J. E. Upp typed the report.

Representatives of the Iowa, Missouri, and Kansas Surveys participated in the correlation of members across state lines. Most of the new names selected for the bed units were passed upon by Miss Grace M. Wilmarth of the U. S. Geological Survey.

DEDICATION

This volume is dedicated to the memory of pioneer geologists — Owen, Swallow, White, Hall, Meek, Hayden, Worthen, Shumard, Broadhead, and others — who, under difficult and trying conditions, accomplished much in the study of the Pennsylvanian formations of Nebraska and adjacent areas and established a basis for later geological survey and research.

PENNSYLVANIAN SYSTEM

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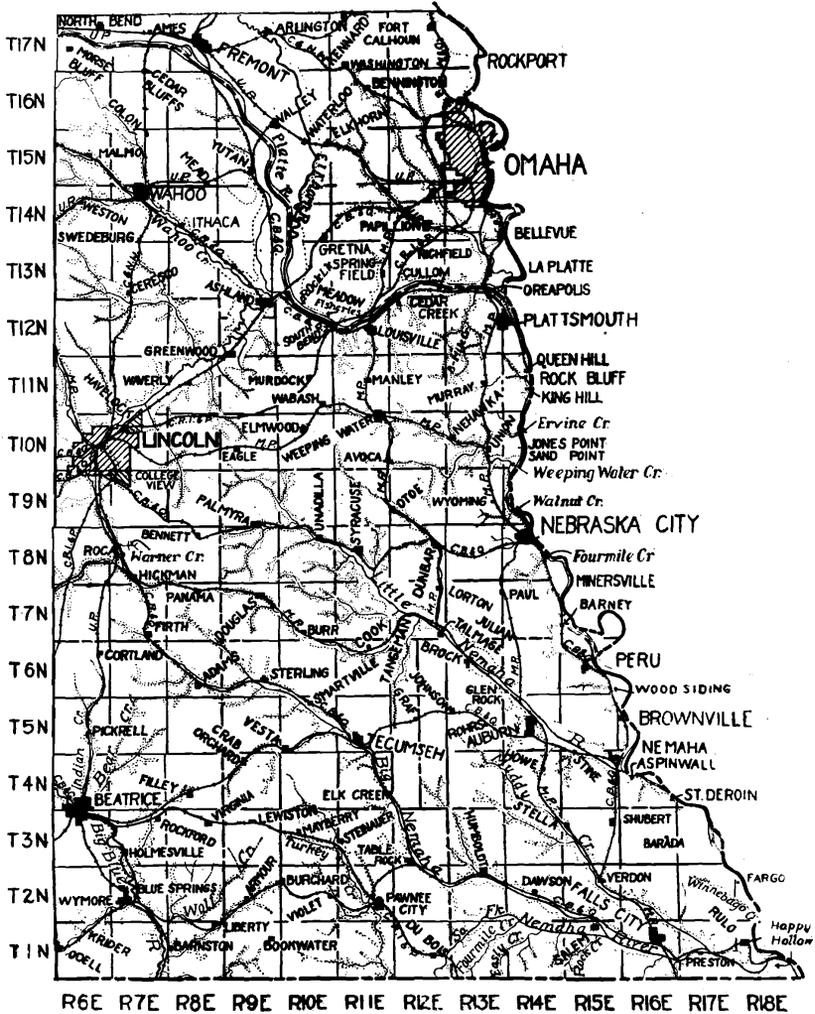
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NEBRASKA GEOLOGICAL SURVEY



Map showing the towns, railroads, and drainage-ways in the Pennsylvanian area of southeastern Nebraska.

THE STRATIGRAPHY OF THE PENNSYLVANIAN SYSTEM IN NEBRASKA

By G. E. CONDRA

Rock Systems of the Carboniferous Periods. The term Coal Measures, or one of similar meaning, has been used in England and western Europe for a century or more to denote an important association of coal-bearing strata. The name Carboniferous System was proposed in 1839 by Phillips of England for the strata between the Devonian and Triassic systems. Later this assembly of strata in Europe was separated into two series, the Lower Carboniferous and the Upper Carboniferous, the latter known also as the Coal Measures. In 1841 Murchison gave the name Permian to a series of rocks exposed in the Province of Perm, Russia. Rogers, in 1838, applied the name Coal Measures to the coal-bearing beds of Pennsylvania.

The Carboniferous System, early accepted by American geologists, came to include the Sub-carboniferous, Coal Measure, and Permian series. Professor Winchell proposed the geographic name, Mississippian for the Sub-carboniferous in 1869, and Professor H. G. Williams gave the name Pennsylvanian to the Upper Carboniferous or Coal Measures in 1891. Many geologists now hold that each of the three series of rocks formerly referred to the Carboniferous period should be ranked as a system.

Boundaries of the Pennsylvania System. In much of the western part of the central area of the United States the lower boundary of the Pennsylvanian is definitely set off from the Mississippian and older beds by faunal break, lithologic change, and erosional unconformity. The system overlaps the Devonian, Silurian, and the upper Ordovician beds on the east and northeast and may rest upon the Ordovician in parts of Nebraska west of the granite ridge. The upper boundary of the system has not been decided beyond question. Many regard the Cottonwood Limestone, which persists over

a wide area and easily recognized at most places, as the upper limit. Some would make this boundary lower, at the Neva Limestone, and others, with whom the writer agrees, would make it higher, probably at the Wreford Limestone. In this report the contact of the Pennsylvanian and Permian is placed at the base of the Cottonwood Limestone in order to conform to the usage of the United States Geological Survey.

Occurrence. The Pennsylvanian rocks are widely distributed in the United States as disconnected provinces. The Western Interior Province extends from north-central Iowa through Missouri, southeastern Nebraska, eastern Kansas, northwestern Arkansas, and Oklahoma to Texas (Figure 1).

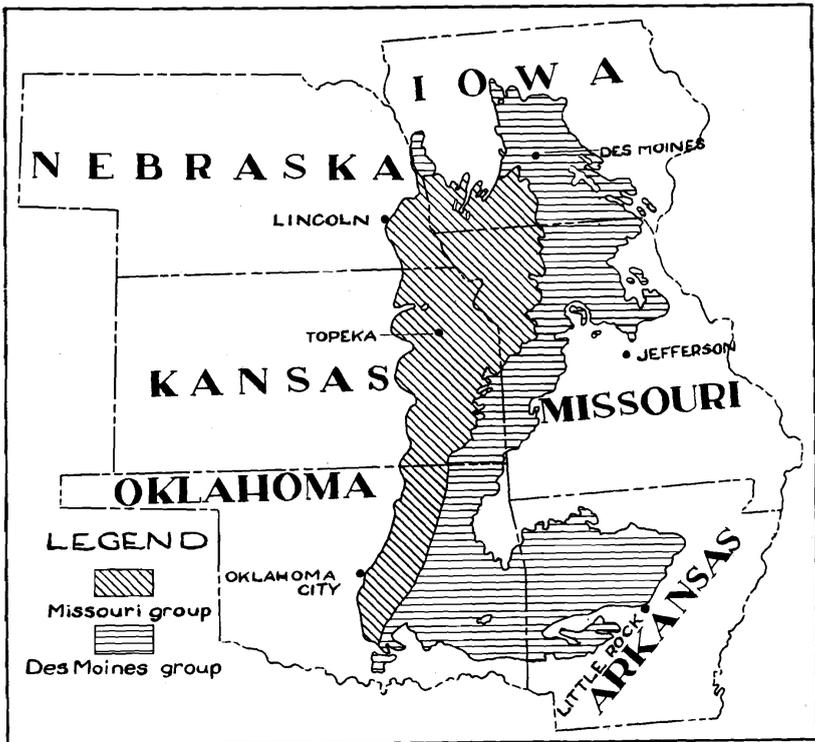


FIGURE 1.—Map showing the outcrop areas of the Des Moines and Missouri groups or systems in the Mid-Continent area.

The Nebraska exposures of the Pennsylvanian beds are in Washington, Douglas, Sarpy, Saunders, Cass, Otoe, Lancaster, Nemaha, Johnson, Pawnee, and Richardson counties (Plate I). They occur principally in valleys where the loess, drift, and other mantling deposits have been eroded, and on the uplands in the southern part of the area where the mantle rock has been removed more generally.

All of Nebraska probably is underlain by Pennsylvanian beds, unless there are buried uplifts in parts of the state from which they have been eroded.

Thickness and Depth. The thickness of the Pennsylvanian System varies much, from a few feet in the northeastern counties to a maximum of about 1,750 feet in Richardson County. In places on the Table Rock and Nehawka anticlines the upper beds of the system have been removed by erosion, leaving a thickness of about 600 feet of the Pennsylvanian beds.

The depth and thickness of the system in most of the western and northwestern counties are not known and will remain a problem until many deep soundings are made. A well drilled to a depth of 5,697 feet in Banner County, and one to 4,400 feet near Agate, Sioux County, did not reach the top of the Pennsylvanian System. The Minnelusa Sandstone of this system was reached at a depth of less than 2,700 feet in the Chadron Dome northeast of Chadron, Dawes County.

The Pennsylvanian beds are deep seated in much of central Nebraska, yet they are much nearer the surface and probably thinner in the southern part of the state, west of the granite ridge, than was formerly supposed.

Lithology. The Pennsylvanian System in Nebraska is largely formed of shale, limestone, and sandstone in thin to thick beds differing in color and induration, the rank in volume of the contents for the system as a whole being in the order just named. There are marked differences in the lithology of the formations, although there is a noticeable repetition of the shale-limestone sequence. There are few sandstones.

Carbonaceous shale and thin coal beds occur at different levels in the general section, but they are relatively unimportant as to volume. The lithologic character of the formations and members of the system are described elsewhere in this report.

Flora and Fauna. The Pennsylvanian beds of Nebraska are poor in flora, having only a few horizons in which plant remains in considerable numbers are found. They have rich invertebrate faunas and scant vertebrate remains.

This volume does not cover the paleontology of the Pennsylvanian beds because faunal studies, made of the small units of the system, are to be published as separate reports.

Subdivisions of the Pennsylvanian. In 1855, Swallow loosely subdivided the Coal Measures (Pennsylvanian) as the "Upper, Middle, and Lower Coal Series." Broadhead, in his Missouri River Section in 1865, established a basis for the definition of the subdivisions proposed by Swallow. Later the "Lower" and "Middle" divisions were combined as the "Lower Coal Measures" and two non-geographic names — Upper Coal Measures and Lower Coal Measures — were used for the major divisions of what is now called the Pennsylvanian System.

In 1893, Keyes¹ proposed the names Des Moines "stage" and Missouri "stage" to apply essentially to the "Lower" and "Upper" Coal Measures. These terms, with some modifications, have gained general recognition and the Pennsylvanian System in Iowa, Missouri, Kansas, and Nebraska is now subdivided into the Des Moines and Missouri groups or series.

Some Pennsylvanian strata, older than the Des Moines of Nebraska and adjacent states, occur in the Morrow formation in Arkansas, Oklahoma, and Texas.

Structure. The Pennsylvanian beds of Nebraska are moderately folded, with some faulting. The normal dip is westward, but this is modified by such deformations as the Forest City Basin, Brownville Syncline, Table Rock Anticline, Hum-

¹ Keyes, C. R., Iowa Geol. Survey, Vol. I, pp. 85-114, 1893.

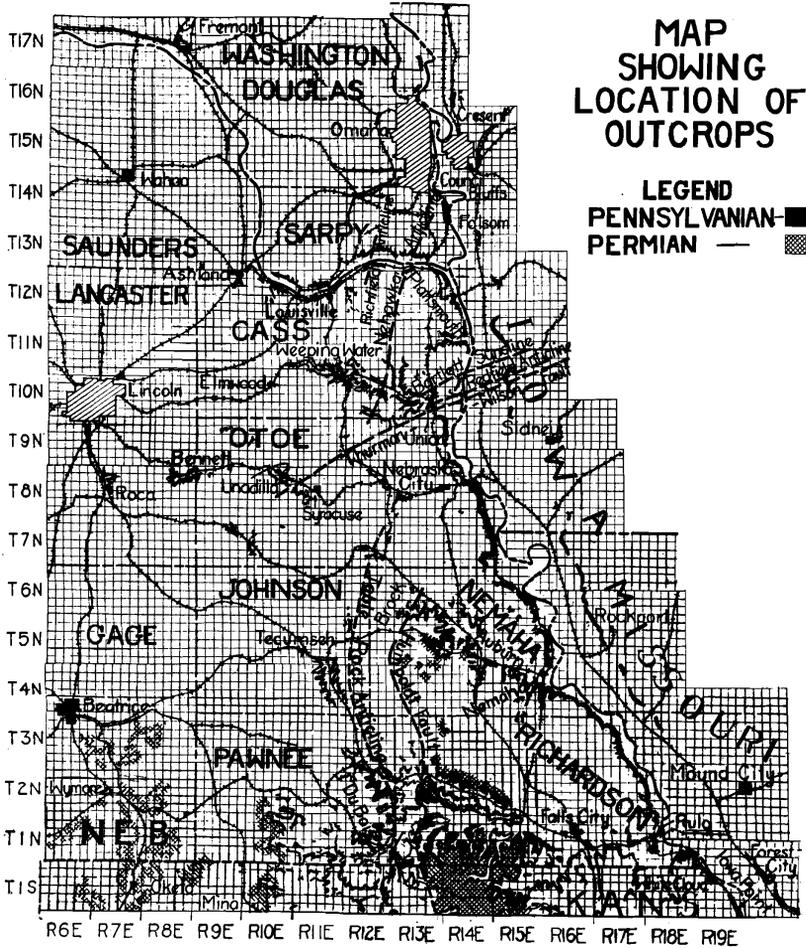


PLATE I.—Map showing the Pennsylvanian and Permian outcrops in southeastern Nebraska.

boldt Fault, Nehawka Anticline, Richfield Anticline, Thurman-Wilson Fault, Redfield Anticline, and the Bartlett Syncline. (Plate 1.)

Although it is generally supposed that the Pennsylvanian beds form a broad, structureless trough between the Mid-Continent and Rocky Mountain areas, there is some apparent error in this deduction as shown by the records of wells drilled the past few years. The beds arch upward in a few places in this distribution, and it cannot be said that they and associated strata do not form other structures or uplifts in this extensive area, beneath the thick mantle of Tertiary and Pleistocene deposits.

The leading deformations of the Pennsylvanian beds of Nebraska are briefly described at this point to serve in the interpretation of data which follow.

Forest City Basin. There is a comparatively deep sag of the Mississippian strata in the vicinity of Forest City, Missouri, extending under a part of southeastern Nebraska. This basin is filled in with the Des Moines series, the top of which dips northwestward to the flanks of the Table Rock and Nehawka anticlines. The beds above the Des Moines Series dip northwestward and westward across the structure basin, beyond which they rise on the above named anticlines.

Brownville Syncline. Dr. G. L. Smith, of Iowa, proposed the name Brownville Syncline for a trough in the vicinity of Brownville, Nebraska. This syncline extends past Nemaha City and probably to or beyond the Big Nemaha Valley. It lies east of the lowest part of the east flank of the Table Rock Anticline.

Table Rock Anticline. This was discovered and named by the writer several years ago. It is a large structure extending from northwest of Talmage southward along Spring Creek, past east of Tecumseh, Elk Creek, and Table Rock, thence southeastward past Du Bois and through Kansas to beyond Wamego and the Kansas River. Its highest point is at the Kansas line where erosion has removed more than 100 feet of Permian beds and cut through the Pennsylvanian down to the top of the Deer Creek Limestone, a vertical dis-

tance in the general section of about 700 feet. In the Kansas Valley, erosion has extended only to the Scranton Shale member.

The Table Rock Anticline is quite regular in form with a low-dipping west flank and steep drops on the east. Its width is about 10 miles. The length in Nebraska is about 40 miles, and the known length in Kansas is 60 miles.

A buried granite ridge, named the Nemaha Mountains by Moore,² is not far below the surface in parts of this anticline. Its depth is about 700 feet at Table Rock, 557 feet near Du-Bois, about 600 feet or less at Seneca, Kansas, and gradually deeper southward through Kansas to near Eldorado. Three wells have been drilled to this granite ridge in Nebraska.

Humboldt Fault. The steep dip of the beds in the east flank of the Table Rock Anticline passes into a fault at places. The maximum displacement is just northwest of Humboldt where there is an upthrow of more than 100 feet on the west.

Nehawka Anticline. This structure, which the writer has described at different times, is well defined near Nehawka. It extends from southeast of Omaha southward and southwestward through Sarpy and Cass counties, into Otoe County. The Pennsylvanian and older beds down to the Pre-Cambrian are involved in the deformation. The details of this, however, cannot be recited in this connection. The anticline is broad and high. Its highest point is thought to be about three miles northwest of Nehawka. The west flank of the structure closes down slowly. The east flank is steeper and broken by terraces.

In places the crest of the Nehawka Anticline has been eroded down to the top of the Stanton Limestone which is thought to be the lowest Pennsylvanian member exposed in Nebraska.

Richfield Anticline. This low arch is shown in the Platte sections south of Richfield. Its axis extends north-south. For further description see the Platte cross section.

² Moore, Raymond C., Oil and Gas Resources of Kansas: Bull. 3, Kan. Geol. Survey, pp. 140-173, 1917.

Relation of the Table Rock and Nehawka Anticlines. Although these structures nearly join, they are set off from each other. Lying in the same general direction and nearly joining, they make a broad up-bend of the beds through the middle of the Pennsylvanian outcrop area of the state, extending into Iowa and Kansas. This condition has importance and should be noted, because it is at variance with the earlier conceptions of the attitude of the beds of this system in Nebraska and northern Kansas.

Thurman-Wilson Fault. This feature extends from Dallas County, Iowa, southwestward to north of Thurman, Iowa, and probably to Nebraska. It was first described by Professor J. E. Todd.³ Dr. G. L. Smith⁴ studied the displacement and confirmed the views advanced by Todd. He estimated the throw of the fault north of Thurman, Iowa, to be about 300 feet, with the uplift on the north. Later Professor John L. Tilton⁵ traced the displacement far northeastward in Iowa and gave it the name of Thurman-Wilson Fault.

Apparently none of the Iowa geologists cited observed the sharp south dip of the beds in this displacement north of Thurman. The writer has seen such, and his observations have been confirmed by others. The Baldwin Brothers, who worked in an old quarry operated on the Howard Limestone, which is exposed just north of where the fault is said to occur, state that the beds here have a strong southeast dip in the direction of the fault line. If this rate of inclination of the strata continues through the fault zone in which there are no exposures, it would account for much of the displacement.

The displacement is very marked. On the south, what appears to be the Brownville Limestone in the Admire member, stands about 20 feet above the level of the Howard mem-

³ Todd, J. E., On the Folding of the Carboniferous Strata in Southwestern Iowa: Proc. Iowa Acad. Sci., Vol. I, p. 61, 1889; Some Variant Conclusions in Iowa Geology, Vol. 13, Proc. Iowa Acad. Sci., p. 184, 1906.

⁴ Smith, G. L., Carboniferous Section of Southwestern Iowa: Iowa Geol. Survey, Vol. XIX, p. 612, 1909.

⁵ Tilton, John L., The Thurman-Wilson Fault Through Southwestern Iowa, and Its Bearings: The Journal of Geology, Vol. XXVII, 1919.

ber on the north. So the amount of displacement here is equal to the thickness of the strata between the Howard and Brownville limestones, less about 20 feet. This interval, as measured on the section across the river in Nebraska, is about 300 feet.

Just how much of the displacement north of Thurman is due to faulting and how much to warping cannot be determined without more than surface study. Apparently there is some faulting here, and it may have more importance than warping, yet only a few miles distant, at Jones Point, on the Nebraska side, all of the deformation except a few feet, can be accounted for by warping.

So far as can be determined, the Thurman-Wilson Fault, represented more by dip than by faulting, extends into Nebraska, past south of Union, north of Otoe, and beyond a point between Syracuse and Unadilla. There may be some faulting along this line in our state, as it seems at places, but there is no conclusive evidence to support a definite conclusion in regard to the amount of displacement.

The writer has used the name Jones Point Deformation for this displacement in Nebraska to apply in a general way to the structure and to include both the arch and the fault if there is such. It is now known that this deformation, as defined by Todd, Smith, Tilton, and others, is a complex structure including the Redfield Arch and the Thurman-Wilson Fault.

Redfield Anticline. This arch, which is just west of the Thurman-Wilson Fault, was named by Leonard⁶ from Redfield, Dallas County, Iowa. Leonard says that the fold brings deeper strata to the surface and that the beds dip in both flanks from the crest of the anticline.

Professor Tilton⁷ in describing the Thurman-Wilson Fault states that parallel to the fault, on its west side, is a slight anticline distinctly seen in Montgomery and Cass counties and that it was described by Leonard as the Redfield Anticline without noting its relation to the fault. It is now evi-

⁶ Leonard, A. G., Iowa Geol. Survey, Vol. VIII, p. 91, 1898.

⁷ Tilton, John L., Iowa Geol. Survey, Vol. XXIX, pp. 298, 299, 1919.

dent that this anticline extends to Nebraska through the Jones Point section where it is better shown than in Iowa.

The Bartlett Syncline. This name is proposed for the shallow trough just north of the Redfield Anticline from exposures east of Bartlett, Iowa, where its depth is 40 feet or more, and the width is 5 or more miles. The syncline extends west of the river, between Rock Bluff and north of the mouth of Ervine Creek, past one mile west of Union, where it noses out between the Redfield and Nehawka anticlines. Just how far it reaches in Iowa, paralleling the Redfield Anticline and Thurman-Wilson Fault, is not known to the writer.

THE DES MOINES SERIES

This series is not exposed in Nebraska but the logs of wells show that it underlies the southeastern counties. Among the wells which penetrated the series are those at or near Lincoln, Omaha, Weepingwater, Nehawka, Nebraska City, and Du Bois. The Davis well at Forest City, Missouri, being only a few miles from our state, has importance in this connection, hence a condensed log of it is run in this report for reference.

Distribution. The Des Moines beds are at the surface in a wide belt extending from south-central Iowa, through central and southwestern Missouri, northwestern Arkansas, southeastern Kansas, and Oklahoma (Figure 1). West of this belt these beds occur beneath the Missouri Series in southwestern Iowa, northwestern Missouri, southeastern Nebraska, in Kansas, and in Oklahoma.

Thickness. The Des Moines Series is 600 feet or more thick in its main outcrop area; increases to 896' 10" at Forest City (See report of Davis Well) and decreases northward and northwestward to 120 feet at Nebraska City, 116 feet at Nehawka and Weepingwater, 110 feet at Omaha, and 62' 6" or more at Lincoln. It thins westward from Forest City across southern Nebraska to a thickness of 100 feet at Du Bois. The thickness and extent west of the Table Rock Anticline are not well known.

PENNSYLVANIAN SYSTEM

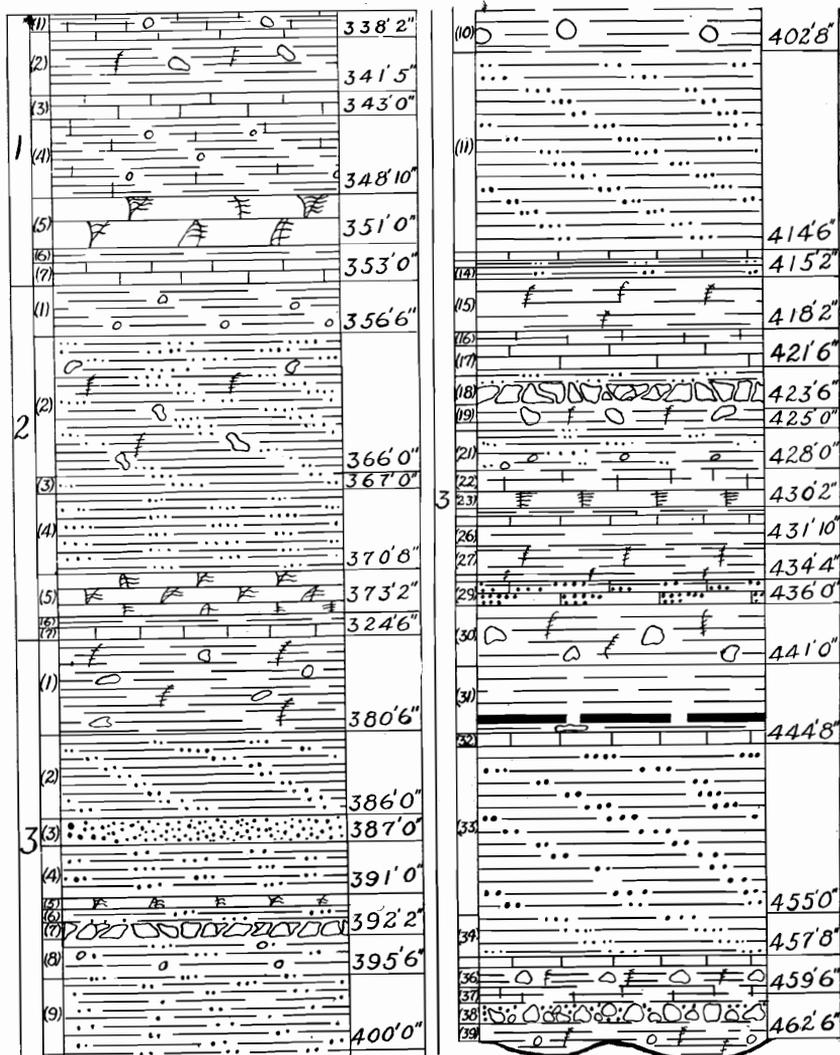


FIGURE 2.—Columnar section of the Des Moines beds penetrated in the Amerada well near Nehawka, Nebraska.

There are no data regarding the Des Moines beds in the extreme southeast corner of Nebraska except those indicated by the wells at Forest City, Missouri, Atchison and Leavenworth, Kansas. No doubt the series is thick at Rulo, Nebraska, as shown by the records of the wells just cited. An estimate of 450 to 500 feet in thickness is given for these beds in the southeastern corner of Richardson County, Nebraska.

Materials. In general the lowest and thickest portion of the Des Moines Series is composed of sandstone, sandy shale, clay shale, coal beds, and a few thin limestones. The middle and upper portions have relatively less sandstone and coal and more limestone. The content of the upper horizons varies much between Iowa and Oklahoma, the limestones increasing in importance southward. Figure 2 is a columnar section of the Des Moines beds penetrated in the core drilling near Nehawka.¹ It shows no coal.

Depth and Extent in Nebraska. The Des Moines strata underlie all of southeastern Nebraska, unless they may have been eroded away on parts of the Table Rock Anticline where the granite is near the surface. How far they extend westward beneath younger beds and what their correlation with carboniferous rocks exposed in the Black Hills and Rocky Mountains may be, is not known. The Des Moines beds probably do not reach to the extreme northeastern part of the state opposite Sioux City, but they do extend some distance north of Omaha. At Omaha they have a thickness of 100 to 116 feet below an altitude of 655 feet, their top being about 310 feet below the river level and the base about 425 feet below. At Fort Crook, which is on the nose of the Nehawka Anticline, the thickness is about the same as at Omaha, with the base 560 feet above sea level and the top 670 feet above.

The Amerada well northwest of Nehawka penetrated the Des Moines beds between 682' 6" and 808' 2" above sea level.

¹ There is some question regarding the correlation of the upper 20' or more of strata as in the Des Moines.

This is higher than at Lincoln where the thickness is about 62' 6" and the base about 151' 8" above sea level.

East of the Nehawka Anticline the Des Moines strata dip southeastward and thicken. At Glenwood, Iowa, the reported thickness is 390 feet, which, if correct, indicates a drop of 287 feet below the elevation at Omaha. The deep well at Nebraska City shows the top to be 30 feet above sea level and the base about 90 feet below sea level.

According to sub-surface data the Des Moines Series thickens rapidly between Nebraska City and Forest City, Missouri, from about 120 feet to 896' 10", the top having a depth of 725 feet at the last named place, which is a little higher than the top at Nebraska City. No doubt the top of the group is a little lower at Brownville.

The Des Moines beds thin rapidly from Forest City westward. The estimated thickness at Rulo, Nebraska, is about 450 or 500 feet, with the top about 900 feet below the river level or 50 to 60 feet below sea level. The group should have about the same character here as at Forest City. Persons wishing the details of the Des Moines beds in Nebraska, as far as they are known, should consult the logs of the Nehawka (Amerada) and Forest City wells, run elsewhere in this report.

*Subdivisions.** The Kansas Survey subdivides the Des Moines Series into the Cherokee and Marmaton formations, whereas the Missouri Survey subdivides it into the Cherokee, Henrietta, and Pleasanton formations. These subdivisions have not been definitely identified as such in the well logs of Nebraska.

THE CHEROKEE SHALE

This division was named by Haworth² and Kirk, from Cherokee County, Kansas. It is the lowest and thickest division of the Des Moines Series in Iowa, Missouri, and Kansas, but older beds of the series occur between it and the Mississippian in Oklahoma and Texas. According to

* The Des Moines Series is thought to be of Pottsville, Allegheny, and lower Conemaugh age.

David White,³ the lower portion of the Cherokee, i.e., below the Bevier Coal, may be of Pottsville age.

The Cherokee is widely exposed between Iowa and Oklahoma. It rests upon a very uneven surface but is comparatively uniform in structure. It is formed of sandstone, sandy shale, and thin coal beds and has importance in the production of petroleum, gas, coal, and clay.

A thickness of about 785 feet is reported for the Cherokee in the Forest City well below a depth of 836' 10". No doubt the formation is quite thick in the extreme southeastern part of Nebraska, thinning out northward and westward.

The Cherokee has not been definitely identified in the wells at Lincoln, Omaha, Nehawka, and Nebraska City. Yet there is some evidence that it is represented in the basal 17' 6" of the Des Moines beds in the Amerada well near Nehawka, below a depth of 445 feet.

Although no coals of Cherokee age have been identified in the wells of Nebraska, some of those penetrated at Leavenworth, Kansas, and Forest City, Missouri, may extend into Richardson County, or farther, at depths about 200 feet greater than at Forest City. Among the Cherokee coals which may reach into southeastern Nebraska are the Tebo, Bevier, Bedford, Summit, and Lexington. (See log of the Davis well, Forest City).*

MARMATON FORMATION

This was named by Haworth⁴ from Marmaton River in eastern Kansas. In Missouri the same beds are grouped under two formations, the Henrietta and Pleasanton, but there is no known basis for such separation in Nebraska, nor, as has been stated, can the boundary between the Henrietta and Cherokee be determined beyond question.

The Marmaton has a comparatively broad outcrop area from Iowa to Oklahoma, just west of that of the Cherokee

² Kansas University Quarterly, Vol. 2, p. 105, 1894.

³ Missouri Bureau of Geol. and Mines, XIII, 2nd Series, p. 262.

⁴ Kansas University Geological Survey, Vol. III, pp. 92-94, 1898.

* The Cherokee is several thousand feet thick in Oklahoma where it has been subdivided as several members and formations.

beds and extends westward under younger strata.* Its basal portion, known as the Henrietta formation of the Missouri Survey, is quite persistent in the exposures from near Center-ville, Iowa, to Oklahoma, with a thickness of 40 to 100 feet or more. The members of the Henrietta formation, in ascending order, in Kansas and Missouri, are the Fort Scott Limestone, Labette Shale, and Pawnee Limestone. None of these has been identified beyond question in Nebraska.

The upper portion of the Marmaton formation, called the Pleasanton formation in Missouri, has quite well defined members in its southern distribution, but becomes somewhat irregular with more shale and less limestone to the north. Its thickness is reported as follows: Bedford, Iowa, 145 feet; Clarinda, Iowa, 142 feet; Trenton, Missouri, 160 feet; Kansas City, Missouri, 181 feet; Leavenworth, Kansas, 155 feet or more.

The Pleasanton includes the following members in Kansas (named upward): Bandera Shale, Altamont Limestone, Nowata Shale, Lenapah Limestone, and Dudley Shale. None of these has been identified as such in Nebraska. It is evident, however, that they are represented in the shales and thin limestones penetrated at the top of the Des Moines Series in the well near Nehawka. The Pleasanton-Henrietta beds were encountered in the Forest City well, with a thickness of about 130 feet. The Ovid Coal, which occurs here near the top of the Pleasanton, probably extends to southeastern Nebraska.

Unconformity. In northern Missouri and southern Iowa the Henrietta indicates a period of emergence and deep erosion to the extent of the entire removal of the formation at places. On this uneven surface was deposited the Pleasanton formation. The unconformity is not shown in the logs of Nebraska wells, unless it is in the Amerada well near Nehawka, at the horizon about 17 feet above the base of the Des Moines Series.

* It probably is of lower Conemaugh age, or of this and upper Allegheny.

THE MISSOURI SERIES

This important series is formed principally of interstratified shale and limestone, but includes some sandstone and a few thin beds of coal. Many of the small units persist in a wide distribution. In general, the lower formations resemble the Pleasanton and Henrietta formations of southwestern Missouri in sequence and lithology, but their faunas differ from the latter, although a good many species carry through from the Des Moines Series.

The base of the Missouri beds, as generally accepted, is the Hertha Limestone, and the top is at the base of the Cottonwood Limestone.* There is no widespread unconformity between the Missouri and Des Moines series.

The Missouri Series has economic importance as a source of clay and stone, and some importance as a source of coal, oil, gas, and water supplies. It has not produced oil and gas in Nebraska.

Distribution. The Missouri Series is widely exposed in northwestern Missouri (where named), southwestern Iowa, southeastern Nebraska, and as a broad band from these areas southward and southwestward across Kansas, Missouri, and Oklahoma to north-central Texas (Figure 1). It probably underlies all of Nebraska in its extension westward to the exposures in the Rocky Mountains and Black Hills.

Thickness. The average combined thickness of the Missouri beds in southeastern Nebraska is about 1,099 feet, about 889 feet being exposed and 210 feet unexposed. This is a little short of the maximum thickness because the Douglas, Lansing, and Kansas City formations are thought to be thicker under the extreme southeastern corner of the state than they are where measured for this general section. For example, the Douglas formation has a thickness of 126 feet in our section and 283 feet at Leavenworth, Kansas. Its thickness under Richardson County, Nebraska, should be about 250 feet. The Lansing is 60' 10" as measured in the general section for

* The Missouri beds have not been correlated with those of this age in Illinois and other states in the Eastern Interior province.

Nebraska and 124 feet in the Davis well at Forest City, Missouri. It should be about 100 feet in the southeast corner of Nebraska. The Kansas City formation is 139' 10" thick, according to the record of the well at Nehawka, Nebraska, and 182 feet at Forest City, Missouri. It is probably 160 feet thick in the southeast corner of Nebraska. The combined increase in thickness of the three formations in the southeast corner of Richardson County over that obtained in the general section is about 183 feet. This, added to the thickness (1,099 feet) as obtained from the exposures and certain wells records, gives a maximum of about 1,282 feet for the Missouri Series in Nebraska.

As noted elsewhere, the full thickness of the series is not intact at any place due to the removal of beds by erosion on the anticlines. For example, all of the group except about 210 feet has been eroded from part of the Nehawka Anticline and all but about 450 feet from the high point on the Table Rock Anticline.

Lithology. The upper portion of the Missouri Series is formed largely of argillaceous shale, thin limestones, and a small amount of lensing sands. The lower portion of it has more limestone than shale. The relative amount of limestone decreases upward in the series.

The lithologic content of the series, measured in the general section, is as follows: Shale, sand, and sandstone, 726 feet; limestone, 368 feet; coal, in three beds (Nodaway, Silver Lake, and Nyman) and scattered seams, 5 feet. The combined thickness is about 1,099 feet. The thickness of the sandstone which grades laterally into shale is difficult to estimate. It probably would average about 80 feet. Deducting this estimated thickness of the sandstone from that of the shale and sandstone combined, we have: Shale, 646 feet; sandstone, 80 feet. The foregoing gives the following in order of importance: Shale, 646 feet; limestone, 368 feet; sandstone, 80 feet; and coal, 5 feet. Total, 1,099 feet.

Formations. On a basis of fauna and lithology, the Missouri Series has been subdivided into five formations, which,

named in ascending order, are the Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee.

The names of the formations were given as follows: Wabaunsee, by Prosser,¹ from Wabaunsee County, Kansas; Shawnee, by Haworth,² from Shawnee County, Kansas; Douglas, by Haworth,³ from Douglas County, Kansas; Lansing, by Hinds and Greene,⁴ from Lansing, Kansas; and the Kansas City, by Hinds and Greene,⁵ from Kansas City, Missouri.

KANSAS CITY FORMATION

This formation is well exposed in the vicinity of Kansas City, also northward to Iowa and southward to Oklahoma. It dips northwestward under the later formations and has been reached by drillings in Nebraska. Our best records of it are in the logs of the Amerada well, near Nehawka, Nebraska (Figure 3), and the Davis well at Forest City, Missouri.

Lithology. The Kansas City formation runs high in limestone, with shale second in volume. It has a thin coal bed and very little sandstone.

TABLE 1. *Lithologic Content of the Kansas City Formation*

Content	Exposures at Kansas City, Mo.	Davis Well, Forest City, Mo.	Amerada Well, Nehawka, Nebr.
Limestone	118' 6" +	96' 2"	98' 4"
Shale	77' 6" +	86' 8"	41' 6"
Total Thickness	196' *	182' 10"	139' 10"

* Minimum.

¹ Prosser, C. R., Classification Upper Paleozoic Rocks of Central Kansas: Journal Geol., Vol. III, pp. 682-705 and 764-800, 1895.

² Haworth, Erasmus, Stratigraphy Kansas Coal Measure: Kans. Univ. Geol. Survey, Vol. III, pp. 93-94, 1898.

³ Haworth, Erasmus, Stratigraphy Kansas Coal Measure: Kans. Univ. Geol. Survey, Vol. III, p. 93, 1898.

⁴ Hinds, Henry, and Greene, F. E., Stratigraphy Penn. Series in Mo.: Missouri Bureau Geol. and Mines, Vol. XIII, 2nd Series, p. 28, 1915.

⁵ Hinds, Henry, and Greene, F. E., Stratigraphy Penn. Series in Mo., Missouri Bureau Geol. and Mines, Vol. XIII, 2nd Series, p. 23, 1915.

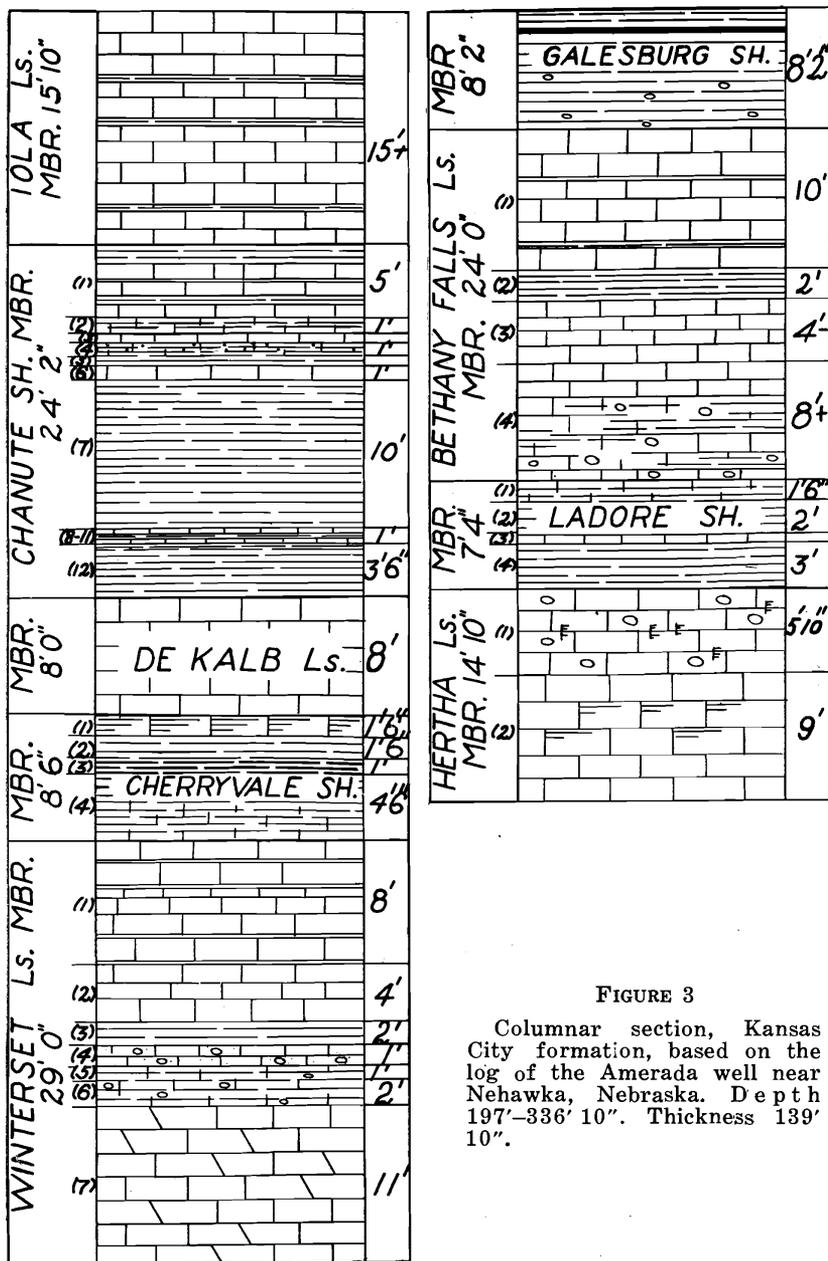


FIGURE 3

Columnar section, Kansas City formation, based on the log of the Amerada well near Nehawka, Nebraska. Depth 197'-336' 10". Thickness 139' 10".

TABLE 2. *Kansas City Formation, Thickness of Members*

Member	Kansas City, Missouri	Davis Well, Forest City, Missouri	Amerada Well, Nehawka, Nebraska
Iola Limestone	30'	11'	15' 10"
Chanute Shale	56' +	29' 2"	24' 2"
DeKalb Limestone.....	20' +	8' 6"	8'
Cherryvale Shale.....	23' +	29' 8"	8' 6"
Winterset Limestone.....	27' +	48' 11"	29'
Galesburg Shale.....	6' +	5' 8"	8' 2"
Bethany Falls Limestone..	21' +	23'	24'
Ladore Shale.....	7' +	14'	7' 4"
Hertha Limestone	6' +	12' 11"	14' 10"
Total Thickness.....	196' +	182' 10"	139' 10"

The foregoing tables show that the thickness of the Kansas City formation decreases northwestward from the type locality, some of the limestones increasing as the shales decrease.

Persons wishing further information regarding the thickness, lithology, fauna, etc., of the Kansas City formation in Nebraska should consult the log of the Amerada well, run elsewhere in this report. For reports on the formation in adjacent states the reader is cited to Volume XIII, 2nd Series

of the Missouri Survey; Bulletin 3 of the Kansas Survey; and the special reports on the Pennsylvanian Series in Iowa, by the Iowa Geological Survey.

KANSAS CITY FORMATION

MEMBERS, AUTHORS, AND TYPE LOCALITIES

- Iola Limestone, by Haworth, Erasmus, and Kirk, M. Z.; The Neosho River Section: Kan. Univ. Quarterly, Vol. II, p. 109, 1894; from Iola, Allen County, Kansas.
- Chanute Shale, by Haworth, Erasmus, and Kirk, M. Z.; The Neosho River Section: Kan. Univ. Quarterly, Vol. II, p. 109, 1894; from Chanute, Neosho County, Kansas.
- DeKalb Limestone, by Bain, H. F.; Geology Decatur County: Iowa Geol. Survey, Vol. VIII, p. 278, 1897. This probably is the same as the Drum Limestone described by G. I. Adams at a later date, from Drum Creek, Montgomery County, Kansas.
- Cherryvale Shale, by Haworth, Erasmus; Stratigraphy Kansas Coal Measures: Kan. Univ. Geol. Survey, Vol. III, p. 483, 1896; from Cherryvale, Montgomery County, Kansas.
- Winterset Limestone, by Tilton, John L., and Bain, H. F.; Geology Madison County, Iowa: Iowa Geol. Survey, Vol. VII, pp. 517-519, 1897; from Winterset, Madison County, Iowa.
- Galesburg Shale, by Adams, G. I.; Stratigraphy and Paleontology Upper Carb. Rocks of Eastern Kansas: U. S. Geol. Survey, Bull. 211, p. 18, 1903; from Galesburg, Neosho County, Kansas.
- Bethany Falls Limestone, by Broadhead, G. C.; Trans. St. Louis Acad. Sci., Vol. II, p. 320, 1868; from Bethany Falls, Harrison County, Missouri.
- Ladore Shale, by Adams, G. I.; Economic Geology Iola Quadrangle, Kansas Series: U. S. Geol. Survey, Bull. 238, pl. I, 1904; from Ladore, Neosho County, Kansas.
- Hertha Limestone, by Adams, G. I.; Stratigraphy and Paleontology Upper Carb. Rocks of Kansas Section: U. S. Geol. Survey, Bull. 211, p. 35, 1903; from Hertha, Neosho County, Kansas.

LANSING FORMATION

This outcrops just west of the exposures of the Kansas City formation from Iowa to Oklahoma and extends under part of Nebraska. Our best record of it is the log of the Amerada well. The top of the Stanton Limestone member is exposed three miles northwest of Nehawka, and a greater thickness of it is shown on the Platte River, two miles west of Oreapolis. A bed exposed in the North Fork Weepingwater and defined by Condra and Bengtson as the Sturm Limestone, is now thought to be a part of the Stanton Limestone member, as is also the Oreapolis Limestone of the Platte Valley.

Figure 4 is a columnar section of the Lansing formation. Table 3 shows the thickness of the members of the formation in three states.

TABLE 3. *Lansing Formation, Thickness of Members*

Member	In Outcrops of Missouri	Davis Well near Forest City, Missouri	Amerada Well near Nehawka, Nebraska
Stanton Limestone *.....	30' +	39' 3"	26' 6"
Vilas Shale †.....	20' †	12' 1"	8' 4"
Plattsburg Limestone §....	20' +	27' 6"	8'
Lane Shale 	50' +	45' 2"	18'
Total Thickness.....	120' +	124'	60' 10"

* Swallow, G. C., Geol. Rept. Miami County, Kan.: Preliminary Rept. Geol. Survey of Kansas, p. 75, 1866; from Stanton, Miami County, Kansas.

† Haworth, Erasmus, and Adams, G. I., Stratigraphy Kansas Coal Measures: Kan. Univ. Geol. Survey, Vol. III, p. 51, 1898; from Vilas, Wilson County, Kansas.

‡ Or less.

§ Broadhead, G. C., Coal Measures in Missouri: Trans. St. Louis Acad. Sci., Vol. II, pp. 317-327, 1868; from Plattsburg, Clinton County, Missouri. The name Allen Limestone has been used for this in Kansas.

|| Haworth, Erasmus, and Kirk, M. Z., Stratigraphy Kansas Coal Measures: Kan. Univ. Quarterly, Vol. III, p. 277, 1895; from Lane, Franklin County, Kansas.

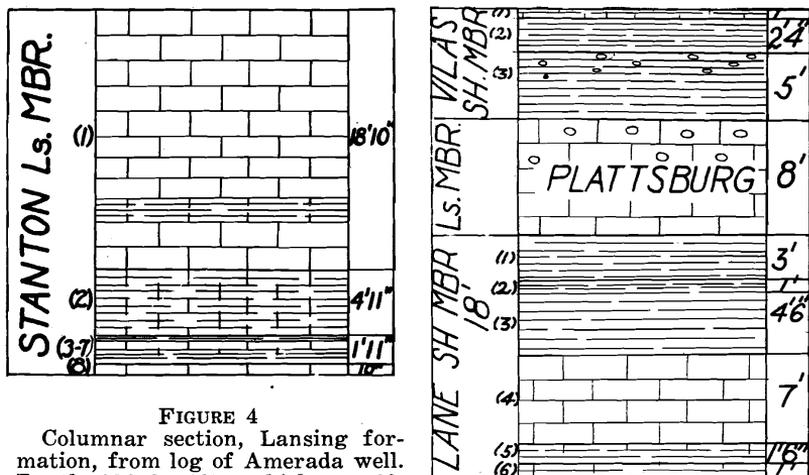


FIGURE 4

Columnar section, Lansing formation, from log of Amerada well. Depth 136' 2"–197'; thickness 60' 10".

Lithologic Content. The Lansing formation is composed of limestone, argillaceous shale, carbonaceous shale, some sandstone, and a thin bed of coal. The combined thickness of the beds of this formation in the log of the well at Forest City, Missouri, shows: Shale, 66' 9"; limestone, 57' 3"; total, 124'. In the Amerada well at Nehawka, Nebraska, it is limestone, 34' 10"; shale, 26' 6"; total, 60' 10". The thickness of the formation decreases between Forest City and Nehawka, due to the thinning of shales.

Unconformity. In the Platte sections west of Oreapolis and La Platte, there is evidence of an unconformity at the top of the Stanton shown by its weathered, slightly uneven surface. Dr. Dunbar observed the further evidence that the slabby surface of the Stanton is broken up and incorporated brecciated-like in the shale above the unconformity.

DOUGLAS FORMATION

This formation is widely exposed from Iowa to Oklahoma. It outcrops prominently in the Kansas River Valley at Lawrence, along the Missouri from Leavenworth north to beyond Nodaway, Missouri, where it dips beneath the river level, and at places in Iowa and Nebraska north of the Thur-

man-Wilson Fault. There are good exposures of its members in the Weepingwater and Platte valleys, and of some of them along the Missouri between Jones Point and beyond Omaha.

The columnar section of the Douglas formation is shown by Figure 5. The details of the distribution of the formation in Nebraska are described in connection with the cross sections run elsewhere in this report.

TABLE 4. *Members of the Douglas Formation*

Members and Beds	Thickness (Feet)					
	Nehawka, Nebraska	Amazonia, Missouri	St. Joseph, Missouri	Atchison, Kansas	Leavenworth, Kansas	Lawrence, Kansas
1. Oread Limestone (1). Plattsmouth Limestone ..	28-30	19†	21	18-21	16†	17½
(2). Heebner Shale	5	5	5-6	5¼	5-6	5-6
(3). Leavenworth Limestone ..	1½	2	2½	1½-2½	2	2
(4). Snyderville Shale	11	17	15*	14-16	14	12
(5). Weepingwater Limestone ..	7-13	6	6†	6-10	8-10	10
2. Lawrence Shale.....	59	75†	118	55*	170	175*
3. Iatan Limestone	5-12	‡	4	‡	8-10	3†
4. Weston Shale	2†	‡	55†	‡	60†	70†
Thickness of formation or exposed thickness	125-128	124†	226 ⅓†	99 5/6†	283†	294 ⅓

* About.

† Exposed.

‡ Not exposed.

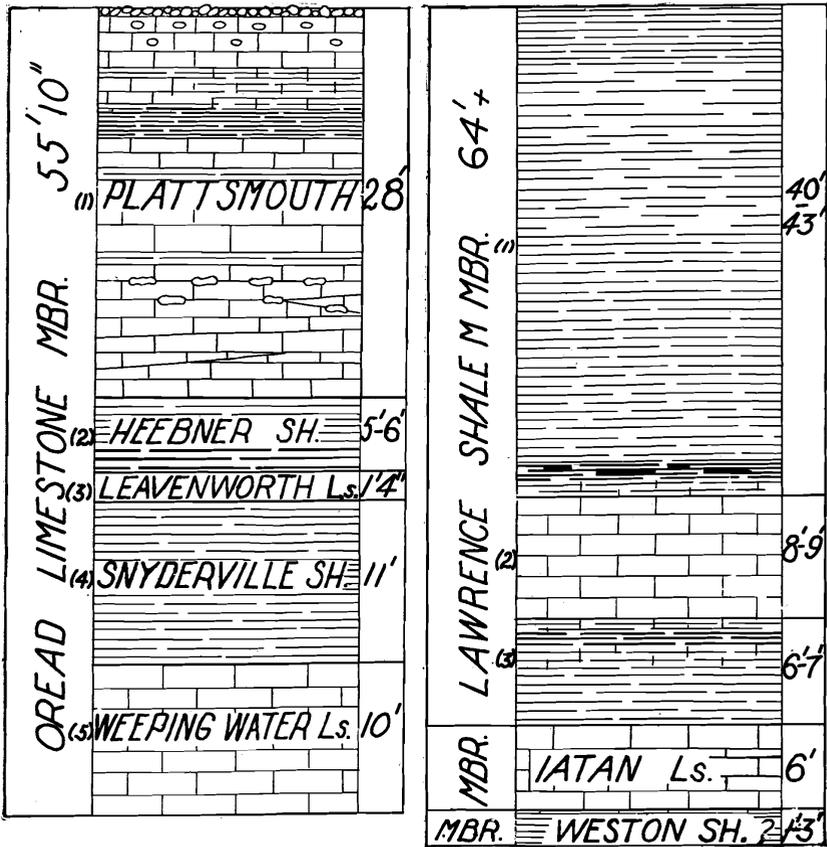


FIGURE 5.—Columnar section, Douglas formation, based on exposures in Cass County, Nebraska. Thickness 125'–128'. The Iatan is about 10' thick, not 6'. The 8'–9' limestone in the Lawrence is the Shoemaker.

Lithologic Content. The Douglas formation thins northward from Kansas to the exposures in Nebraska, due to shale shrinkage, there being little change in the limestones. The combined thickness of its principal contents in the outcrops near Nehawka, Nebraska, is about as follows: Shale, 73'; limestones, 52' 6"; two or more coal seams, 6" to 8". Much of the shale is argillaceous, but some of it grades into sand and sandstone.

Weston Shale Member. This, the lowest member of the Douglas formation, was named by Keyes⁶ from outcrops near Weston, Missouri. It is largely bluish, argillaceous shale at the type locality, but becomes very sandy, and grades into a friable sandstone at places south of Leavenworth. The member thins northward from 60 feet or more at Leavenworth to a few feet in Iowa and probably 2 feet or less in the Platte sections of Nebraska where it is argillaceous to calcareous.

Iatan Limestone Member. Next above the Weston is the Iatan Limestone, named by Keyes⁷ from Iatan, Missouri. Haworth and Kirk called it the Kickapoo Limestone, and Condra and Bengtson gave it the name Nehawka Limestone.

The Iatan varies considerably in thickness and character. It is thought to persist from southern Kansas to north of the type locality in Missouri beyond which it probably lies below younger beds to the exposures northwest of Nehawka, Nebraska.

At most places, the Iatan is dark to light gray, fairly dense, massive, somewhat irregular, fossiliferous, and 8 to 10 feet thick. It makes large irregular blocks with rough surface. In some exposures it is interbedded with shale.

The Nebraska exposures of the upper portion of the Iatan on the North Fork Weepingwater, closely resemble those of the type locality in Missouri in lithology and fauna. The

⁶ Keyes, C. R., The Missouri Series of the Carboniferous: Amer. Geologist, Vol. XXIII, pp. 298-316, 1899.

⁷ Keyes, C. R., The Missouri Series of the Carboniferous: Amer. Geologist, Vol. XXIII, pp. 298-316, 1899.

lower portion here is more distinctly bedded and more fossiliferous. The member extends to the Dyson Hollow section on the Platte where it is represented by the lower portion only.

Lawrence Shale Member. Haworth and Kirk^{8a} named this from Lawrence, Kansas. The member is formed principally of argillaceous shale, sandy shale, and sandstone, but carries some coal and limestone. It includes the Amazonia Limestone which is well developed in northeastern Kansas and at places in northwestern Missouri, but has not been identified in Nebraska. Most of the shale above the Amazonia Limestone is bluish gray or reddish and argillaceous, but the horizons below it in Kansas are largely formed of sandy shale and sandstone.

The Lawrence member thins northward from 150 feet or more at Lawrence, Kansas, to 50 feet or more in the Weeping-water sections and 3 to 10 feet in the Platte Valley. In Nebraska its basal 6 feet to 7 feet is mostly bluish argillaceous shale with small calcareous concretions and a few lime pebbles. Next above this shale, in the vicinity of Nehawka, is the Shoemaker^{8b} Limestone which occurs at a lower horizon than the Amazonian bed. It has been eroded from the Platte exposures. This limestone was erroneously correlated as the Oreapolis bed by Condra and Bengtson⁹ in confusion with a unit in the Platte Valley. That portion of the Lawrence above the limestone just noted is mostly bluish to reddish argillaceous shale, with a thin fossiliferous limestone. It carries a coal seam below the middle.

There is some evidence of erosional unconformity in the Lawrence Shale member along the Platte in which most of it was eroded. In places a thickness of only 3 feet of shale remains between the Weepingwater and Stanton limestones. The full details of this erosional unconformity have not been determined.

^{8a} Haworth, Erasmus, and Kirk, M. Z., Kan. Univ. Quarterly, Vol. II,

^{8b} Named from Shoemaker farm and the Shoemaker bridge about three miles northwest of Nehawka, Nebraska.
p. 110, 1894.

⁹ Nebraska Acad. Sci., Vol. IX, No. 2, p. 10, 1915.

Oread Limestone Member. This prominent member was named by Haworth¹⁰ to include three limestones and two shales, well shown in the vicinity of Lawrence, Kansas. The limestones are described in the Kansas and Missouri surveys as the "Upper," "Middle," and "Lower," and the shales as the "Lower" and "Upper." In places the so-called "Waverly Flagging," as one bed, or as two beds separated by shale, occurs above the upper limestone separated from it by a few feet of shale. It is thought by the writer that the upper limit of the Oread should be held to the top of the "Upper limestone" and that the so-called "Waverly Flagging" beds are in the Kanwaka Shale member rather than in the Oread Limestone member.

The beds of the Oread differ much in their lithologic and faunal features, hence the writer has separated them as units. The Weepingwater Limestone, now known to be

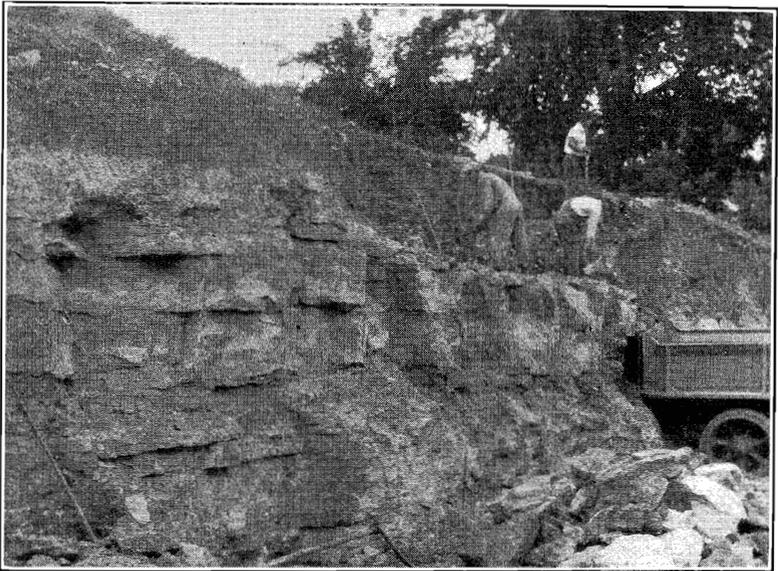


FIGURE 6.—The Weepingwater Limestone at Lawrence, Kansas.

¹⁰ Haworth, Erasmus, *Stratigraphy of the Kansas Coal Measure*: Kan. Univ. Quarterly, Vol. II, pp. 123-124, 1894.

the lowest unit of the Oread, was named by Condra and Bengtson.¹¹ It has been quarried quite extensively in the vicinity of Lawrence, Kansas (Figure 6), and other places.

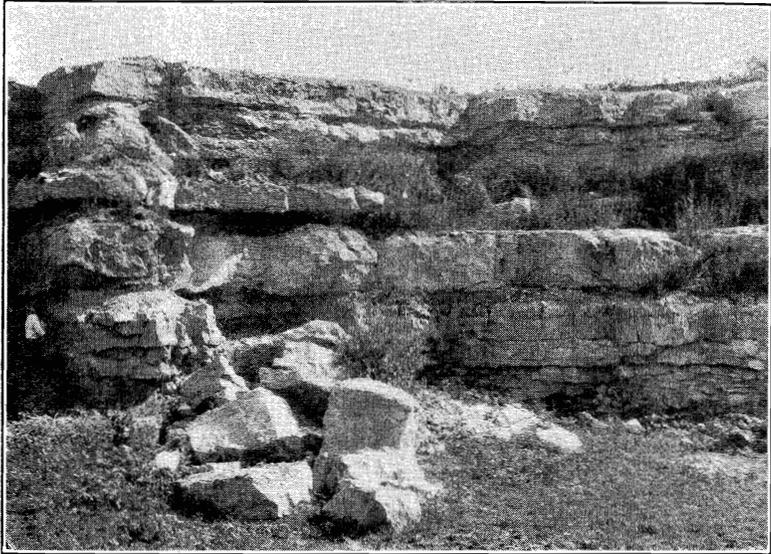


FIGURE 7.—Plattsmouth Limestone at Snyderville Quarry, west of Nehawka, Nebraska.

The following names are proposed for the unnamed beds of the Oread Limestone member:

1. Plattsmouth Limestone, for the "top" and thickest unit of the member, from Plattsmouth, Nebraska. The bed has been known by this name since the days of Meek and Hayden, but has not been closely defined, there being more or less misunderstanding regarding its relation to the Oread member as a whole.

One of the best developments of the Plattsmouth bed is in the Weepingwater Valley, at Snyderville (Figure 7) where its zones are weathered to a condition, ideal for fossil collecting.

2. Heebner Shale, for the first shale below the Plattsmouth Limestone, from Heebner Creek and the Heebner farm west of Nehawka, Nebraska. The top portion of the bed is bluish and argillaceous; the lower portion is black, finely bedded, and somewhat carbonaceous. The thickest is 5 feet or more.

¹¹ Condra, Geo. E., and Bengtson, N. A., Pennsylvania Formations of Southeastern Nebraska, *Nebr. Acad. Sci.*, Vol. IX, No. 2, p. 10, 1915.

3. Leavenworth Limestone, for the "middle limestone" of the member, from a roadside exposure high in the upland spur northwest of the Federal Penitentiary at Leavenworth, Kansas (Figure 8). The stone is dark gray, dense, vertically jointed, fossiliferous, and in one or two beds. Its thickness averages about 2 feet.
4. Snyderville Shale, for the shale between the Leavenworth and Weepingwater limestones, from exposures in Heebner Creek east of the Snyderville Quarry located between 3 and 4 miles west of Nehawka, Nebraska. It is largely argillaceous. In most exposures its upper portion is bluish or grayish, and the lower portion is reddish. The thickness of this unit in the sections between Nehawka, Nebraska, and Lawrence, Kansas, varies between 11 and 17 feet.



FIGURE 8.—Leavenworth Limestone northwest of the Federal Penitentiary, Leavenworth, Kansas.

SHAWNEE FORMATION

This formation was named by Haworth,¹² from Shawnee County, Kansas. It is supposed to occupy the interval between the Plattsmouth and Burlingame limestones, but there is more or less misunderstanding in regard to its upper boundary, and some question as to its lower limit. For ex-

¹² Haworth, Erasmus, *Stratigraphy of the Kansas Coal Measures*: Kan. Univ. Geol. Survey, Vol. III, pp. 93-94, 1898.

ample, Hinds and Greene in their Missouri report make the upper boundary too high, at the Tarkio Limestone, which they supposed to be the Burlingame, and place the so-called "Waverly Flagging" in the Oread member rather than in the Kanwaka Shale member of the Shawnee where it seems to belong. The Iowa Survey by Professor Tilton is also in error regarding the top of the formation in placing it at the base of the Emporia Limestone ("Preston Limestone").

The Shawnee, as now defined, is not distinctly set off by faunal and lithologic change. Its lower beds resemble those of the Douglas formation with no marked change in fossil species, and the upper portion of the top member carries a fauna more like the lower members of the Wabaunsee formation. On a faunal basis, the boundary between the Shawnee and Wabaunsee should be at the Silver Lake Coal below the Rulo Limestone, where it was placed by Keyes in his original description, yet the Burlingame Limestone, now held to be the base of the Wabaunsee, is a better marker.

The members of the Shawnee formation have been traced through the exposures of Iowa, Nebraska, Kansas, and in some cases to Oklahoma and found to be very persistent.

NEBRASKA GEOLOGICAL SURVEY

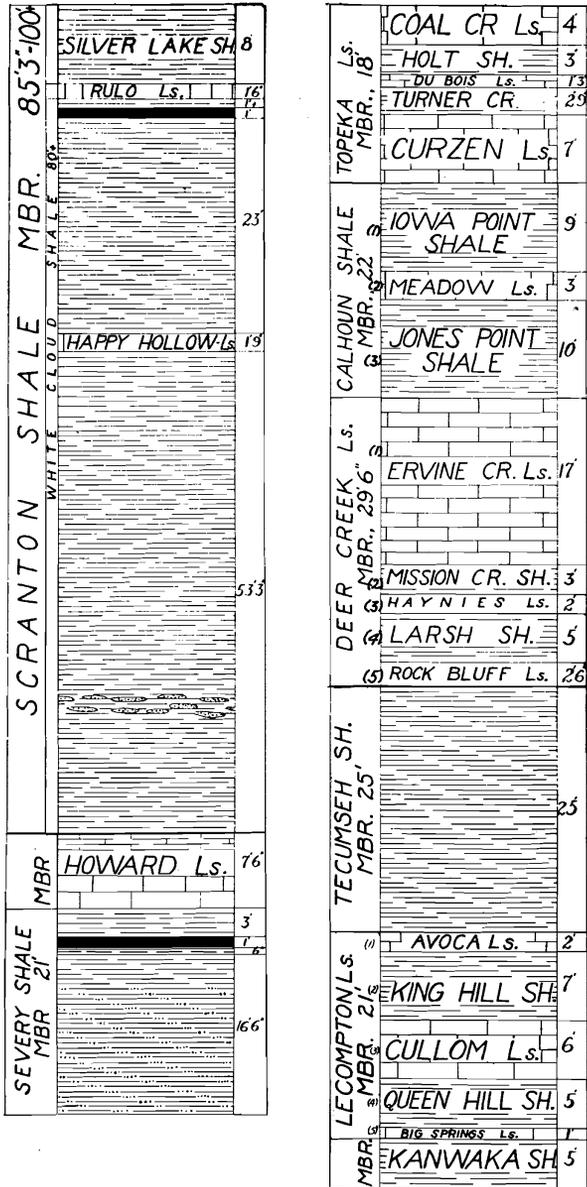


FIGURE 9.—Columnar section of the Shawnee formation.

Figure 9 represents a columnar section of the Shawnee formation based on exposures in southeastern Nebraska (near Du Bois and Rulo) and in northeastern Kansas west of White Cloud and below Iowa Point. The thickness of the Kawwaka is based on exposures near Weepingwater.

The following tables show the thickness and lithologic content of the Shawnee members in Nebraska:

TABLE 5. *Lithologic Content, Members of Shawnee Formation in Nebraska*

Members and Beds	Thickness (Feet)				
	Shale and Sandstone	Limestone	Coal	Bed or Division	Member
1. Scranton Shale Member.....	112	24+	1+		137
(1). Silver Lake Shale.....	7+			7+	
(2). Rulo Limestone.....		1¾+		1¾+	
(3). White Cloud Shale.....	71+	1¾	1+	73¾+	
(4). Limestone	1+			1+	
(5). Shale	12			12	
(6). Cass Limestone		12		12	
(7). Plattford Shale	15	1		16	
(8). South Bend Limestone..	1	8+		9+	
(9). Rock Lake Shale.....	5+			5+	

TABLE 5 (Continued). *Lithologic Content, Members of Shawnee Formation in Nebraska*

Members and Beds	Thickness (Feet)				
	Shale and Sandstone	Limestone	Coal	Bed or Division	Member
2. Howard Limestone Member..	2½	14			16½
(1). "Louisville" Limestone		12		12	
(2). Kiewitz Shale.....	2½			2½	
(3). Church Limestone.....		2-6		2-6	
3. Severy Shale Member.....	18½	½	1+		20+*
(1). Shale	4			4	
(2). Nodaway Coal			1+	1+	
(3). Shale	14½	½		15	
4. Topeka Limestone Member *..	7¾	11¼			19
(1) Coal Creek Limestone....	1†	3†		4†	
(2). Holt Shale.....	2½			2½	
(3). Du Bois Limestone		1¼+		1¼+	
(4). Turner Creek Shale.....	3			3	
(5). Curzen Limestone	1¼	7		8¼	

* In south part of state.

TABLE 5 (Continued). *Lithologic Content, Members of Shawnee Formation in Nebraska*

Members and Beds	Thickness (Feet)				
	Shale and Sandstone	Limestone	Coal	Bed or Division	Member
5. Calhoun Shale Member.....	18	3½+			21½
(1). Iowa Point Shale.....	9	¼+		9¼+	
(2). Meadow Limestone.....		3+		3+	
(3). Jones Point Shale.....	9	¼+		9¼+	
6. Deer Cr'k Limestone Member	4+	27			31
(1). Ervine Creek Limestone	¾+	24		24¾+	
(2). Mission Creek Shale.....	1¼			1¼	
(3). Haynies Limestone.....		1+		1+	
(4). Larsh Shale	2			2+	
(5). Rock Bluff Limestone....		2+		2+	
7. Tecumseh Shale Member	34	7			41
(1). Shale	13-35	1		30	
(2). Cedar Creek Limestone	1	0-8		8+	
(3). Shale	7-8			7½	

TABLE 5 (Concluded). *Lithologic Content, Members of Shawnee Formation in Nebraska*

Members and Beds	Thickness (Feet)				
	Shale and Sandstone	Limestone	Coal	Bed or Division	Member
8. Lecompton Limestone M'ber	14+	9+			23+
(1). Avoca Limestone.....	1	2-9		2-9	
(2). King Hill Shale.....	6-8			6-8	
(3). Cullom Limestone.....	1	6		7	
(4). Queen Hill Shale.....	5+			5+	
(5). Big Springs Limestone		1+		1+	
(6). Doniphan Shale‡.....					
(7). Spring Branch L'stone‡.					
9. Kanwaka Shale Member.....	5+			5+	5+
Total Thickness.....	215¾	96	2		314

‡ Exposed in Missouri and Kansas; probably not exposed in Nebraska.

DESCRIPTION OF THE SHAWNEE MEMBERS

Kanwaka Shale Member. This, the basal division of the Shawnee, was named by Adams,¹³ from Kanwaka Township, Douglas County, Kansas. It is reported to be quite thick and

¹³ Adams, G. I., *Stratigraphy and Paleontology of the Upper Carboniferous Rocks of Eastern Kansas*: U. S. Geol. Survey, Bull. 211, p. 45, 1903.

sandy in southern Kansas, in the vicinity of Elgin. Its thickness decreases northward to about 60 feet along the Kansas River at the type locality, 40 feet or less in northwestern Missouri, and about 5 feet in the Weepingwater Valley of Nebraska. Near Lecompton and Atchison, Kansas, and at Amazonia, Missouri, the lower portion of the member contains one or more lensing limestones for which the name Kereford Limestone is proposed. Heretofore this limestone has been known as the "Waverly Flagging," a non-geographic name and has been loosely correlated as the top portion of the Oread member. It is not persistent enough to serve as a horizon marker. The stone is dense, somewhat arenaceous, in part oolitic, and quite fossiliferous.

Lecompton Limestone Member. Bennett¹⁴ named this from Lecompton, Douglas County, Kansas. It includes four limestone and three shale units. The member is quite well shown at the type locality and south of Atchison, also north of Nodaway, Missouri.

The top unit, here called the *Avoca Limestone*, from an exposure in the South Fork Weeping Water about 3 miles east of Avoca, Otoe County, Nebraska, is a dense, bluish limestone in two or three beds, thickness about 2 feet in most of its distribution but greater in the Platte sections and north of Big Springs, Kansas. It carries some bryozoa, brachiopods, pelecypods, crinoid joints, and many *Fusulina* in places. The stone weathers yellowish brown.

The second unit, named the *King Hill Shale*, from exposures in King Hill southeast of Rock Bluff, Nebraska, is formed of bluish green and reddish argillaceous shale. Its thickness is about 7 feet at the type locality. The *Cullom Limestone* or third unit was named by Condra and Bengtson from near Cullom Station, Cass County. It consists of two limestones separated by about one foot of bluish gray, argillaceous-calcareous fossiliferous shale. The upper limestone, about 2 feet thick, is gray, massive, and quite fossiliferous. Its upper surface is wavy and somewhat pitted. *Fusulina* are abundant. The shale carries many specimens of *Campophyl-*

¹⁴ Bennett, John, Kan. Univ. Geol. Survey, Vol. I, p. 116, 1898.

lum torquium, Syringoporoid corals, a good many crinoids, and brachiopods. In most exposures the lower limestone is somewhat thinner than the upper one and weathers yellowish brown. It is quite fossiliferous.

The *Cullom Limestone* unit (Figure 10) is very persistent, holding its faunal and lithologic features from southern Kansas to Rock Bluff, Nebraska, and Folsom, Iowa. However, from Murray, Nebraska, to the Platte sections near Cedar Creek and Richfield its lower bed and the shale give way to a yellowish sandy-lime bed in which there are few fossils. The absence of the characteristic corals here is very noticeable. This locally developed sandy-lime zone is correlated with the unit next below rather than with the Cullom. The top limestone of the Cullom in the Platte sections is thicker and more massive than it is farther south.

The *Queen Hill Shale*, or fourth unit of the Lecompton, is named from Queen Hill northeast of Rock Bluff, Nebraska. It is bluish and argillaceous in its upper portion and black, fissile, and somewhat carbonaceous in the lower portion. The



FIGURE 10.—Cullom Limestone in the bluff north of Nodaway, Missouri.

Big Springs Limestone or fifth unit, named from near Big Springs, Kansas, is bluish gray to light gray, massive, jointed, and quite fossiliferous. It is 1 foot to 3 feet thick and has many *Fusulina*. The Doniphan Shale next below, named from exposures in northern Doniphan County, Kansas, has not been identified in the exposures of Nebraska. In Missouri and Kansas, it is a bluish, argillaceous shale with some sand and rusty calcareous material. The *Spring Branch Limestone* or basal unit of the Lecompton, also not found exposed in Nebraska, is massive above, and chalky and friable below. This weathers yellowish or brownish. It is named from exposures on Spring Branch north of Big Springs, Kansas.

The following table shows the thickness of the units of the Lecompton member in Nebraska, Iowa, Missouri, and Kansas exposures:

TABLE 6. *Lecompton Limestone Member*

Bed Units	Thickness (Feet)				
	Nehawka, Nebraska	Rock Bluff, Nebraska	Folsom, Iowa	North of Amazonia, Missouri	South of Atchison, Kansas
Avoca Limestone	2+	2	*	1+	1+
King Hill Shale.....	8	7+	*	4	6-7
Cullom Limestone.....	6-7	4-5	3	5+	4½-6
Queen Hill Shale	5	5½	6	5	5-6
Big Springs Limestone.....	¾	1+	1+	1 1/6	2½-3
Doniphan Shale	†	†	†	14+	7-8
Spring Branch Limestone	†	†	†	4-6	7-8
Thickness of Member.....	21 ¾+	19+	10+	37 1/6+	32+

* Not exposed.

† Does not extend northward to these sections.

The *Cullom Limestone*¹⁵ is one of the best horizon markers in the Pennsylvanian System. It is quite fossiliferous, with *Fusulina*, *Fistulipora nodulifera*, *Campophyllum torquium*, *Syringopora* (two species), and *Monilopora bennetti* (not *Aulopora*), usually in considerable numbers. (Figure 10.) The limestones are light gray, weathering buff; the shale is bluish, calcareous, and very fossiliferous. The usual combined thickness of the unit is 4 to 8 feet, averaging 6 feet.

Tecumseh Shale Member. This was named by Beede,¹⁶ from Tecumseh, Shawnee County, Kansas. It is formed principally of argillaceous and sandy shales, but contains some sandstone and limestone. The member extends from Iowa and Nebraska to central Kansas and probably to Oklahoma. Its thickness is about 50 feet in northeastern Kansas and northwestern Missouri and about 40 feet in the Platte and Weepingwater sections of Nebraska, where it includes two shales separated by the Cedar Creek Limestone. The lower shale is bluish green, argillaceous, and 6 to 9 feet thick. It has a dark carbonaceous band near the top. The upper shale is formed of gray, reddish, and bluish bands of argillaceous and sandy shale. Its thickness is from 13 feet to 35 feet in the Platte-Weepingwater sections.

The Cedar Creek Limestone¹⁷ varies from 2 to 9 feet in thickness. Its best development is at the type locality on Cedar Creek, 1½ miles southwest of the town of Cedar Creek. This division is a dark gray, dense limestone, with some shale partings. It thins southward to about 2 feet in the Weeping Water Valley and probably does not extend to Missouri and Kansas.

Deer Creek Limestone Member. The name Deer Creek has been used quite loosely. As originally defined by Bennett,¹⁸ from Deer Creek, east of Topeka, Kansas, it represents three limestones and two shales, i. e., a member and no bed in particular. Its subdivisions differ much in their faunal and

¹⁵ Condra and Bengtson, *Nebr. Acad. Sci.*, Vol. IX, No. 2, p. 11, 1915.

¹⁶ Beede, J. W., *Trans. Kan. Acad. Sci.*, Vol. XV, pp. 27-34, 1898.

¹⁷ Condra and Bengtson, *Nebr. Acad. Sci.*, Vol. IX, No. 2, p. 12, 1915.

¹⁸ Bennett, John, *Kan. Univ. Geol. Sur.*, Vol. I, p. 117, 1896.

lithologic features, hence they should be considered as separate units, especially when detailed studies are made of them relating to utilization and stratigraphic paleontology.

The upper unit of the Deer Creek has been called the Forbes Limestone in Missouri, Iowa, and Nebraska, from Forbes, Missouri, where it is well exposed. The writer is of the opinion that this name should be retained for this unit, but the U. S. Geological Survey holds that it would be preferable to select some other name.

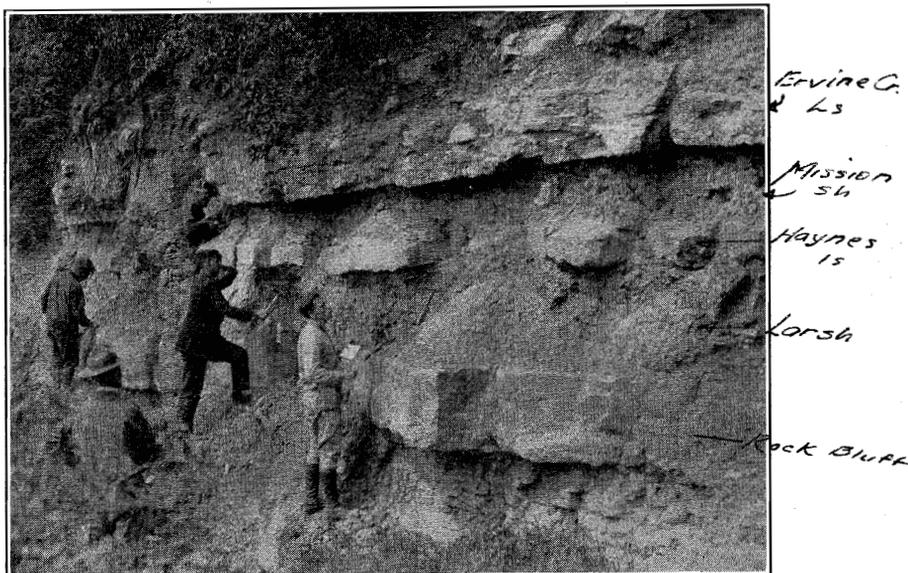


FIGURE 11.—Units of the Deer Creek Limestone member, southeast of Haynies Station, Iowa. The top of the Tecumseh Shale is shown below the Rock Bluff bed.

The following names are proposed for the units of the Deer Creek member (named downward): Ervine Creek Limestone, from Ervine Creek, northeast of Union, Nebraska; Mission Creek Shale, from exposures on Mission Creek, southeast of Iowa Point, Kansas; Haynies Limestone, from an outcrop in the foot of the bluffs southeast of Haynies Station, Mills County, Iowa; Larsh Shale, from the Larsh farm, on

Ervine Creek, northeast of Union, Nebraska; and Rock Bluff Limestone, from exposures high in the Missouri River bluffs northeast of Rock Bluff, Nebraska. All the units named above extend through outcrops in Nebraska, Iowa (Figure 11), Missouri, and Kansas, as shown by the following table:

TABLE 7. *Deer Creek Limestone Member*

Bed Units	Thickness (Feet)					
	Louisville, Nebraska	Nehawka, Nebraska	Rock Bluff, Nebraska	Haynies, Iowa	Forbes, Missouri	Kans. Valley east of Topeka, Kans.
Ervine Creek Limestone	28	20+*	24	22½	16	12
Mission Creek Shale.....	½-¾	1+	1½	1½	3-4	2-3
Haynies Limestone.....	¾	1	1	¾	1¾	2+
Larsh Shale	1¾-2	2	2	2	6-8	8+
Rock Bluff Limestone....	¾	1¾	1½	1¾	5+	6
Thickness of Member....	31 1/6	25¾+†	30	28½	31¾+	30+

* Top eroded.

† Part eroded.

The thickest and best known zonal development of the Ervine Creek Limestone is near Louisville, Nebraska, yet there are good exposures of this and the other Deer Creek beds in the Weepingwater Valley, between Wabash and east of Weepingwater, from Nehawka to near Union; and along the Missouri, in Nebraska and Iowa north of the Thurman-Wilson Fault. The Ervine Creek bed rises southward above the Missouri below Forest City, Missouri, and Iowa Point, Kansas, becoming well exposed in and near the bluffs east of the river to beyond Forbes, Missouri, and past Atchison

on the Kansas side, turning southwestward high in the upland to the Kansas Valley between Big Springs and east of Topeka. It thins from Nebraska southward to Oklahoma as the other units of the member increase in thickness. The Haynies and Rock Bluff beds thicken somewhat southward to northwestern Missouri and northeastern Kansas beyond which no detailed data concerning them are available.

Calhoun Shale Member. Beede¹⁹ named this from Calhoun, Shawnee County, Kansas. The member is formed of argillaceous shale, sandy shale, some limestone, and thin layers of coal. Its thickness is about 50 feet at the type locality but decreases to 20 or 25 feet in northwestern Missouri, northeastern Kansas (Iowa Point), and southern Nebraska (near Du Bois), and less at Jones Point, Nehawka, Union, Wabash, and Louisville.

The Calhoun includes three units in the exposures cited above. These, named upward, are the Jones Point Shale, Meadow Limestone, and the Iowa Point Shale.

The *Jones Point Shale* is named from Jones Point, a spur in the Missouri River bluffs east of Union, Nebraska. This unit is a bluish gray, argillaceous to calcareous shale, with some carbonaceous material. It is 8 to 10 feet thick and quite fossiliferous. It has a rich fauna of fenestrated bryozoa, brachiopods, and pelecypods.

The *Meadow Limestone* was named in 1915 by Condra and Bengtson²⁰ from exposures west of Meadow Station, Sarpy County, Nebraska. The bed is bluish gray and massive, except in the slabby upper portion. It is 3 to 4 feet thick, forms large blocks, is quite fossiliferous, carrying several species of bryozoa, brachiopods, and some pelecypods.

The *Iowa Point Shale* is thin in the Platte section and a little thicker at Jones Point and 2 miles north of Thurman, Iowa. Its thickness is about 10 feet at Iowa Point, Kansas, and Forest City, Missouri. The type exposure is in the Missouri River bluff just east of Iowa Point, Kansas. The shale

¹⁹ Beede, J. W., Trans. Kan. Acad. Sci., Vol. XV, pp. 27-34, 1898.

²⁰ Nebr. Acad. Sci., Vol. IX, No. 2, p. 13, 1915.

here, as at Forest City, is quite irregular, grading laterally into sand and sandstone. It carries thin lentils of coal.

Topeka Limestone Member. Although this division was named from Topeka,²¹ Kansas, there are places where it is now better exposed, as at Iowa Point, Kansas, Forest City, Missouri, and on Turner Creek southeast of DuBois, Nebraska. The member is formed of five persistent units — three limestones and two shales — for which names are given to serve in detailed faunal studies. In order of age, they are the Curzen Limestone, Turner Creek Shale, Du Bois Limestone, Holt Shale, and Coal Creek Limestone.

Years ago the Missouri Survey used the name *Curzen* for what seems to be the basal 5 to 8 feet of the Topeka. This unit is a bluish gray to brownish limestone, interbedded with thin shales. Next above it is 3 feet or more of bluish gray, calcareous shale, named from the *Turner Creek* exposure southeast of Du Bois, Nebraska. The *Du Bois Limestone* or third unit is one or two dark blue, dense, fossiliferous limestones forming large flat blocks. Pelecypods and Fusulina are a feature. The name is given from exposures on Turner Creek, southeast of Du Bois Nebraska.

The *Holt Shale*, though thin, is very persistent. It is bluish and argillaceous above and black and fissile in the middle and lower portions. There are good exposures of this in Holt County, Missouri, just below Forest City and northwest of Oregon, hence the name.

The upper unit of the Topeka was named the Union Limestone by Condra and Bengtson. This name being pre-occupied, the division is here called the *Coal Creek Limestone* from exposures on Coal Creek, north of Union, Nebraska. The limestone is dark blue, dense, brittle, and quite fossiliferous. It is split into two or three beds at places. Among its fossils are crinoid joints, bryozoa, brachiopods, and pelecypods in a fauna of many specimens and few species.

The following table shows the thickness of the Topeka beds at five widely separated places:

²¹ Bennett, John, Kan. Univ. Geol. Survey, Vol. I, pp. 116, 117, 1896.

TABLE 8. *Topeka Limestone Member*

Beds	Thickness (Feet)				
	Jones Point, Nebraska	2 ½ Miles north of Thurman, Ia.	Near Du Bois, Nebraska	Iowa Point, Kansas	Forest City, Missouri
Coal Creek Limestone	6 1/6	4+	5+	3+	5+
Holt Shale.....	1 1/6	1 5/6	2¾	2½	2¾
Du Bois Limestone	1	1	2 5/6	1 1/12	1 1/12+
Turner Creek Shale		5	3¾	4½	5+
Curzen Limestone..		0-3	6+	8+	6+
Thickness of Member	8 1/3	11 5/6-14	18 5/6	19 1/12	19 5/12

The Topeka member is poorly exposed in the abandoned quarries in the southeast part of Topeka, Kansas, as follows (descending order): Limestone, 1' or more; shale, drab, 4' 6"; limestone, fossiliferous, weathers buff, 1' 4" to 1' 6"; shale, calcareous, probably in part weathered limestone, quite fossiliferous, 2'; limestone, blue, with dark chert near top, weathers brownish, 5' to 6'; shale, blue, 1' 6"; limestone, blue, in two layers at places, quite fossiliferous, weathers buff or yellowish, 6'+.

Severy Shale Member. Adams²² named this in 1898, from Severy, Greenwood County, Kansas. The division has been traced from southern Kansas to the Platte sections of Nebraska, the thickness decreasing northward, as shown by the

²² Adams, G. I., Kan. Univ. Geol. Survey, Vol. III, p. 67, 1898.

following measurements: 45 feet, in the vicinity of Topeka, Kansas; 30 feet, Forest City, Missouri; 20 to 21 feet, near Du Bois, Nebraska; 10 to 11 feet, on Indian Creek, three miles north of Thurman, Iowa; 10 feet, north of Union, Nebraska; and 2 to 4 feet, in the Platte sections near Louisville, Nebraska.

The member is formed principally of bluish to nearly black argillaceous shale, grading into sand and sandstone. It carries limy lenses at places and considerable carbonaceous material in the form of scattered seams and thin layers of coal. The Nodaway Coal, varying from a few inches to about 2' 6' in thickness, occurs near the top of the member in most sections, as near Burlingame, Osage, Topeka, and White Cloud, Kansas; Forest City, Quitman, and Burlington Junction, Missouri; on Indian Creek about three miles north of Thurman, Iowa; and at Du Bois, Union, and Jones Point in Nebraska. The coal has been mined at the points cited. It has been penetrated in wells and shafts at Coin, College Springs, Clarinda, New Market, and other places in Iowa.

Howard Limestone Member. Adams²³ named this from Howard, Elk County, Kansas. The member is reported to be exposed from southern Kansas northward past Scranton, Carbondale, Osage City, and Topeka. It is quite well exposed at the brick plant west of Topeka, from which it extends northeastward through the upland to the base of the Missouri River bluffs at White Cloud. There are good exposures of it in the bluffs above Forest City, Missouri, on Indian Creek north of Thurman, Iowa, on Turner Creek southeast of Du Bois, Nebraska (Figure 12), and north of Union, Nebraska.

The Howard consists of two limestones separated by a shale bed of variable thickness. In much of its distribution the lower limestone, here called the *Church Limestone*, from the Church farm on Turner Creek southeast of Du Bois, Nebraska, is the most important unit of the member. It is bluish gray, dense, brittle, massive, quite fossiliferous, and in one or two beds forming large blocks. The thickness is 2 to 6 feet.

²³ Adams, G. I., Kan. Univ. Geol. Survey, Vol. III, p. 67, 1898.

The shale next above, named the *Kiewitz Shale*, from the Kiewitz Quarry, west of Meadow, Nebraska, is bluish to gray, argillaceous to quite calcareous and fossiliferous. Its thickness is 2 feet or more. The upper limestone is variable. At many places it breaks down as fine debris, as near Topeka. This bed or its equivalent is well developed in the Platte sections from Cedar Creek westward. It was named the "Louisville Limestone" by Condra and Bengtson, from Louisville, Nebraska. The name, though pre-occupied, is in use for this unit in Nebraska.

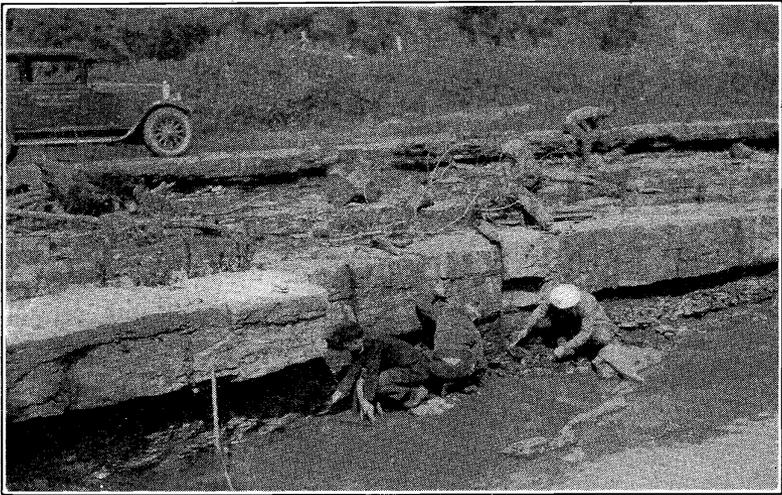


FIGURE 12.—Howard Limestone at the waterfall south of Du Bois, Nebraska.

The correlation of the Howard in Nebraska has been made beyond doubt at DuBois, Union, and Jones Point, by tying in with well determined horizons in Kansas, Missouri, and Iowa, but there is some doubt in regard to the beds assigned to the member in the Platte sections from Cedar Creek westward. Here a thin bluish gray limestone, a calcareous shale next above, and the "Louisville Limestone" are thought to form the Howard, because the basal bed is similar to and apparently in the horizon of the lower Howard Limestone as exposed

north of Union, and is underlain by what is thought to be the Severy. But the "Louisville Limestone" assigned to the top of the member is thicker and lithologically unlike the upper Howard Limestone in the exposures of Missouri and Kansas, which means that it is either a different development equivalent to the latter, or a bed which does not occur in the sections of southern Nebraska and the other states.

The Howard has a rich fauna, both as to species and number of specimens. Its units differ much in faunal content and lithologic features, hence they are given names for use in future study.

Scranton Shale Member. This, named from Scranton, Osage County, Kansas, by Haworth and Bennett,²⁴ is a thick member formed of argillaceous to sandy shale, considerable sand and sandstone, two or more thin limestones, and thin coal beds. One of the coals, called the Silver Lake in Kansas and the Elmo in Missouri, persists in the exposures of Missouri, Nebraska, and Kansas.

According to Haworth and Moore, the Scranton Shale member is 150 to 200 feet thick in central Kansas, decreasing northward. Its thickness is about 140 feet in the sections west of Topeka, 100 feet or more in northeastern Kansas (at White Cloud), about the same in northwestern Missouri, and 72 feet at DuBois, Nebraska. In the lower portion of the member along the Platte in Nebraska, are limestones and shales which do not extend to southern Nebraska, Kansas, and Missouri. These beds are above what seems to be the Howard horizon and represent either an unnamed member or a development in the Scranton. They probably thin out southeastward not far from the Platte sections.

As noted elsewhere, the Missouri and Iowa surveys place the upper boundary of the Scranton too high, in the Wabaunsee formation. Hinds and Greene, describing the Scranton in Volume XIII, Second Series, Missouri Geological Survey, page 185, say in part as follows: "The lower half is prevail-

²⁴ Haworth, Erasmus, and Bennett, John, Kan. Univ. Geol. Survey, Vol. IX, p. 112, 1908.

ingly clay and sandy shale or sandstone; the upper half contains a number of thin, buff-weathering limestones. Near the middle of the Scranton is a coal horizon, containing locally the Elmo Coal (Silver Lake of Kansas). The shale near the top of the Scranton is commonly variegated. On account of its soft nature the Scranton was eroded deeply prior to the deposition of the Kansan drift, and good outcrops are rare. No complete outcrop has been found in the state. Farther south, in Kansas, it appears in the face of escarpments capped by the overlying Burlingame Limestone (probably the same as the Tarkio Limestone of this report)."

Part of the above statement is at variance with the investigations made by Kansas and Nebraska geologists. Prior to its publication, Beede traced the Burlingame Limestone northward to exposures in the Missouri River bluffs at the Kansas-Missouri line west of White Cloud and published his findings. Condra and Bengtson also went over the same line of outcrops and confirmed the work done by Beede. This gave the Nebraska Survey a definite horizon for correlation. About this time the Big Nemaha section of Nebraska was worked out in detail for all of the beds up to the Tarkio Limestone, which is 80 feet or more above the Burlingame. Later Condra correlated the Tarkio of these and other exposures with the Iowa and Missouri sections and gave Messrs. Hinds and Greene the results of his investigations in conference held at Washington, telling them that the Burlingame of the Kansas Survey outcrops high in the bluffs at the Missouri-Kansas line west of White Cloud.

Evidently, Hinds and Greene did not study the sections at the mouth of the Big Nemaha west of White Cloud and north of Rulo, Nebraska, which are along-side Missouri. The exposures here include key beds for correlation in Missouri. The statement of Greene and Hinds, as cited above, should be corrected as follows:

1. The Burlingame and Tarkio limestones are not the same. They are separated by 80 to 100 feet of beds.
2. There are good outcrops of the Scranton near the Missouri boundary.

3. The hindrance in the study of the Scranton of Missouri is due more to the deep cover of drift and loess than to erosion.
4. The Elmo-Silver Lake Coal is quite persistent. It is near the top of the Scranton, i.e., just below the Rulo Limestone and not near the middle of the Scranton.
5. The variegated shale and thin limestones which Hinds and Greene refer to the top of the Scranton are in the Wabaunsee formation.
6. The Scranton, as described by Hinds and Greene, is too thick by 80 feet or more, because its upper boundary is placed at the base of the Tarkio rather than at the base of the Burlingame Limestone which is next above the Scranton according to the U. S. Geol. Survey.

Names of Scranton Beds. The divisions of the Scranton member and their thickness are given in the table showing the members of the Shawnee formation. The Silver Lake Shale, named by Beede,²⁵ is exposed in the Missouri River bluff below the mouth of the Big Nemaha, southeast of Rulo, Nebraska. It increases in thickness southward to 20 or more feet in the outcrops a few miles west of Topeka, Kansas. The Rulo Limestone, next below, was named in 1915 by Condra and Bengtson.²⁶ It holds a nearly uniform thickness from Nebraska south to beyond east of Emporia, Kansas. The Silver Lake-Elmo Coal, just below the Rulo Limestone, occurs in many outcrops between Missouri and southeast of Emporia, Kansas.

The *White Cloud Shale* is here named from exposures west of White Cloud, Kansas, where its thickness is about 100 feet. The salmon-colored limestone in the White Cloud Shale, about 26 feet below the Rulo bed, is here called the *Happy Hollow Limestone* from exposures in the bluffs at the mouth of Happy Hollow Creek located below the mouth of the Big Nemaha River.

Divisions 4 and 5 of the Scranton, as shown by Table 5, seem to be just below the White Cloud Shale. The *Cass Limestone* is named from exposures along the Platte northwest of South Bend, Cass County, Nebraska. The *Plattford Shale* is named from outcrops along the Platte, in Plattford Township, Sarpy County, Nebraska. The *South Bend Limestone*, next below, was named in 1915 by Condra and Bengt-

²⁵ Kan. Acad. Sci., Trans., Vol. XV, p. 30, 1898.

²⁶ Nebr. Acad. Sci., Vol. IX, No. 2, p. 14, 1915.

son, from exposures just north of South Bend, Nebraska. The name *Rock Lake* is given from an outcrop at Rock Lake, in Section 3, Township 12 North, Range 10 East, Sarpy County, Nebraska. The details regarding these lower beds of the Scranton member are brought out in the description of the Platte Valley cross section, run later on in this report.

WABAUNSEE FORMATION

Position and Boundaries. This formation, at the top of the Pennsylvanian System, was named by Prosser²⁷ from Wabaunsee County, Kansas. Prosser says on page 689 of his report: "I have considered the base of this formation as defined by the top of the Osage Coal horizon and the top by the base of the massive limestone known locally as the Cottonwood, Alma, and Manhattan limestones."

The Cottonwood Limestone, at the base of the Permian, fixes the upper limit of the Wabaunsee, but there is some doubt as to what Prosser meant to be the lower boundary. Prosser says, in a footnote, page 689 of his report: "Professor Haworth has shown that on the Kansas River the Silver Lake Coal, 125 feet above the Topeka, is the equivalent of the Osage Coal. (Kan. Univ. Quarterly, Vol. III, pp. 304-305, and Plate XX.)" This would indicate that the coal which Haworth and Prosser called the Osage is the Silver Lake, and that the Topeka Coal, 125 feet lower, is the Osage. It also shows that Prosser meant the base of the Wabaunsee to be at the Silver Lake Coal, not the Osage. Later, however, the lower boundary of the formation was placed higher, at the bottom of the Burlingame Limestone which is widely persistent and a good horizon marker. This change in the position of the base of the formation, from the Silver Lake Coal to the Burlingame Limestone may have been made because some geologists then claimed that the Silver Lake Coal is non-persistent and therefore not a good marker.

²⁷ Prosser, Chas. S., Classification Upper Paleozoic Rocks of Central Kansas: Journal of Geology, Vol. III, pp. 682-705, 1895.

Beede²⁸ held that the base of the Wabaunsee, as defined by Prosser, is the shale just below the Howard Limestone. This would refer all of the Scranton Shale and the Howard member to the Wabaunsee formation. I believe, though, as stated above, that Prosser meant to place the lower boundary of his formation at the Silver Lake Coal, then erroneously correlated as the Osage Coal, and not at the Nodaway Coal located below the Howard Limestone.

The writer finds that the Silver Lake Coal persists in many widely separated exposures, and that faunally the Rulo Limestone and the Silver Lake Shale above, should be grouped with the Wabaunsee formation rather than with the Scranton. This adds to the validity of Prosser's original definition, yet the Kansas Geological Survey places the base of the Wabaunsee formation at the Burlingame Limestone.

The position of the base of the Wabaunsee is a subject for further investigation. It should be determined whether the lower boundary is the Burlingame Limestone, the Silver Lake Coal, or in Beede's Shunganunga Shale under the Howard Limestone.

The Missouri Survey,²⁹ by correlating the Tarkio Limestone as the Burlingame, is in error by many feet in regard to the bottom of the Wabaunsee formation, as defined by the Kansas Survey and the U. S. Geological Survey. Tilton,³⁰ of the Iowa Survey, describes the first limestone below the Tarkio as at the base of the Wabaunsee, which is also incorrect. He refers to the "Preston" Limestone now known to be the Emporia.

Outcrop Areas. The Wabaunsee is widely exposed from southwestern Iowa to Oklahoma. It has three outcrop belts in Nebraska and northeastern Kansas — one, to the east, the beds dipping normally westward; and two, farther west, in the flanks of the Table Rock Anticline.

²⁸ Beede, J. W., Stratigraphy of Shawnee County: Kans. Acad. Sci., Vol. XV, p. 29, 1898.

²⁹ Hinds and Greene, Stratigraphy of the Pennsylvanian Series: Missouri Bureau of Geol. and Mines, Vol. XIII, 2nd Series, p. 186, 1914.

³⁰ Tilton, John L., The Missouri Series of the Pennsylvanian System Southwestern Iowa: Iowa Geol. Survey, Vol. XXIX, p. 231, 1920.

Sub-divisions. There has been much misunderstanding regarding the units of the Wabaunsee formation due to the method employed in establishing them and a lack of field investigation and correlation over wide areas, extending across state lines. This is shown in the descriptions of the members, some of which need correlation and revision.

Most members of the Wabaunsee formation were named in Kansas from cross section traverse before their distribution had been determined. This method led to confusion and some error. The following members of the formation (descending order) are recognized by the Kansas Survey:

1. Eskridge Shale.
2. Neva Limestone.
3. Elmdale Shale.
4. Americus Limestone.
5. Admire Shale.
6. Emporia Limestone.
7. Willard Shale.
8. Burlingame Limestone.

These sub-divisions have been traced from their type localities in Kansas and correlated in the Nebraska sections. Numbers 1, 2, 3, 4, and 8 are valid members in Nebraska, unless it might be held that the Americus should be reduced in rank. The Admire member includes the McKissick Grove Shale of Iowa at its base. Next below is the Tarkio Limestone member of Iowa which has not been recognized by the Kansas Survey, although it is prominently developed in Kansas. The Willard Shale and the so-called Emporia Limestone have been difficult to work out. The beds called by these names in Kansas need re-defining in order to establish a basis for correlation in Nebraska.

Nemaha Beds. In 1915 Condra and Bengtson³¹ described the Nemaha formation from exposures in the Big Nemaha Valley of Nebraska to include all strata from the base of the

³¹ Condra and Bengtson, Nebr. Acad. Sci., Vol. IX, No. 2, pp. 3-39, 1915.

Rulo Limestone up to and including the Tarkio Limestone (Figure 13). This assembly of beds, less the Silver Lake Shale and Rulo Limestone, which some geologists would assign to the Scranton, represents a strong member at the base of the Wabaunsee. The limestones are quite important. Although this is a natural strong member, it has not been accepted generally as such. Some of its units have been called members in Kansas, Missouri, and Iowa, and there may be some objection to the reduction of their rank. The seven units of the so-called Nemaha member or formation (reduced) persist southward to Lyon County, Kansas, or farther, about as follows:

1. Limestone (Tarkio Limestone of the Iowa Survey), 6' to 10'.
2. Shale, 30' to 60'.
3. Limestone, two beds, separated by 1' to 5' of shale, combined thickness, 9' to 10'. ("Preston" Limestone of Condra and Bengtson.)
4. Shale, 13' to 20'.
5. Limestone, 2' to 6'. ("Fargo" Limestone of Condra and Bengtson.)
6. Shale, 12' to 26'.
7. Limestone (Burlingame of the Kansas Survey), 6' to 12'.

The distribution of these units has been determined. It is known that number 1 is the Tarkio, and that number 7 is the Burlingame, but the following problems are confronted in correlation and nomenclature:

1. Is number 1 to be called the Tarkio Limestone or the Emporia Limestone?
2. What is the Willard Shale—number 2, number 6, or numbers 2 to 6 inclusive?
3. Is the Emporia Limestone—number 1, number 3, or numbers 1 to 5 inclusive?
4. What names should be accepted for numbers 4, 5, and 6?
5. Do the Nemaha units constitute one member (Nemaha), five members, or seven members?
6. Are the Tarkio Limestone and Willard Shale in the Admire Shale member?

These problems should be decided on a basis of data published by the geologists who described and named the members and smaller units held in question. It is thought advisable, therefore, to review the literature on the subject in order to arrive at the basic facts.

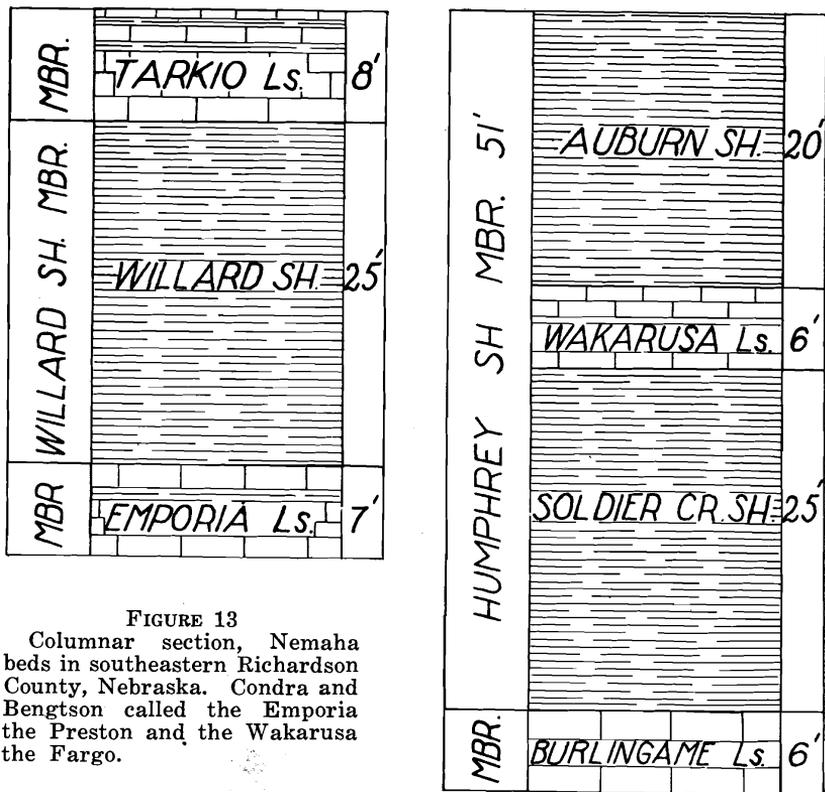


FIGURE 13

Columnar section, Nemaha beds in southeastern Richardson County, Nebraska. Condra and Bengtson called the Emporia the Preston and the Wakarusa the Fargo.

REVIEW OF PUBLICATIONS

1859. Meek and Hayden¹ made a reconnaissance along the Kansas River in 1858. They reported upon this survey in 1859 and later, but their reports contain nothing of direct bearing on our problems. However, it is of interest to know that they observed that the waterfall south of Maple Hill, Kansas, is held by the unit now known as the Tarkio Limestone.

1866. Swallow² described the Kansas River section in which the Nemaha beds are included in a general way. The Tarkio

¹ Meek and Hayden, Proc. Acad. Natl. Sci., Phila., pp. 8-30, 1859.

² Swallow, Prelim. Rept. Geol. Survey of Kansas, 1866.

was called the Chocolate Limestone, and the Burlingame was called the Stanton Limestone in confusion with a member which occurs at a much lower horizon.

1894. Prosser ³ reviews Swallow's Kansas River section and makes some corrections which do not contribute directly to our problem in nomenclature and correlation.

1894. Haworth ⁴ and Kirk describe the Neosho-Cottonwood River section of Kansas. Their division number 9, called the Wyckoff Limestone, is the Burlingame. There is some doubt in regard to the measurements and interpretation of some of their higher divisions, the interval between the Burlingame and Cottonwood limestones being much greater than that given by Haworth and Kirk. See later report by Kirk, in Volume I, Kansas Geological Survey, for a further description of this section.

1896. Bennett.⁵ The following subdivisions, representing the Nemaha beds, named in descending order, are compiled from Bennett's Kansas River section:

1. Limestone, yellowish, holds fall on Mill Creek south of Maple Hill; with many robust *Fusulina* and large *Lophophyllum profundum*, 8'.
2. Shale slope, 50' to 60'.
3. Limestone, buff, with many *Fusulina* and other fossils, 2' 6".
4. Shale, 25'.
5. Limestone, blue, thinning westward, 5'.
6. Shale, 21'.
7. Limestone, going below the river at Willard, 6'.

These subdivisions are practically the same as the Nemaha beds in Nebraska. Number 1 is the Tarkio (Figure 14), and number 7 is the Burlingame.

1896. Kirk ⁶ says: "Above the Wyckoff Limestone is a heavy bed of shale exposed along the hills to the southeast of Emporia. In the road and ravines to the north of Wyckoff

³ Prosser, Chas. S., Kan. River Section: Bull. Geol. Soc. Am., Vol. VI, pp. 29-54, November, 1894.

⁴ Haworth, Erasmus, and Kirk, M. Z., Neosho and Cottonwood Rivers Sections: Kan. Uni. Quarterly, pp. 104-115 and Figure 2 of Plate IV, January, 1894.

⁵ Bennett, John, Kansas River Section—Kansas City to McFarland: Kan. Geol. Sur., Vol. I, pp. 107-124, 1896.

⁶ Kirk, M. Z., The Cottonwood and Neosho River Sections: Kan. Univ. Geol. Survey, Vol. I, p. 80, 1896.

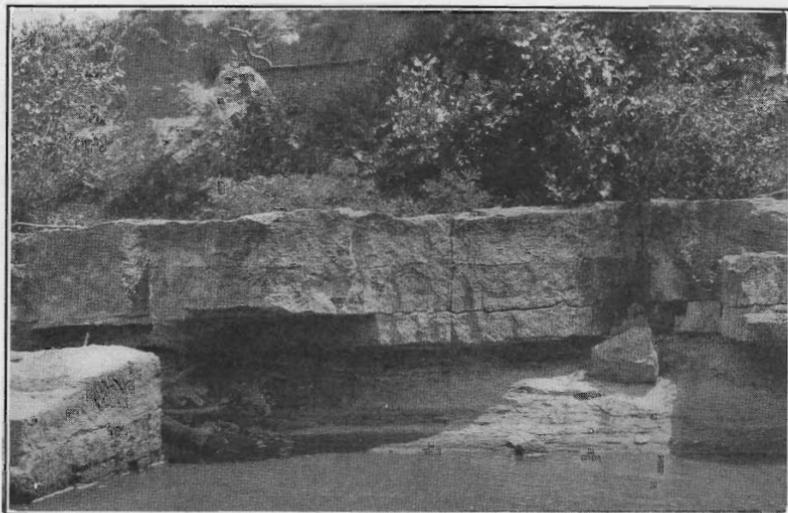


FIGURE 14.—Tarkio Limestone on Mill Creek, southwest of Maple Hill, Kansas.

occurs the Emporia Limestone. It was first seen in Chicago Mound, which is near Wyckoff and is by far the highest hill in this vicinity. This rock has been quarried to some extent at Emporia and to the northeast for street and bridge purposes. This system disappears under the river near the Emporia waterworks."

I have studied the exposures in the vicinity of Wyckoff, Chicago Mound, and Emporia in the hope of determining which bed Kirk meant to call the Emporia Limestone, but have not been able to decide the matter definitely. More than one limestone is exposed at different distances north of Wyckoff, and Kirk does not say which one is the Emporia. The Burlingame Limestone is exposed in Chicago Mound about 40 or 50 feet above the base and is here overlain by divisions 6, 5, 4, and 3 of the Nemaha beds. Division 3 of the Nemaha beds caps Chicago Mound. This may be the one Kirk meant to call the Emporia, but of this I am not positive.

The reference Kirk makes to the Emporia Limestone is not a definition. However, his name Emporia is used by the

Kansas Survey. If Kirk meant to refer to a single unit, as the Emporia, probably it was division 3 of the Nemaha beds.

1898. Beede⁷ in his *Stratigraphy of Shawnee County, Kansas*, uses the following names for the portion of his section which represents the Nemaha beds:

1. Chocolate Limestone, 7' to 10'.
2. Willard Shale, 55'.
3. Elmont Limestone, 1' to 2'.
4. Auburn Shale, 8' to 20'.
5. Wakarusa Limestone, 2' to 4'.
6. Soldier Creek Shale, 40' or less.
7. Stanton Limestone, 4' to 7'.

These units are about the same as in Nebraska. The name used for number 1, after Swallow, has been abandoned because it is non-geographic. This unit was later named the Tarkio Limestone by Calvin of Iowa.

A point of special interest in this section is that Beede definitely locates his Willard Shale—its top at the base of what is now known to be the Tarkio Limestone, and the base at the top of our division 3 of the Nebraska section of the Nemaha beds. Later, however, the Kansas geologists defined the Willard Shale as extending down to the Burlingame Limestone. Why this was done is not known to the writer, unless it was the result of faulty correlation.

The Elmont Limestone is one bed of the unit which Kirk may have meant to call the Emporia Limestone. It is the "Preston" Limestone of Condra and Bengtson. The name Auburn was free at the time Beede used it and should be retained for the fourth unit. It was used at a later date for a chert in the Ordovician of Missouri. The Wakarusa Limestone is Condra and Bengtson's "Fargo" Limestone and has priority.

Division 6 is 21 to 26 feet thick in Shawnee County. Beede makes it 40 feet or less. The name Soldier Creek should be retained for this unit. Division 7 is the Burlingame Limestone as later defined by the Kansas Survey.

⁷ Beede, J. W., *Stratigraphy of Shawnee County*: Kan. Acad. Sci. Proc., Vol. XV, pp. 27-34, 1898. Read before the Academy January 4, 1896; published in 1898.

1900. Smith,⁸ in connection with his paper on the Americus Limestone, has a vertical section of Lyon County, Kansas, in which I have correlated the Nemaha beds exposed in the vicinity of Emporia, Kansas, as follows:

1. Shale and limestone, about 20'. The basal portion of this is the Tarkio Limestone.
2. Shale, 60' 6". Beede's Willard Shale.
3. Limestone and shale, basal bed 3' thick; combined thickness including a top limestone and shale separation, 4' to 9'. This seems to be Smith's Emporia Blue.
4. Shale, 13'. The Auburn Shale by Beede.
5. Limestone, 6'. Beede's Wakarusa Limestone, which is the "Fargo" Limestone of Condra and Bengtson.
6. Shale, with two thin beds of limestone, 24'. Beede's Soldier Creek Shale.
7. Limestone, 8'. The Burlingame Limestone.

1903. Adams⁹ proposed the name Olpe to apply to the shales between the Barclay (Burlingame) and Emporia limestones, and assumes the thickness of the shales to be 50 to 60 feet. He says that the shales had not been named, which is in error. Adams states that A. J. Smith mapped the Emporia Limestone in Lyon County where it persists in a thickness of about 10 feet.

It is quite certain that his (Adams) map, based in part on the work of Smith, shows the outcrop of Smith's Emporia System, the lower portion of which is the Tarkio Limestone. If this interpretation is correct, Adams' name Olpe was proposed for all of the interval between the Tarkio and Burlingame limestones, the units of which had been named the Willard Shale, Emporia Blue Limestone, Auburn Shale, Wakarusa Limestone, and Soldier Creek Shale. All of these names were then in good standing except Smith's Emporia Blue, which probably is Kirk's Emporia Limestone.

1904. Smith,¹⁰ after considerable study of the geology of Lyon County and adjacent areas, states that in the vicinity of Emporia, the strata which Kirk named the Emporia Lime-

⁸ Smith, Alva J., Kan. Acad. Sci. Trans., Vol. XVII, 1899-1900. Maps and section on pages 191-193.

⁹ Adams, Geo. I., Upper Carboniferous Rocks of the Kansas Section: Bulletin 211, U. S. Geol. Survey, pp. 52-53, 1903.

stone have a thickness of about 86 feet including three limestones and intervening shales, and that in a previous paper he (Smith) suggested that the name Emporia System be retained for the limestones at the top, and the name Emporia Blue be applied to Kirk's lower unit. He says that the Emporia Blue has importance and persistence, and proposes to name its lower bed the Reading Blue Limestone.

According to Smith, his Emporia System is composed of about four limestones separated by thin shales and 10 feet of shale overlain by a thin limestone which is exposed at the water works northwest of Emporia. This section has been examined, and I am quite sure that Smith's so-called Emporia System represents the Tarkio Limestone, the Pierson Point Shale, and the Maple Hill Limestone, described herein, and that the 60 feet of shale below his system is Beede's Willard Shale.

Smith's lower bed of the Emporia Blue, later called the Reading Blue Limestone is the lower layer of division 3 of the Kansas River and Nebraska sections. It is the Elmont Limestone of Beede which is the "Preston" Limestone of Condra and Bengtson. There remains some question, however, regarding the name that should be applied to the whole of this unit.

Smith, in his paper of 1904, restricts Adams' Olpe Shale and applies the name Olpe to the 60 feet of shale next above the Reading Blue. Obviously he did not know that Beede had named this unit the Willard Shale. Smith also proposes the name Humphrey Shale for the lower portion of Adams' Olpe Shale, i.e., for the interval between the Reading Blue and Burlingame limestones. This division is composed of three units, then called the Auburn Shale, Wakarusa Limestone, and the Soldier Creek Shale. So, evidently, there is no basis for using the name Humphrey in this connection unless it should apply as a member to include the three units just named.

¹⁰ Smith, Alva J., The Reading Blue Limestone: Kan. Acad. Sci. Trans.: Vol. XIX, pp. 150-154, with plate and map, 1904.

Smith's names Emporia Blue and Reading Blue are non-geographic and therefore not binding. The name Emporia has been used with too much freedom as Emporia, Emporia System, and Emporia Blue. This profusion of names has contributed to the confusion of strata.

Since the date of Smith's publication the basal portion of the Emporia System, i.e., the Tarkio Limestone, has been recognized southward in Kansas to near the Oklahoma line.

1908. Haworth,¹¹ then state geologist of Kansas, says in regard to the Willard Shale: "These shales were named by Beede from a little village by that name on the south side of the Kansas River about 15 miles above Topeka, and the name is used to designate the shales between the Burlingame and Emporia limestones. Adams called them the Olpe shales subsequently, as appears, to the time they were named by Beede. The Willard shales are, perhaps, in the vicinity of Olpe, not over 60 feet thick. Smith makes this interval a little less in Lyon county — that is, reckoning up to his Emporia blue; but if the interval be carried up to what he calls the Emporia System it would be about 190 feet."

As stated before, the Willard Shale, as defined by Beede, is above the Emporia Blue unit. However, Haworth's definition places this shale below the Emporia Blue with a provisional extension upward to Kirk's Emporia System, the main portion of which is the Tarkio. It might be noted also that the interval between the Burlingame and the base of the so-called Emporia System is about 120 feet and not 190 feet, as given by Haworth.

It would seem that Haworth, by assigning a thickness of not over 60 feet to the Willard Shale, and in placing its base at the top of the Burlingame, may not have been fully conversant with the units of the Nemaha beds, or more likely, he correlated our division 3 as the Emporia Limestone.

Haworth's description of the Emporia Limestone is as follows: "This name is applied by Kirk and designates the limestone above the Willard Shales. These limestones are

¹¹ Haworth, Erasmus, and Bennett, John, General Stratigraphy: Kan. Univ. Geol. Survey, Vol. IX, p. 113, 1908.

described by Smith, and Prosser draws his description from Smith, as follows: 'The Emporia Limestone is composed of three feet of hard blue limestone at the base, the upper 6-inch layer making a good flagstone which is extensively used in Emporia. Then there is 4 feet of shale capped by another hard blue limestone 2 feet in thickness. The Emporia Limestone is about 9 feet in thickness, and is found in two layers separated by about 4 feet of shale.'

The above statement is descriptive of division 3 of the general section of the Nemaha beds in the vicinity of Emporia and not of the Tarkio Limestone, which indicates that Haworth's Emporia Limestone is our division 3 of the general section, and that all of his Willard Shale is below that defined by Beede. If this is true, Haworth omitted the Willard Shale proper from his section, leaving out about 60 feet of the Wabaunsee formation.

1917. Moore¹² says: "The Willard Shale is a rather thin member immediately above the Burlingame Limestone, composed of blue and yellow shale with a small amount of friable limestone. The thickness in Lyon county, where it is typically developed, is about 45 to 55 feet. Above the shale thus described is about 9 feet of hard blue limestone of sufficient stratigraphic importance to receive recognition as a distinct member under the name Emporia Limestone. The Emporia consists of two limestone beds, the lower 3 feet in thickness and the upper 2 feet, separated by about 4 feet of shale. It has been traced across Lyon and Wabaunsee counties into Shawnee county. On account of its characteristic blue color it was called the 'Emporia blue Limestone' by Smith in his account of Lyon county."

The above statement by Dr. Moore, state geologist of Kansas, shows that he correlates division 3 of the Nemaha beds as the Emporia Limestone and places the Willard Shale below this unit. Since he describes the Admire Shale member as next above the Emporia, it would appear that he too omits some beds from the section, i.e., Beede's Willard Shale and the Tarkio Limestone, or that the latter are held to be in

¹² Moore, Raymond C., Geol. Survey of Kansas, Bull. 3, p. 106, 1917.

the Admire member. It seems, however, that both Haworth and Moore have not realized that divisions 1 and 3 of the Nemaha beds are not the same, and that they are separated by about 60 feet of strata, called the Willard Shale, the base of which is about 45 feet above the Burlingame Limestone.

Conclusions Regarding the Nemaha Beds. The following is a summary of conclusions based on the foregoing discussion:

1. Number 1 of the Nemaha beds in the Kansas and Nebraska sections should be called the Tarkio Limestone member, because there is no reason to assume that Kirk's name Emporia suggested in 1896 was applied to this unit, and because the name Tarkio proposed by Calvin in 1900 has priority over Smith's name Emporia System.
2. The Willard Shale is number 2 of the section. It was clearly defined by Beede as such, and the name has priority over the term Olpe Shale proposed by Adams and re-defined by Smith.
3. The name Emporia, if it is retained, should apply to number 3, because Kirk seems to have meant to apply it to this unit, and because Haworth and Moore have, in effect, defined it as such. This name has priority over Beede's Elmont Limestone.
4. Number 4 is Beede's Auburn Shale. The name is in good standing.
5. Number 5 is the Wakarusa Limestone, after Beede, and in good standing.
6. Number 6 is the Soldier Creek Shale, after Beede. The name is in good standing.
7. There seem to be five members in the Nemaha beds, viz: (1) Tarkio Limestone; (2) Willard Shale; (3) Emporia Limestone; (4) a member including the Auburn Shale, Wakarusa Limestone, and the Soldier Creek Shale; and (5) the Burlingame Limestone. Smith suggested the name Humphrey Shale in 1904 to apply to the beds between the Reading Blue and Burlingame limestone, which is the interval represented by the Auburn Shale, Wakarusa Limestone, and the Soldier Creek Shale, each of which is about as important as some of the members of the Wabaunsee. However, the three units in question form an important natural member to which the name Humphrey, revived, is here applied.
8. The Tarkio and Willard members are not units of the Admire member. Their names have priority over the Admire. This places the base of the Admire at the top of the Tarkio Limestone and not at the top of the Emporia Limestone.
9. The names "Preston" Limestone and "Fargo" Limestone are abandoned, because the names Emporia Limestone and Wakarusa Limestone have priority over them.
10. The name Nemaha formation is dropped provisionally, to be revived if it is decided by the State and Federal Geological Surveys that the Wabaunsee beds represent two formations, and the boundary of the lower one is placed at the Rulo Limestone or at the Silver Lake Coal.

Revision of the Admire Shale Member. The so-called Admire member, which the Kansas geologists define as occupying the interval between the Emporia and Americus limestones, should be re-defined or the names abandoned. As now defined in Kansas the member includes in its lower portion the McKissick Grove Shale, the Tarkio Limestone, and the Willard Shale.

Adams,¹³ in proposing the name Admire in 1903, said: "This name is introduced for the shales lying between the Emporia Limestone and the Americus Limestone. The thickness assigned to them is 40 feet, although they have been studied in only a very general way." Just what bed or beds Adams erroneously correlates as the Emporia Limestone in arriving at the thickness of 40 feet for the Admire is not known. It may have been the Falls City Limestone which is poorly exposed southwest of Admire, about 60 feet below the Americus. It could not have been the Emporia Limestone which is much lower in the section and does not crop out in this vicinity. Only the upper portion of the Admire as later recognized by Prosser,¹⁴ Haworth,¹⁵ Moore,¹⁶ and others, is exposed at Admire, which means that the name Admire, as now used, is not properly applied.

It seems that Adams did not take into account Beede's¹⁷ Dover Shale and Sandstone, Dover Limestone, and Rossville Shale and Sandstone when he named the Admire. These divisions occupy practically all of the interval represented by the Admire Shale member. However, only one of these names is defined acceptably. It is the Dover Limestone which extends northward to Nebraska and Iowa.

Dr. Moore,¹⁸ in his description of the Admire, says: "A thick succession of shale and sandstone with thin beds of limestone and coal is included in the Admire Shale member.

¹³ Adams, G. I., *Stratigraphy and Paleontology Upper Carboniferous Rocks of Kansas Section*: U. S. Geol. Survey, Bulletin 211, p. 53, 1903.

¹⁴ Prosser, Chas. S., *Journal of Geol.*, Vol. X, p. 707.

¹⁵ Haworth, Erasmus, *Kan. Univ. Geol. Survey*, Vol. XI, p. 114, 1908.

¹⁶ Moore, Raymond C., *Kan. Geol. Survey, Bulletin* 3, p. 106, 1917.

¹⁷ Beede, J. W., *Stratigraphy of Shawnee County*: *Kan. Acad. of Sci.*, Vol. XV, p. 31, 1898.

¹⁸ Moore, Raymond C., *Geol. Survey of Kansas, Bull.* 3, p. 106, 1917.

The total thickness of the member in Lyon county is approximately 300 feet. About 70 feet above the base of the Admire are five thin limestone beds called by Smith 'The Emporia System,' and mapped by Adams as the Emporia Limestone."

Obviously, according to this statement, Dr. Moore places the base of the Admire Shale member at the top of Smith's Emporia Blue Limestone, which is thought to be the Emporia Limestone proper, and includes in its lower portion the Willard Shale and Tarkio Limestone, both of which have priority over Adams' name Admire. In other words, he probably did not know the exact horizon of Beede's Willard Shale and that the Tarkio Limestone is in the so-called Admire member.

The Willard Shale¹⁹ and the Tarkio Limestone,²⁰ having priority and being recognized as members, are therefore not in the Admire Shale member. This means that the lower boundary of the Admire is at the top of the Tarkio Limestone, or higher in the section, or that the name Admire should be abandoned.

The Admire, as defined by the Kansas geologists, includes at its base the McKissick Grove Shale member, named by Dr. Geo. L. Smith²¹ in 1908 from McKissick's Grove, located northeast of Hamburg, Iowa, to include all of the Pennsylvanian beds above the Tarkio Limestone in Iowa. Smith's definition is objectionable, however, because the top-most bed of the Pennsylvanian of Iowa probably is covered somewhere in the Missouri River bluffs or in the uplands awaiting discovery, and therefore is not a fixed horizon. The highest known exposed Pennsylvanian horizon of Iowa is in the lower portion of the Aspinwall Shale, but the highest well-defined marker would be the Brownville Limestone or the better shown Dover Limestone which outcrops under the steel bridge at McKissick Grove, below which the Tarkio Limestone is exposed.

¹⁹ Beede, J. W., Kan. Acad. Sci., Vol. XV, p. 31, 1898.

²⁰ Calvin, Samuel, Iowa Geol. Survey, Vol. IX, p. 634, 1900.

²¹ Smith, Dr. Geo. L., Iowa Geological Survey, Vol. XIX, p. 641, 1908.

If the name McKissick Grove is to be retained, it should be made to apply to strata having definite upper and lower boundaries as here shown. This matter has been taken up with representatives of the Iowa Survey, in the field, and decided that the top of the McKissick Grove member should be at the base of the Brownville Limestone. (Figure 15).

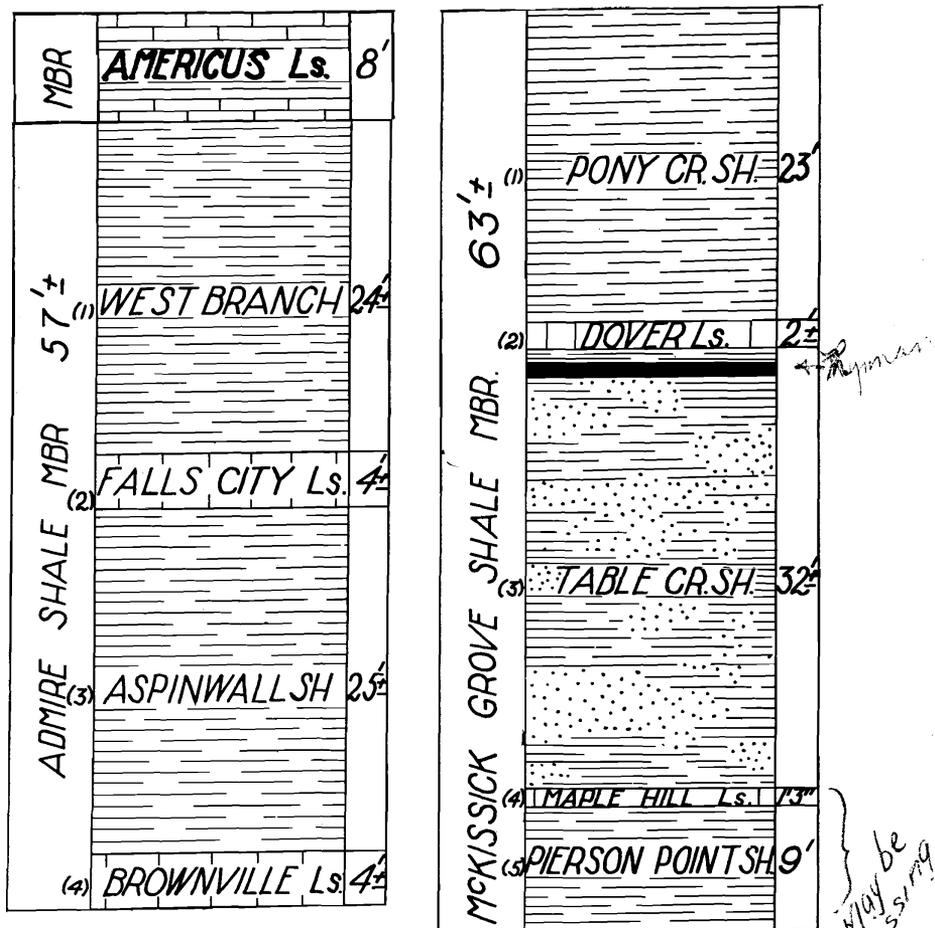


FIGURE 15.—Columnar section, the Americus, Admire, and McKissick Grove members.

It may be held by some that the Dover Limestone, which is better exposed at a few places in Iowa, should be made the upper limit of the McKissick Grove Shale. The argument in favor of this is found in the fact that this unit is a good marker in Iowa, Nebraska, and Kansas, and in the fact that the Nyman Coal just below marks a stage in physiographic development.

Conclusions:

1. The definition of the Admire should be revised or the name should be abandoned.

2. The definition of the McKissick Grove Shale should be revised and made to apply to the strata between the Tarkio and Dover limestones or to those between the Tarkio and Brownville limestones, probably the latter.

3. The Nebraska Survey is to use the name Admire Shale member for the beds between the base of the Brownville Limestone and the Americus Limestone, because this portion of the section constitutes about what Adams defined as a member. The Brownville outcrops on the creek just northeast of Admire, and the Americus is exposed southwest of it.

Major Divisions of the Wabaunsee. The members of the Wabaunsee formation, as now constituted, fall naturally under two main subdivisions in contact at the top of the Tarkio Limestone. These major divisions represent two well-defined stages of development, but the lower stage starts in the Scranton Shale at the base of the Rulo Limestone.

The beds of the Wabaunsee, together with the two top units of the Scranton Shale member, really constitute two formations. This conclusion is supported by lithologic and faunal data.

Basic Units. The foregoing review of the lower divisions of the Wabaunsee covers the natural subdivisions of the formation up to the Americus Limestone, above which all of the members, named by the Kansas geologists, extend into Nebraska without much change.

The subdivisions of the members of the Wabaunsee have been worked out in detail in Nebraska and correlated with adjacent states. Collections of rock materials have been made

from them and studied or tested with respect to their lithologic and chemical properties. Fossils also of these units have been collected, listed, and described for publication in special reports.

The Wabaunsee units named in this report have distinctive physical features, wide persistence, and in most cases mark faunal zones. Their designation should be of use in future study in stratigraphic paleontology and economic geology.

DESCRIPTION OF THE WABAUNSEE MEMBERS

Following are brief descriptions of the members and smaller units of the Wabaunsee in ascending order, in which the top of each unit is in contact with the base of the next higher unit, which shows the position of each subdivision without further definition. Except in the northern distribution, where some of the higher subdivisions have been removed by erosion, all of the members and smaller units persist from Iowa to east-central Kansas or farther, which means that it will not be necessary to repeat this fact in connection with the descriptions of the various subdivisions. It should be recognized, however, that some of the members, although persistent as such, include lenses and beds which grade between shale, sand, sandstone, and limestone. This condition, which has been misunderstood, is a feature of the McKissick Grove Shale member and portions of the Admire Shale member, but is not of the other members.

Burlingame Limestone Member

Several names have been proposed for this member, among them Stanton, by Swallow;²² Wyckoff, by Haworth and Kirk;²³ Burlingame, by Hall;²⁴ Eureka, by Haworth;²⁵ and Barclay by Adams.²⁶ The name Stanton was given to two members at the same time. It has been retained for the lower one. The names Wyckoff and Eureka were pre-occupied, leaving Burlingame, which was first applied to a shale and a limestone and later by the Kansas Survey to the limestone only.

²² Prelim. Rept. Geol. Survey of Kansas, 1866.

²³ Kan. Univ. Quarterly, Vol. II, p. 111, 1894.

²⁴ Univ. Geol. Survey Kansas, Vol. I, p. 105, 1896.

The Burlingame Limestone is a dense, massive to irregular, bluish gray bed, or separated at places by two or more thin shale seams. It is well shown at Sand Point east of Union, at the base of the spur south of Rulo, high in the bluffs south of the mouth of the Big Nemaha (thickness 5'), at places between west of White Cloud, Kansas and five or six miles west of Topeka, and thence southward past west of Auburn and east of Emporia to beyond the south boundary of Kansas; also in the flanks of the Table Rock Anticline between Elk Creek, Nebraska and the Kansas River valley. Among its best exposures are those at the S. B. A. and other quarries west of Topeka, Kansas, where the thickness is 8 to 10 feet. This limestone is unimportant or very thin in southwestern Iowa and in the northwest county (Atchison) of Missouri. It is thin in the Table Rock Anticline. The stone is not very fossiliferous. It weathers yellowish brown.

Fauna: Crinoid joints, a few bryozoa, several species of brachiopods such as *Chonetes granulifer*, *Composita subtilita*, *Ambocoelia planoconvexa*, *Spirifer cameratus*, *Productus semireticulatus*, *Productus cora*, *Pustula semipunctata*, *Entiletes hemiplicata*, and a few pelecypods.

Humphrey Shale Member

Smith²⁷ named this in 1904 to apply to the interval between the Burlingame and Emporia Blue (now Emporia) limestones. Its thickness is about 45 feet or more, including the Soldier Creek Shale, Wakarusa Limestone, and Auburn Shale, which together form a natural member of about the same rank as the Willard Shale.

Soldier Creek Shale, named by Beede²⁸ from Soldier Creek in Shawnee County, Kansas; composed of bluish, argillaceous shale modified by some sand and thin limestones, thickness about 25 feet. This has bands of reddish shale in some sections.

²⁵ Univ. Geol. Survey Kansas, Vol. III, p. 67, 1898.

²⁶ U. S. Geol. Survey, Bull. 211, p. 51, 1903.

²⁷ Smith, Alva J., Kan. Acad. Sci., Vol. XIX, pp. 150-154, 1904.

²⁸ Beede, J. W., Stratigraphy Shawnee County: Kan. Acad. Sci. Trans., Vol. XV, p. 31, 1898.

Fauna: *Entiletes hemiplicata*, *Pustula semipunctata*, *Productus cora*, *Allorisma terminale*, etc.

Wakarusa Limestone, named by Beede²⁹ from exposures near Wakarusa, Shawnee County, Kansas; formed of two dense, blocky, bluish limestones separated by 1 to 4 feet of argillaceous shale, or in places, formed of one solid limestone about 6 feet thick.

Fauna: A few *Fusulina*, ostracods and bryozoa; crinoid columns, common and very noticeable; *Lophophyllum profundum*, rare; several species of brachiopods such as, *Entiletes hemiplicata*, *Productus cora*, *Spirifer cameratus*, *Chonetes granulifer*, *Ambocoelia planoconvexa*, and *Productus semireticulatus*.

Auburn Shale, named by Beede from near Auburn, Kansas; formed principally of bluish and reddish argillaceous shale and some sand, thickness 10 to 25 feet.

Fauna: Several species of brachiopods and a few bryozoa.

Emporia Limestone Member

The name of this is not very well established so far as its definite application is concerned. As used in this paper, it denotes the first limestone unit below the Willard Shale. Typically the member is formed of two, three, or four limestones and interbedded shale, but becomes nearly solid stone at places. The upper layers of stone are grayish, and the lower ones are bluish. The combined thickness of the limestones and shales ranges between 6 and 9 feet.

Fauna: Ostracods, plentiful at places; a few ramose and fenestrated bryozoa; several species of brachiopods; and crinoid columns.

Willard Shale Member

This member was named by Beede³⁰ from exposures south of Willard, Kansas, but has been wrongly correlated at places. Its thickness is 30 feet or more in Nebraska, Iowa,

²⁹ Beede, J. W., *Stratigraphy Shawnee County*: Kan. Acad. Sci. Trans., Vol. XV, p. 29, 1898.

³⁰ Beede, J. W., *Stratigraphy of Shawnee County*: Kan. Acad. Sci., Vol. XV, p. 31, 1898.

and Missouri, and 50 to 60 feet in Kansas. The member is formed of bluish and reddish argillaceous shale with some calcareous material and sand.

Fauna: Crinoid columns, *Chonetes granulifer*, *C. geinitzianus*, *Derbya crassa*, *Ambocoelia planoconvexa*, *Spirifer cameratus*, *Productus semireticulatus*, *Spiriferina kentuckyensis*, *Entiletes hemiplicata*, *Pustula nebrascensis*, *Lingua carbonaria*, other brachiopods, and a few pelecypods.

Tarkio Limestone Member

This well-defined unit has a thickness of 7 to 11 feet. It is formed of three or more limestones and interbedded shale. In most places the lower limestone, 3 to 6 feet thick, is crowded with very large *Fusulina* and *Osagea incrustacea*.

The Tarkio was named by Calvin³¹ in 1900, from Tarkio Township and Tarkio Creek, north of Coin, Page County, Iowa. It outcrops at a few places in southwestern Iowa; in the Missouri River bluffs southwest of Rockport, Missouri; on the bed of Pony Creek south of Falls City, on Spring Creek four miles south and two miles east of Burr, southeast of Tecumseh, west and southwest of Humboldt; and at many other places in Nebraska; also in the top of the bluffs west of Wamego, on the bed of Mill Creek southwest of Maple Hill, southeast of Valencia, and at other points in Kansas.

SECTION AT THE TYPE LOCALITY OF THE TARKIO LIMESTONE NORTH OF COIN, IOWA

Modified after Dr. Calvin

1. Tarkio Limestone, 6' to 8':
 - (1). Limestone, with *Fusulina*, 1'.
 - (2). Shale, 3' to 5'.
 - (3). Limestone, rather soft, 8".
 - (4). Limestone, bluish, fine grained, a quarry ledge, 1' 4".
2. Willard Shale member, 12':
3. Emporia Limestone member, "Preston" Limestone:
 - (1). Limestone, not very dense, 1' 6".
 - (2). Shale, 3' 6".
 - (3). Limestone, 2'.

³¹ Calvin, Samuel, Geology of Page County: Iowa Geol. Survey, Vol. IX, p. 634, 1900.

McKissick Grove Shale Member

This, as has been stated, was named by Dr. George L. Smith to apply to the topmost Pennsylvanian beds in Iowa, without a definite upper boundary. Its top is here restricted to the base of the Brownville Limestone. Descriptions of the units of this member follow:

Pierson Point Shale, named from Pierson's Point southeast of Falls City, Nebraska; composed of bluish argillaceous shale and some sand; upper portion, and at places the lower portion, nearly black; thickness 8 to 10 feet in Nebraska and Kansas.

Fauna: *Ambocoelia planoconvexa*, *Chonetes granulifer*, *Aviculopecten whitei*, *Bucanopsis*, sp., and a few bryozoa.

Maple Hill Limestone, named from exposures south of Maple Hill, Kansas; bluish gray, somewhat arenaceous, irregular; thickness 2 to 4 feet. This bed forms a small fall in Maple Creek about two miles southwest of Maple Hill. It is quite well shown under the Pony Creek bridge south of Falls City and at other places in Nebraska, thinning north-eastward.

Fauna: *Fusulina*, rare to common; crinoid columns, common; *Rhombopora lepidodendroides* and few fenestrated bryozoa, rare to common; several brachiopods, common; small gastropods, rare; pelecypods, rare.

Table Creek Shale, named from outcrops on Table Creek at Nebraska City, Nebraska; well shown at the clay pit southeast of Nebraska City and on Mill Creek southeast of Maple Hill, Kansas. This shale is largely bluish gray and argillaceous to sandy. Its top portion is quite sandy in Kansas. Its thickness varies from 25 to 45 feet in the exposures of Nebraska, Missouri, and Iowa, but increases to 50 feet in Kansas south of the Kansas River. The Nyman Coal in the top portion of this unit persists in Iowa, Missouri, Nebraska, and at places in Kansas.

Fauna: Bryozoa, rare; brachiopods, rare; pelecypods, rare.

Dover Limestone, named by Beede from exposures near Dover, Kansas; composed of one impure, massive gray lime-

stone or of two limestones separated by a thin shale; combined thickness 2 to 4 feet.

Fauna: Fusulina, abundant at places; bryozoa and several species of brachiopods, rare to common; a few pelecypods.

Pony Creek Shale, named from exposures east of Pony Creek, between the Kansas-Nebraska line and 2 miles south of Falls City, Nebraska; composed of bluish to reddish argillaceous shale, brownish sandy shale and some sandstone. The unit thickens southward. It varies much in color and texture. See detailed sections of the Big Nemaha, Little Nemaha, and Missouri River cross sections.

Fauna: Crinoid stems, common; several brachiopods, among them: Ambocoelia planoconvexa, Derbya crassa, Entiletes hemiplicata and Meekella striatacostata.

Admire Shale Member

The Admire Shale (revised) is exposed from Iowa to east-central Kansas or farther, as follows: the lower portion of the Aspinwall Shale, in southwestern Iowa; and the full thickness of the member, in Nebraska and Kansas. In Nebraska all or nearly all of the units are shown southeast of Peru, north of Brownville, and in the southern part of Pawnee County. In Kansas they are exposed between Manhattan and Zeandale, in the vicinity of St. Mary's and at many other places. See Table 16 for thickness and lithologic content.

Brownville Limestone, named by Condra and Bengtson³² in 1915, from exposures low in the Missouri bluffs south of Brownville, Nemaha County, Nebraska; formed of two grayish limestones separated by a thin shale; combined thickness 3 to 5 feet. As a rule the top limestone is the thinner. Both limestones weather yellowish or brownish. The lower one forms rounded blocks.

Fauna: Crinoid joints, common; Rhombopora lepidodendroides and a few fenestrated bryozoa, common; Lopophyllum profundum, rare; Bucanopsis sp., rare; several brachiopods such as, Marginifera splendens, M. wabashensis, Chonetes granulifer, Composita subtilita and Productus semireticu-

³² Nebr. Acad. Sci., Vol. IX, No. 2, p. 17, 1915.

latus; pelecypods, rare. *Marginifera splendens* is the most noticeable fossil.

Aspinwall Shale, named from Aspinwall (abandoned), southeast of Nemaha City, Nemaha County, Nebraska; composed of bluish and reddish argillaceous to calcareous shales and two or more thin, bluish gray limestones. The thickness is 25 feet or more in Nebraska and greater in Kansas. For details see the Aspinwall section.

Fauna: Crinoid joints, common; *Productus cora*, *Chonetes granulifer* and *Marginifera splendens*, common; *Derbya crassa*, *Composita subtilita* and *Spiriferina kentuckyensis*, rare to fairly common.

Falls City Limestone, named by Condra and Bengtson³³ in 1915 from exposures in the Lehmer Quarry in section 32, 21½ miles south and 1½ miles west of Falls City, Richardson County, Nebraska; one massive limestone or separated by shale seams; stone soft, weathers yellowish to brownish and porous; thickness 1' 6" to 5'. This is formed nearly wholly of shell fragments. It is weathered like a coquina at places.

Fauna: Largely pelecypods; bryozoa and brachiopods, rare.

West Branch Shale, named from exposures in West Branch Township, Pawnee County, Nebraska; composed of greenish blue, argillaceous, massive and crumbly shale, dark near the top; with calcareous bladed material above middle, and calcareous lensing material near the base; thickness about 26 feet. See the detailed section made at the type locality.

Fauna: There are few fossils in this shale. At places several genera, represented by comparatively few specimens, occur in limy seams and limestone lenses.

Americus Limestone Member

Kirk³⁴ named this in 1896 from exposures in the south bank of Neosho River, 2 miles west and one-half mile south of Americus, Lyon County, Kansas. In most places the member is formed of two thin limestones separated by 2 to 4 feet of shale. The upper limestone weathers light gray with

³³ Nebr. Acad. Sci., Vol. IX, No. 2, p. 30, 1915.

³⁴ Kirk, M. Z., Geol. Section Along Neosho and Cottonwood Rivers: Kan. Univ. Geol. Survey, Vol. I, p. 80, 1896.

rough granular feel and forms large flattish or rounded blocks which become a feature on the slopes below most outcrops.

Fauna: There are many *Fusulina* in the upper portion of this bed. Crinoid joints, echinoid spines, bryozoa, *Pinna* sp., and about five species of brachiopods are common.

The shale is bluish to dark, mostly argillaceous and usually crumbly. The lower limestone is gray to buff. It is shaly to quite pure and shatters. The combined thickness of the member is 5 to 8 feet.

In 1925 the writer traced the *Americus* in Kansas from its type locality to the sections at Buffalo Mound (southwest of Maple Hill), north of St. Mary's, north of Bellevue, southwest of Wabaunsee, and the foot of the slope east of Manhattan; and in Nebraska to southeast of Dunbar. (See detailed Nebraska sections).

Elmdale Shale Member

This was named by Prosser and Beede³⁵ in 1902, from Elmdale, Chase County, Kansas. It is largely bluish, argillaceous shale, but includes very dark shale, red shale, and several thin limestones (Figure 16). The combined thickness is between 110 and 125 feet in Nebraska and northern Kansas. The member is thought to persist from Nebraska to northeastern Payne County, Oklahoma.

The upper and middle portions of the member are well exposed at the type locality east of Elmdale, Kansas. Both shales and limestones are quite fossiliferous, being rich in the number of specimens and number of species. The subdivisions of the Elmdale follow:

Stine Shale, named from exposures in the slopes south of Stine, Nemaha County, Nebraska; formed of blue, gray, and reddish shale, and two or three limestone seams, the lower one being about one foot thick, somewhat arenaceous and forming

³⁵ Prosser, Chas. S., and Beede, J. W., Revised Classification of the Upper Paleozoic Formations of Kansas: *Journal Geology*, Vol. X, p. 718. 1912.

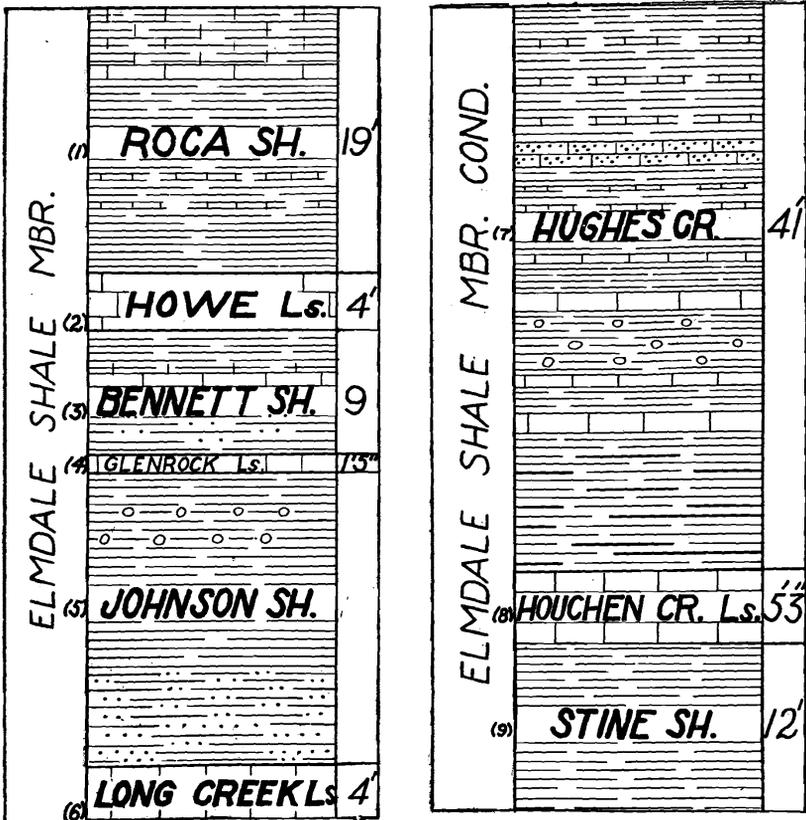


FIGURE 16.—Columnar section, the Elmdale Shale member.

rounded blocks; combined thickness 9 to 18 feet. The shale below the limestone layer is very fossiliferous.

Fauna: *Meekopora prosseri*, *Rhombopora lepidodendroides*, *Septopora biserialis*; *Productus semireticulatus*, *Composita subtilita*, *Chonetes granulifer*, *Hustedia mormoni*, *Obiculoidea missouriensis*; small gastropods; pelecypods; crinoid joints, etc.

Houchen Creek Limestone, named from exposures on Houchens Creek, in Section 29, Township 6 N., Range 13 E., Nemaha County, Nebraska; bed massive to irregular or separated by bluish shale partings; characterized by the

presence in most exposures of large masses of an algal growth. This unit has been traced to the Kansas Valley, north of Belvue.

Fauna: A few species of bryozoa and brachiopods; three or four species of pelecypods.

Hughes Creek Shale, named from Hughes Creek, Nemaha County, Nebraska; formed of blue argillaceous shale, dark shales, and thin limestones; combined thickness 35 to 50 feet; in three zones, the top one formed of three sub-zones at places. (See the Bennett section.)

Although the zones of this unit persist quite uniformly in the Nebraska sections, they are less regular in Kansas. The lowest zone (C) is formed of bluish shale and thin limy seams which carry some fossils. Its thickness is 10 feet or more. Next above (zone B) are four or five dark gray, earthy, thin fossiliferous limestones and interbedded shales with a combined thickness of 12 to 20 feet. Its upper shales carry *Orbiculoidea missouriensis*, *Chonetes granulifer*, and other brachiopods. The limestones have a few bryozoa and brachiopods and at places in Kansas are nearly filled with *Fusulina*.

The top zone (A), where typical, is formed from the base upward of three sub-zones, as follows: Six feet or more of bluish, argillaceous shale with very fossiliferous calcareous seams above the middle; about 2 feet of thin arenaceous-limy, fossiliferous seams separated by blue shale; and 10 to 12 feet or more of bluish to dark argillaceous shale. The lower sub-zone has a distinctive persistent fauna in the calcareous seams. This has been of assistance in correlation. It is rich in large *Fusulina*, bryozoa and brachiopods. The genera *Thamniscus*, *Meekopora*, *Septopora*, *Fenestella*, *Polypora*, *Rhombopora*, *Stenopora*, *Chonetes*, *Productus*, *Spirifer*, *Spiriferina*, *Composita* and *Hustedia* are represented by abundant specimens. The second sub-zone has many *productus cora*, Echinoid spines, and bryozoa.

Long Creek Limestone, named from exposures on Longs Creek, at the foot of the bluff west of the cemetery at Auburn, Nemaha County, Nebraska; stone usually weathered buff to

yellowish, somewhat cavernous and irregular; thickness 2 to 7 feet, averaging about 4 feet. This unit usually carries small geodes and a few fossils representing bryozoa, brachiopods, and two or more genera of pelecypods.

Johnson Shale, named from exposures 1½ miles north of Johnson, Johnson County, Nebraska; formed of bluish argillaceous shale modified by thin, grayish, sandy layers, calcareous plates, and some gypsiferous material, and geodes; thickness 16 to 18 feet. There are very few fossils.

Glenrock Limestone, named from exposures high in the valley side just northwest of Glenrock, Nemaha County, Nebraska; dark gray, dense, weathering light gray or slightly buff; thickness 1 to 2 feet. This forms rectangular blocks. The leading fossils are *Fusulina*, bryozoa, brachiopods, and *Pinna* sp.

Bennett Shale, named from exposures along the Little Nemaha and its branches south of Bennett, Lancaster County, Nebraska; formed of bluish gray and nearly black argillaceous shale, with one carbonaceous streak resembling coal and a thin yellowish to brownish limestone; combined thickness 5 to 11 feet. (See section at Bennett).

Fauna: *Orbiculoidea missouriensis*, *Lingula* sp., *Composita subtilita*, *Spirifer cameratus*, and a few other species.

Howe Limestone, named from exposures south of Howe, Nebraska; stone in its unweathered condition, dark gray, massive, and dense, with considerable free calcite; weathers buff to yellowish, granular, vesicular or cavernous, and very irregular; thickness about 4 feet. This carries geodes at places. It has few fossils.

Roca Shale, named from Roca, Lancaster County, Nebraska; composed of bluish gray, olive green, and reddish argillaceous shale. There are thin fossiliferous limestone seams in the upper portion; thickness of division 18 to 20 feet in Nebraska and somewhat greater in Kansas. (See Roca section.) The limestone seams carry many pelecypods, as *Pleurophorus* sp., *Pseudomonotis* sp., and *Aviculopecten occidentalis*.

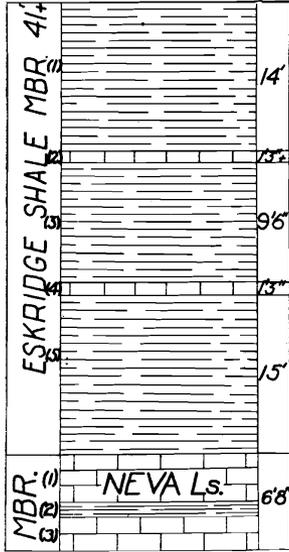
Neva Limestone Member

FIGURE 17.—Columnar section of the Eskridge and Neva members at Douglas, Nebraska.

The name of this was proposed by Prosser and Beede³⁶ in 1896, from Neva, Chase County, Kansas. The member is widely exposed between northern Nemaha County Nebraska, and Payne County, Oklahoma. Typically, in Kansas, it consists of two light gray limestones separated by a thin shale bed which includes a thin limestone at places. To the north, as at Auburn, Nebraska, the member is formed of four or five limestones and interbedded shales. Near Douglas, Nebraska, it consists of two comparatively heavy limestones separated by a thin shale (Figure 17). The thickness varies from 6 to 11 feet or more. At places, as about 4 miles northeast of Sabetha, Kansas, the main shale zone is quite dark, carrying many *Oribiculoidea missouriensis*.

This member is not very fossiliferous. Its principal fossils are *Fusulina*, brachiopods, bryozoa and pinna.

Eskridge Shale Member

This was named from Eskridge, Wabaunsee County, Kansas, by Prosser and Beede.³⁷ The member consists of bluish, olive, chocolate, and reddish, argillaceous shale separated by two or more thin limestones. Its thickness is 50 feet or more near Auburn, Nebraska, and about 30 feet in southern Nebraska and northern Kansas.

³⁶ Prosser, Chas. S., and Beede, J. W., Revision and Classification Upper Paleozoic Formations of Kansas: *Journal of Geology*, Vol. X, p. 718, 1902.

³⁷ Prosser, Chas. S., and Beede, J. W., Revision and Classification Upper Paleozoic Formations of Kansas: *Journal of Geology*, Vol. X, p. 718, 1902.

TABLE 9. *Subdivisions of the Wabaunsee Formation*

Subdivision	Content in Nebraska				Thickness (Feet)							
	Shale	Lime- stone	Sand- stone	Coal	In Nebraska		N. E. Kans.		S. W. Iowa		N.W.Mo.	
					Bed	M'ber	Bed	M'ber	Bed	M'ber	B'd	Mbr
1. Eskridge Shale Member	38+	2+				40+		26-40				
2. Neva Limestone Member....	2+	4+			6-10	6-10		6-8				
3. Elmdale Shale Member.....	97*	23*		0-¼		120*		149*				
(1). Roca Shale.....	16+	2			18-20		20-44					
(2). Howe Limestone.....	½+	4+			4-5		4-5					
(3). Bennett Shale	7+	1		0-¼	8-10		12					
(4). Glenrock Limestone ..		1-1 ½			1-1 ½		1+					
(5). Johnson Shale	16-25				16-25		16-20					
(6). Long Creek Limestone	¼+	3-5			3 ¼-5		3-6					

* About.

TABLE 9 (Continued). *Subdivisions of the Wabaunsee Formation*

(7). Hughes Creek Shale..	38+	5½			43½	45+		
(8). Houchen Creek Limestone	2+	2+			4-8+	3+		
(9). Stine Shale	7-17	½-1			7-17½	12-14		
4. Americus Limestone Member	4½	3½			8	8	8-10	8-10
5. Admire Shale Member.....	51½	10*			61½*	89½		14**
(1). West Branch Shale....	24-26				24-26	37-50		
(2). Falls City Limestone..		3-6			3-6	1½-5		
(3). Aspinwall Shale	25+	1½+			26+	40+		7-18**
(4). Brownville Limestone	1+	2+			3-6	3-5		2

* About.

** Exposed.

PENNSYLVANIAN SYSTEM

TABLE 9 (Continued). *Subdivisions of the Wabaunsee Formation*

Subdivision	Content in Nebraska				Thickness (Feet)			
	Shale	Lime- stone	Sand- stone	Coal	In Nebraska Bed M'ber	N. E. Kans. Bed M'ber	S. W. Iowa Bed M'ber	N.W.Mo. B'd Mbr
6. McKissick Grove Shale Member	35	5½	33	1-3	72½	80½	62	56
(1). Pony Creek Shale.....	4-16	2	2-16		18-28	20-25	25	22+**
(2). Dover Limestone.....		2-3½			2-3½	2-4	2-4	2-3
(3). Table Creek Shale	10-30	1½	10-40	1-2¾	40	40+	26+	22
(4). Maple Hill Limestone		1-2			1-2	1-2	¾	1+
(5). Pierson Point Shale....	7+			0-¼	7-11	9-10	8	8-10
7. Tarkio Limestone Member	2+	5+			7-9	6-8	6-8	6+
8. Willard Shale Member.....	30+		1¼		30+	40-60	12-25	25+

** Exposed.

TABLE 9 (Concluded). *Subdivisions of the Wabaunsee Formation*

9. Emporia Limestone Member	1-2	4-7			5-11	4+	3+	3+
10. Humphrey Shale Member	26-39	6+	5		32-45	38-67	25*	28*
(1). Auburn Shale	11-24	1	3		12-25	15-30	8-20	15+
(2). Wakarusa Limestone	1+	4+			5-7	3-7	1½-2	2+
(3). Soldier Creek Shale..	22	1	2		25	20-30	20?	20?
11. Burlingame Limestone Member		5-6			5-6	8-9	‡	‡
Total Thickness.....	297¾	67+	39¼	1-2¾	406*	470*	141*	128*

* About.

** Exposed.

‡ Thin.

PENNSYLVANIAN SYSTEM

MISSOURI RIVER CROSS SECTION, LEAVENWORTH
TO OMAHA

The Missouri River exposures have attracted the attention of many geologists since the days of exploration and trade with the Indians. Lewis and Clark observed some of the geologic features. Major Long studied the Pennsylvanian exposures in the vicinity of Engineers Cantonment, near Omaha, in 1819-1820. Systematic study of the stratigraphy began soon after 1850. The geologists of this period were Owen, Marcou, Swallow, Meek, Hayden, White, and Broadhead, whose investigations remain outstanding on account of what they accomplished under trying conditions. Broadhead's cross sections — Kansas City to Burlington Junction, and of Atchison County, Missouri — published by the Missouri Geological Survey in 1872, established a dependable basis for further study.

White, Calvin, Udden, Todd, Keyes, Smith, Tilton, and others have contributed to this section, the Iowa part especially. Todd described the structure at Jones Point, Nebraska and north of Thurman, Iowa. Keyes published a general section from Kansas City to Omaha. Dr. G. L. Smith made a careful investigation of the Pennsylvanian beds of Iowa and adjacent areas. His report was published in the Iowa Geological Survey, Volume XIX, 1907. The latest report of the Iowa Survey, having a bearing on the Missouri River cross section, is by Tilton. (See Iowa Geol. Survey, Vol. XXIX, pp. 223-314, 1920.) The report by Hinds and Greene, "Stratigraphy of the Pennsylvanian Series in Missouri," published in 1915, covers the Missouri River section in detail for all of the formations up to the Wabaunsee. Haworth, Beede, and others have studied northeastern Kansas, the latter carrying the correlation of the Burlingame Limestone to the Nebraska line. Condra and Bengtson published the Missouri River section of Nebraska in 1915.¹

¹ Pennsylvania Formation of Southeastern Nebraska: Nebr. Acad. Sci., Vol. IX, No. 2, 1915.

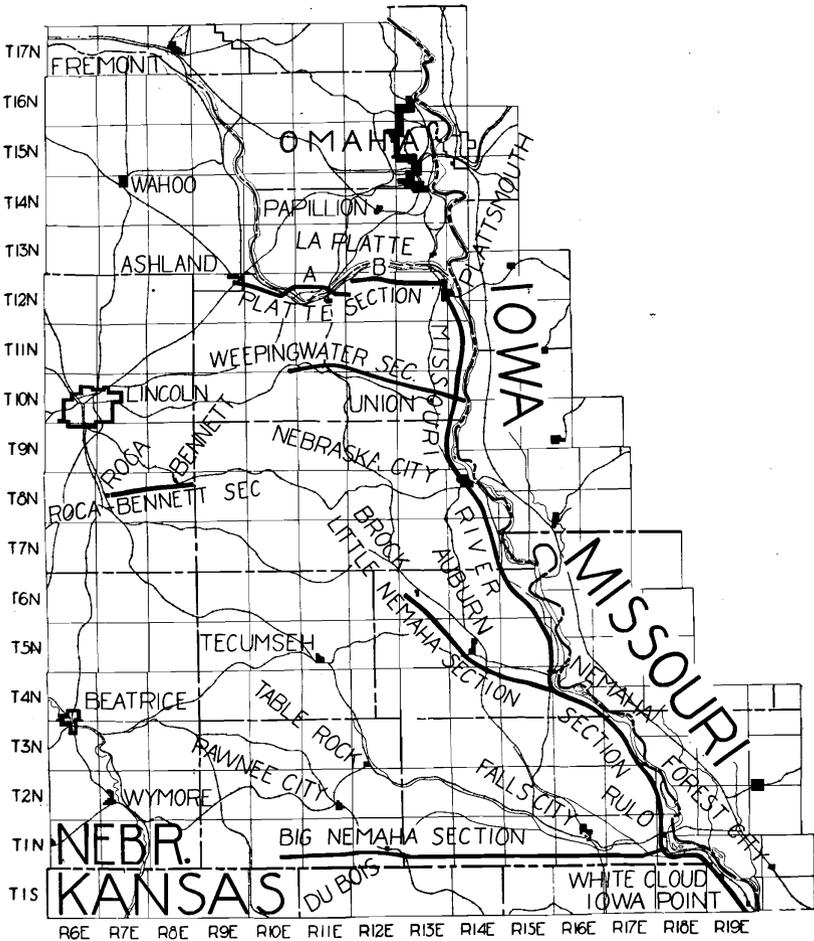


FIGURE 18.—Map showing location of cross sections.

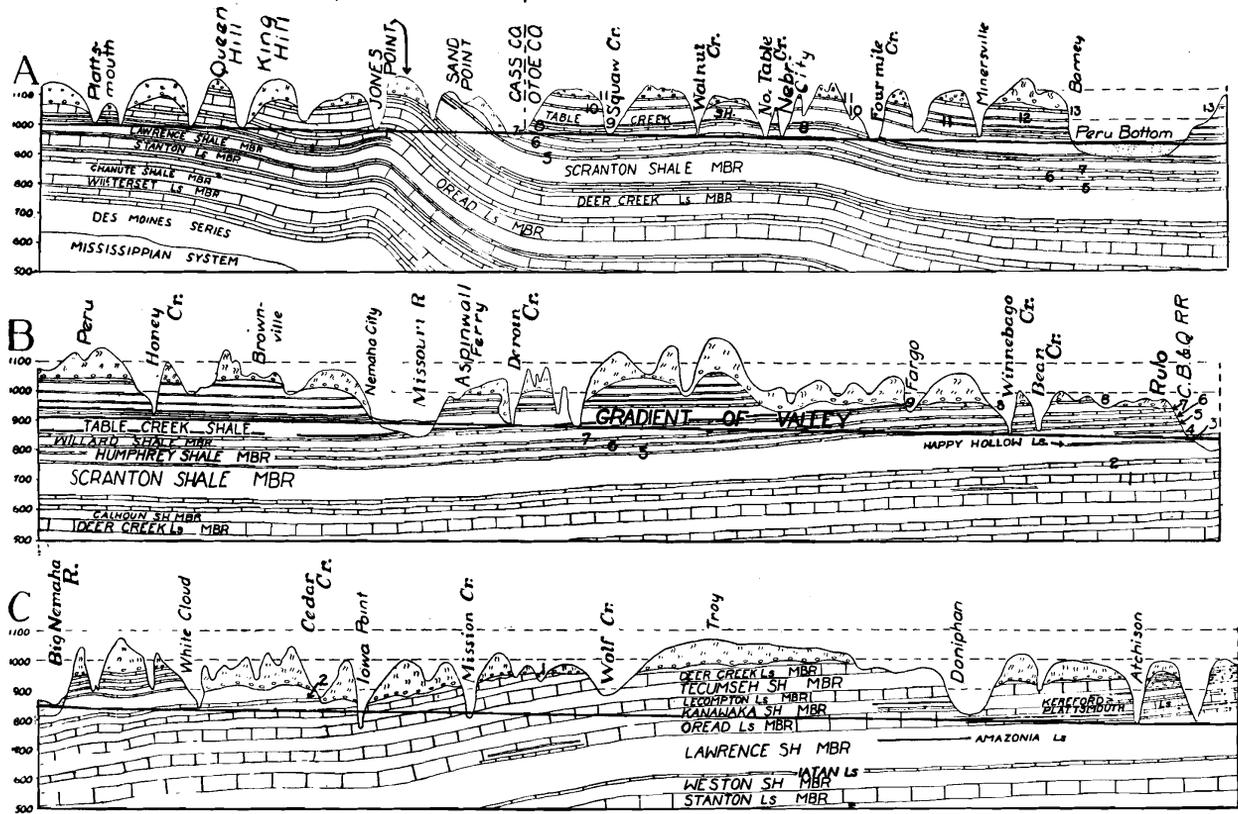


PLATE II.—The Missouri River cross section from below Atchison, Kansas, to north of Plattsmouth, Nebraska. Limestones: 1, Topeka; 2, Howard; 3, Happy Hollow; 4, Rulo; 5, Burlingame; 6, Wakarusa; 7, Emporia; 8, Tarkio; 9, Maple Hill; 10, Dover; 11, Brownville; 12, Falls City; 13, Americus.

The Missouri River, by cutting through the thick mantle rock and into the bed rock, has opened up many exposures of the Pennsylvanian strata along the valley. The outcrops on the west side of the valley are nearly continuous. These include the constants on which the cross section is based. Plate II is a cross section along the Missouri from Atchison, Kansas, to north of Plattsmouth, Nebraska.

Attitude of Strata. The beds dip up-valley and westward from Kansas City to northwestern Missouri and Brownville, Nebraska, bringing the Kansas City, Lansing, Douglas, and Shawnee formations to below the river level. The Wabaunsee formation occupies the surface (in the Brownville Syncline and the Forest City Basin) most of the distance from below Kulo, Nebraska and southern Atkinson County, Missouri, to eleven miles north of Nebraska City and two miles north of Thurman, Iowa, where the older beds, down to below the Deer Creek Limestone member, come to the surface by faulting and warping. The structure north of Thurman marks an important change in the cross section. North of it, the beds dip northwestward for a few miles beyond which they rise gradually to the nose of the Nehawka Anticline southeast of Omaha.

SECTION NORTH OF LEAVENWORTH, KANSAS

The members of the Kansas City and Lansing formations drop below the river level between Kansas City and north of Leavenworth. The Stanton Limestone at the top of the Lansing is well exposed at East Leavenworth and at the Fort Bridge north of Leavenworth. It is a well-defined horizon from which to start the up-river cross section. The Leavenworth section follows:

1. Oread Limestone member, about 41' 6" exposed:
 - (1). Plattsmouth Limestone (Broadhead's 150), high in upland west and northwest of city; quarried northwest of the Federal Penitentiary and northwest of Fort Leavenworth; top eroded away at places, 8' to 16'.
 - (2). Heebner Shale (Broadhead's 148, 149), upper portion blue; lower portion black and fissile; combined thickness 5' to 6'.

- (3). Leavenworth Limestone (Broadhead's 147), blue, massive, well exposed in highway cut northwest of the Federal Penitentiary, 2'. (Figure 7.)
 - (4). Snyderville Shale (Broadhead's 144-146), exposed below the Federal quarries high in upland northwest of the Federal Penitentiary, 8' to 10'.
 - (5). Weepingwater Limestone (Broadhead's 143), exposed in the upland below the Federal quarries northwest of the Federal Penitentiary, 8' to 10'.
2. Lawrence Shale member (Broadhead's 122-127 and 137-142), not well exposed; thickness according to hand level and barometer, 175'. About 85' of the upper portion outcrops in the slope and clay pit west of the Federal Penitentiary where a 6" seam of coal occurs 60' below the top. The middle portion is covered. The lower portion is exposed as follows in the Federal clay pit north of Fort Leavenworth:
 - (1). Limestone, granular, sandy, formed largely of shell fragments, 1'.
 - (2). Shale, 6" to 7".
 - (3). Claystone, fossiliferous, with *Marginifera splendens*, etc., 4".
 - (4). Shale, 4'.
 - (5). Claystone, 3'.
 - (6). Shale, 3' 6".
 - (7). Coal, 8" to 10".
 - (8). Shale, 21' 8".
 3. Iatan Limestone member (Broadhead's 121), exposed in the bluff at Fort Leavenworth; worked in a quarry north of the U. S. Military Detention Barracks, 8' to 10'.
 4. Weston Shale member (Broadhead's 114-120), in bluff at the west end of the Fort Bridge; top well exposed below ledge quarried north of Detention Barracks, 60' to 65'.
 5. Stanton Limestone member (Broadhead's 110-113), exposed just above the river at the west end of the Fort Bridge; composed of bluish gray limestones and interbedded shale; 20' or more shown.

FROM LEAVENWORTH TO ATCHISON, KANSAS

The extension of the strata exposed northward from Leavenworth is about as follows:

1. Stanton Limestone member, to the bottom land level at Weston, Missouri.
2. Weston Shale member, to the railroad level at Iatan, Missouri.
3. Iatan Limestone member, to the valley-floor near the north line of Leavenworth County, Kansas, and to the bottom land about four miles north of Iatan, Missouri.
4. The Lawrence Shale and Oread members persist in many exposures from Leavenworth and near East Leavenworth to beyond Atchison, Kansas, and St. Joseph, Missouri.

SECTION AT ATCHISON, KANSAS

1. Tecumseh Shale member, exposed high in the slopes just south of city along the highway which leads to Leavenworth, only the basal portion shown.
2. Lecompton Limestone member, in the highway cut northwest of the Kereford Quarry southeast of Atchison, about 32' 6":
 - (1). Avoca Limestone (Broadhead's 169), weathered rusty, with crinoid joints and other fossils, 1'.
 - (2). King Hill Shale (Broadhead's 168), blue, argillaceous, bedded, 3' 9".
 - (3). Cullom Limestone (Broadhead's 166, 167), separated by an irregular, calcareous shale seam in which are *Aulopora* sp., *Campophyllum torquium*, and other fossils; combined thickness, 4' 6" to 6'.
 - (4). Queen Hill Shale (Broadhead's 163-165), bluish gray, argillaceous to calcareous in upper portion; black and fissile in lower 2'; combined thickness, 5' to 6'.
 - (5). Big Springs Limestone (Broadhead's 162), gray to buff, massive, 2' 6" to 3'. Large *Fusulina* abundant.
 - (6). Doniphan Shale (Broadhead's 161), blue to dark, argillaceous, bedded to massive, 5' 6".
 - (7). Spring Branch Limestone (Broadhead's 160), upper 2' yellowish and badly weathered, the rest being yellowish and firm; combined thickness, 7' to 8'.
3. Kanwaka Shale member (Broadhead's 151-159), in covered slopes and exposures south of city, 40' or more:
 - (1). Shale (Broadhead's 159), 2'.
 - (2). Coal seam (Broadhead's 157), 5" to 7".
 - (3). Shale (Broadhead's 156), bluish gray to brownish, part quite sandy, about 10'.
 - (4). Limestone, 3' 6" or more.
 - (5). Shale, bluish to bluish gray, argillaceous, bedded, 16' to 20'.
 - (6). Limestone, a thin slabby horizon above the quarry just southeast of Atchison. This becomes a hard, bluish bed, 2' or more thick at the Kereford Quarry.
 - (7). Shale, dark gray, 3' to 4' in the quarry southeast of town and 5' or more at the Kereford Quarry.
 - (8). Kereford Limestone (Broadhead's 152), the "Waverly Flagging" Limestone. This is a calcareous mudstone, 1' to 1' 8" thick at the quarry southeast of Atchison, and a firm, bluish limestone 4' to 6' thick at the Kereford Quarry. Divisions (6) and (7) probably should be included with the Kereford Limestone.
 - (9). Shale (Broadhead's 151), bluish gray, massive or bedded, thickness 5' 4" southeast of city and 5' 9" in the Kereford Quarry.
4. Oread Limestone member, about 52':
 - (1). Plattsmouth Limestone (Broadhead's 150), heavily bedded, with flint near top and middle; about 18' to 20' exposed in the quarry just southeast of Atchison, where 2' of its base occurs below

the quarry floor which is 40' or more above the river. This is the main ledge at the Kereford Quarry, where its thickness is 21' 8".

- (2). Heebner Shale (Broadhead's 148-149), bluish, argillaceous, jointed in upper portion; basal portion black and fissile; combined thickness, 5' 3".
 - (3). Leavenworth Limestone (Broadhead's 147), bluish gray, dense, jointed, quite fossiliferous, 1' 10" to 2' 11". This forms large blocks and weathers buff to yellowish.
 - (4). Snyderville Shale (Broadhead's 144-146), mostly bluish, argillaceous and massive; exposed at and above the railroad level just southeast of Atchison and southward to and beyond the creek at the Kereford Quarry, 12' to 17'.
 - (5). Weepingwater Limestone (Broadhead's 143), exposed below the railroad level just southeast of the city and gradually higher southeast, 6' to 10'.
5. Lawrence Shale member, about 50' to 55' exposed south of the Kereford Quarry, where the upper 4' 7" is maroon, massive, argillaceous to sandy. The next 7 feet is bluish and argillaceous, with some fine sand and limy concretions. Farther down the creek about 1' or more of coal occurs 25' below the Weepingwater Limestone, and still farther southeast about 30' of shale is exposed below the coal.

The beds in the Atchison section rise southeastward. The Lecompton, Tecumseh, and Deer Creek members outcrop at places southwest of the city in an area extending to the Kansas River valley. The cross section (Plate II) shows that the strata drop only a few feet between Atchison and west of Doniphan. The beds are nearly level in the section between Doniphan and west of Troy, beyond which they drop considerably to Iowa Point.

There is a big bend eastward of the Missouri River valley between Forest City, Missouri, St. Joseph, Missouri, and Doniphan, Kansas. This makes the outcrops on certain west-dipping beds along the river, higher at St. Joseph and nearby points than they would be along the valley if it extended south from Forest City to Doniphan and Atchison. This position of the outcrops on the dip-plain seems to have been misunderstood by some geologists who described a prominent anticline as extending from St. Joseph westward.

SECTION AT ST. JOSEPH, MISSOURI

1. Kanwaka Shale member, 5' 6" exposed:
 - (1). Kereford Limestone (Broadhead's 152), exposed high in the upland slope, 2' 6".
 - (2). Shale (Broadhead's 151), dark blue, argillaceous, 3'.

2. Oread Limestone member, about 50':
 - (1). Plattsmouth Limestone (Broadhead's 150), 20' to 21'.
 - (2). Heebner Shale (Broadhead's 148, 149), about 5'.
 - (3). Leavenworth Limestone (Broadhead's 147), 2' 3".
 - (4). Snyderville Shale (Broadhead's 144, 146), badly covered, about 16'.
 - (5). Weepingwater Limestone (Broadhead's 143), exposed at top of the clay pit in the southwest part of city, bluish gray, weathered brownish, massive; forms large blocks, 6' to 7'.
3. Lawrence Shale member:
 - (1). Shale, exposed in clay pit in southwest part of city, bluish gray, argillaceous to sandy, about 45'.
 - (2). Amazonia Limestone (Broadhead's 137), dark gray, impure, not typical, quite fossiliferous, 3' to 4'.
There is a long covered slope between the Amazonia bed and the bottom land. The strata have a high elevation at St. Joseph, because the section is relatively far east on beds which dip westward and northward.

SECTION AT AMAZONIA, MISSOURI

1. Kanwaka Shale member, 15' 3" exposed:
 - (1). Kereford Limestone (Broadhead's 152), exposed in Stewart Quarry, bluish gray to brownish, thin bedded, dense, part oolitic, 12' 8".
 - (2). Shale (Broadhead's 151), dark blue, fossiliferous, 2' 7".
2. Oread Limestone member, 47' 4":
 - (1). Plattsmouth Limestone (Broadhead's 150), exposed in Stewart Quarry, 21'.
 - (2). Covered slope, the interval being occupied by the Heebner Shale, Leavenworth Limestone and Snyderville Shale, about 22'.
 - (3). Weepingwater Limestone (Broadhead's 143), exposed in creek northeast of town, 4' 4".
3. Lawrence Shale member, 28' exposed:
 - (1). Shale, 16' or more.
 - (2). Amazonia Limestone (Broadhead's 137), exposed in bluffs at town and on creek north, dark gray to light gray, somewhat mottled, massive, forms large blocks, 9'.
 - (3). Shale, 3' exposed on creek bed 1 mile north of town and 35' or more shown in foot of the bluff at Amazonia.

FROM AMAZONIA TO FOREST CITY, MISSOURI

The strata are well shown in this stretch, dipping north-westward. The Amazonia Limestone lowers to the Missouri River flood plain two miles northwest of Amazonia, and the top of the Lawrence Shale member, in which it occurs, comes to the bottom land near Nodaway. The higher members of the section go below the bottom land level as follows:

1. Oread Limestone member, 1 mile below Forbes.
2. Kanwaka Shale member, 2 or 3 miles west of Forbes.
3. Lecompton Limestone member, midway between Forbes and Forest City. It is well shown between Nodaway and Forbes where the Cullom unit is typically developed.
4. Tecumseh Shale member, 2 or 3 miles below Forest City.
5. Deer Creek Limestone member, just below Forest City.

The above members drop below the river level on the Kansas side in regular sequence between Atchison and Iowa Point.

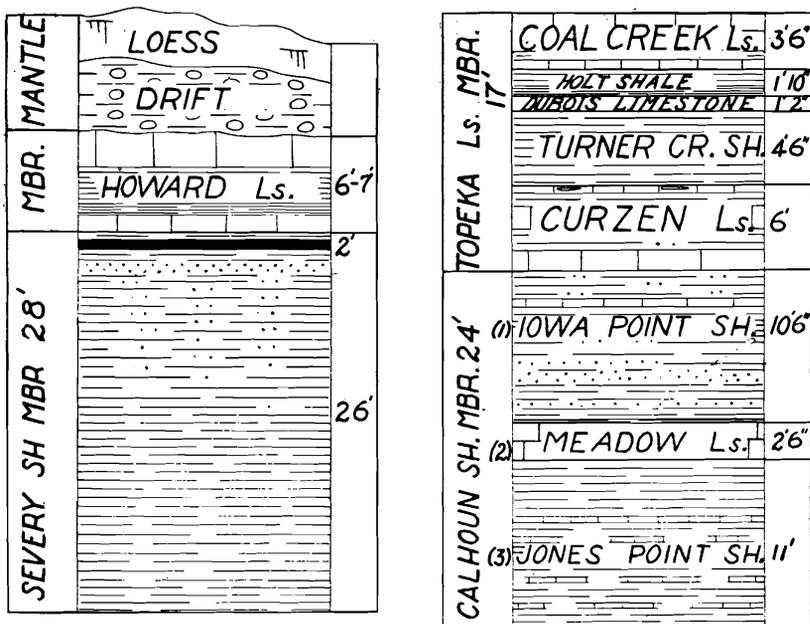


FIGURE 19.—Columnar section at Forest City, Missouri.

SECTION AT FOREST CITY, MISSOURI

This is made on the exposures in the bluffs and old quarry southeast of the C., B. & Q. station (Figure 19). The bluffs here are heavily mantled with loess and drift.

1. Howard Limestone member, 6' to 7':
 - (1). Limestone (Broadhead's 220), dark gray, massive, weathers brownish, fossiliferous, best exposed in ravine above old quarry, about 2'.

- (2). Shale (Broadhead's 219), blue to dark, massive to finely bedded, 3' to 4'.
 - (3). Limestone (Broadhead's 218), dark gray, siliceous, forms large blocks which weather tabular, 1' or more. Fauna: Brachiopods, bryozoa, and many ostracods.
2. Severy Shale member (Broadhead's 213-217), about 28':
- (1). Shale and the Nodaway Coal (Broadhead's 215), now covered, about 2'.
 - (2). Sandstone, buff, friable, micaceous, 1'.
 - (3). Shale, mostly bedded, quite arenaceous above, somewhat argillaceous below, 24' to 25'.
3. Topeka Limestone member, about 19':
- (1). Coal Creek Limestone (Broadhead's 209-212), 3' 6" or more:
 - a. Limestone, weathered yellowish, 1' to 1' 6". Fauna: Fusulina, crinoid joints, fenestrated bryozoa, Rhombopora lepidodendroides, and Composita subtilita.
 - b. Limestone, dense, with many Fusulina and Composita subtilita, 1' 4" to 1' 6".
 - c. Shale, non-persistent, evidently weathered from limestone, 6" or more.
 - d. Limestone, 1 or 2 layers, 6" to 10".
 - (2). Holt Shale (Broadhead's 207-208), 1' 10"; top bluish, argillaceous; base dark and fissile. This is well exposed on Davis Creek below Oregon where it carries Marginifera splendens, Orbiculoidea, etc.
 - (3). Du Bois Limestone (Broadhead's 206), blue, massive, compact, with free calcite in fossils and fractures, weathers dark gray, 1' 1" to 1' 2". Fauna: Myalina sp., Composita subtilita, etc.
 - (4). Turner Creek Shale (Broadhead's 200-205), bluish with greenish hue, argillaceous, 4' 6" to 6'.
 - (5). Curzen Limestone (Broadhead's 197-199), about 6':
 - a. Limestone, with some chert near top, weathers yellowish brown, 5" to 6".
 - b. Shale, bluish, argillaceous, 1'.
 - c. Limestone, ashy blue, massive, very fossiliferous, weathers rusty and shatters, 1' 6". This has many brachiopods.
 - d. Shale, bluish, argillaceous to arenaceous, weathers yellowish, quite fossiliferous, 1' 6" or more.
 - e. Limestone, bluish, massive, not very fossiliferous, weathers brownish, 1' 6". This thickens below at one point where it includes a foot or more of rusty, rotted, fossiliferous limestone.
4. Calhoun Shale member, about 24':
- (1). Iowa Point Shale (Broadhead's 193-196), 10' 6" or more.
 - a. Shale, blue, mostly argillaceous but somewhat sandy, 2'.
 - b. Limestone, blue, blocky, fossiliferous, 6" to 7".
 - c. Shale, mostly bluish gray and argillaceous, part sand, 4' 6"; upper 1' or more fossiliferous.
 - d. Sandstone, buff, friable, 1' +.

- e. Shale, blue, argillaceous, with some sand in middle, 2' 6" or less.
- f. Shale, part carbonaceous, bedded, 4".
- (2). Meadow Limestone (Broadhead's 190-192), exposed in ravine below old quarry, light to dark gray, somewhat shattered, separated by shale seam, 2' 6".
- (3). Jones Point Shale (Broadhead's 187-189), exposed southeast of quarry, about 11'; upper 3', blue, argillaceous; next 4", blue limestones; basal 8', blue to gray shale with calcareous seams.
- 5. Deer Creek Limestone member:
 - (1). Ervine Creek Limestone (Broadhead's 186), in foot of bluffs below Forest City, 15' or more exposed.

SECTION AT IOWA POINT, KANSAS

Based on exposures in the bluffs between one-fourth mile above the depot and the Mission Creek valley southeast of town.

- 1. Topeka Limestone member, 19' to 20':
 - (1). Coal Creek Limestone (Broadhead's 209-212), exposed east of town, in two beds separated by a calcareous shale seam, 3' or more. Stone, dark blue, massive, and fossiliferous. Fauna: *Fusulina*, *Productus cora*, and other fossils.
 - (2). Holt Shale (Broadhead's 207, 208), exposed east of depot, 2' 6"; top bluish, argillaceous; middle and base black, fissile, and blocky at places. Fauna: *Marginifera splendens*, *Productus pertenuis*, etc.
 - (3). Du Bois Limestone (Broadhead's 206), dark blue, massive, jointed, quite fossiliferous, weathers grayish, 1' 1". Fauna: *Pelecypods* and *Composita subtilita* are the main fossils.
 - (4). Turner Creek Shale (Broadhead's 200-205), bluish, argillaceous, bedded to massive, with lime seams and calcareous concretions; some fossils at base, 4' 6".
 - (5). Curzen Limestone (Broadhead's 197-199), massive, irregular, separated by calcareous shale seams, about 8' to 9'.
- 2. Calhoun Shale member, 24' to 25':
 - (1). Iowa Point Shale (Broadhead's 193-196), 10'; top portion bluish, argillaceous, bedded to massive, with carbonaceous flakes and plant leaves; middle portion, blue to brownish, with some sand, becoming a loose sandstone at places; base, bluish to brownish, bedded, argillaceous.
 - (2). Meadow Limestone (Broadhead's 190-192), exposed between level of railroad three-eighths mile east of town and Mission Creek valley. Stone, bluish gray, massive or separated by shale seams above and below, 4' or more. The massive middle bed forms large blocks. The details of the Meadow Limestone are shown in the following exposure at the spur of the bluff two miles below Iowa Point:

- a. Limestone, irregularly bedded, grades upward into slabby shale, 1' to 1' 4". Fauna: Many *Rhombopora lepidodendroides*, *Polypora elliptica*, *Spirifer cameratus*, *Composita subtilita*, and other species.
- b. Limestone, massive in middle, shattered above and below, 3'.
- c. Shale, argillaceous to sandy, weathers buff, 9".
- d. Limestone, massive, jointed, blocky, 6" to 7".
- (3). Jones Point Shale (Broadhead's 187-189), 9':
 - a. Dark, with some carbonaceous material, fossiliferous, 3'.
 - b. Dark blue, bedded, argillaceous, 6'.
- 3. Deer Creek Limestone member, 22' 4" exposed:
 - (1). Ervine Creek Limestone (Broadhead's 186), in railroad cut southeast of Iowa Point:
 - a. Dark gray, with cone-in-cone structure at places, quite fossiliferous, 1'.
 - b. Massive, weathers buff, 15' 2".
 - c. Earthy, blocky, limestone, 8".
 - (2). Mission Creek Shale (Broadhead's 185), 3' 6"; upper one-third bluish to nearly black; lower two-thirds black, fissile.
 - (3). Haynies Limestone (Broadhead's 184), massive, jointed, dark blue, fossiliferous, in railroad gutter at spur southeast of Iowa Point, 2'.

SECTION AT WHITE CLOUD, KANSAS

There is some topographic evidence of the presence of the Burlingame Limestone high in the bluff west of town. The exposed section follows:

1. Scranton Shale member, about 100' in bluffs west of town, with no evidence of the presence of the Cass Limestone and the other lower beds of the member.
2. Howard Limestone member, badly covered; formerly exposed at the flour mill, thickness (?); lower portion penetrated in a well at garage south of the depot.
3. Severy Shale member, in lower part of bluff for some distance west of town as shown by well records. An abandoned coal mine, at the railroad level about three-eighths mile west of town, is thought to have operated on the Nodaway Coal bed in the Severy.
4. Topeka Limestone member, with the top probably near the river level at White Cloud.

SECTION BELOW THE MOUTH OF THE BIG NEMAHA RIVER

This is about three-eighths mile east of where the Burlingame crosses the Big Nemaha. It is 1½ miles south and 2½ miles east of Rulo, Nebraska.

1. Burlingame Limestone, about 70' above the railroad or 80' above the river, massive, weathered yellowish brown, forms large blocks, 5' 10".
2. Scranton Shale member, about 86' exposed:
 - (1). Silver Lake Shale, bluish gray, argillaceous to sandy, with thin sandy flakes, 8'.
 - (2). Rulo Limestone, bluish gray, massive, with few joints, 1' or more.
 - (3). White Cloud Shale, about 78':
 - a. Shale, a thin seam.
 - b. Silver Lake or Elmo Coal, about 1'.
 - c. Shale, gray, massive, argillaceous, bedded, with some rusty flakes, 3'.
 - d. Shale, gray, massive, argillaceous, indurated, 3'.
 - e. Shale, grayish, bedded, with sandy lenses and seams, 15'.
 - f. Shale, grayish, finely bedded, 2'.
 - g. Happy Hollow Limestone (Broadhead's 224), dark gray, massive, weathers salmon-colored, with a few fossils, 1' 9".
 - h. Shale, exposed in slope to railroad, 37'; the upper 2' is bluish gray, argillaceous, bedded; the lower portion, about 35', is massive with large hard bluish gray sandstone lenses in the lower portion which extends to the railroad about 14' above the river.

The Scranton Shale member is 100 feet or more thick here, extending probably 25 feet or more below the river. The beds of the section dip slowly northwestward, bringing the Burlingame Limestone down to a much lower position south of Rulo.

East of the above section, i. e., just below Happy Hollow, is a narrow sharp up-bend or flexure followed by a drop eastward which brings the Silver Lake Coal down to within 35 feet of the railroad level. Beyond this small deformation the beds rise southeastward to Kansas.

FOREST CITY, MISSOURI, TO THE THURMAN-WILSON FAULT, NORTH OF THURMAN, IOWA

The Howard Limestone member outcrops north of Forest City for a distance of about 2 miles beyond which, to near Craig, there are no bed rock exposures. The Scranton Shale member should occur in this covered stretch with a thickness of about 100 feet, but its top has not been definitely located. Broadhead says that his division number 224, which seems to be the Happy Hollow Limestone, is exposed in the northern part of Holt County. I did not find the Happy Hollow Limestone, the Rulo Limestone, and the Silver Lake Coal exposed

here, but what seem to be the Rulo bed and the Elmo or Silver Lake Coal below it are reported to have been penetrated in a shallow well at the foot of the bluffs northwest of Craig. The relation of the lowest beds exposed here to known horizons near Elmo, Nodaway County, has been described by Hinds and Green, whose Elmo section is given for comparison. It is as follows: ²

SECTION NEAR ELMO, MISSOURI

1. Shale, gray, sandy, 2'.
2. Limestone, gray; shaly at top; loose nodular at bottom, 1'.
3. Shale, gray, 1'.
4. Coal, bituminous (Elmo), 1'.
5. Shale, with thin layer of clay at top, 13'.
6. Limestone (Broadhead's 224), salmon-colored; argillaceous, nodular at bottom, 2'.

In comparing these beds with Broadhead's Atchison County section and his general Missouri River section, Hinds and Greene say: "Number 1 is the lower part of No. 27 of the Atchison county section; No. 2 is No. 28 of the Atchison County section; and No. 6 is No. 224 of the Missouri River section."

Hinds and Greene refer to the section in Atchison County, Missouri, as follows: "Along the Missouri river, the lowest member of Broadhead's Atchison county section is exposed near where the line between sections 34 and 35, T. 63 N., R. 40W., crosses the bluffs. At that place shaly limestone No. 28 outcrops, underlain by a foot of light shale and that in turn by black shale and coal, according to Mr. Fisher on whose farm the outcrop is located."

Broadhead's No. 28 referred to by Hinds and Greene is the Rulo Limestone. The coal just below it is the Silver Lake or Elmo bed. Broadhead's No. 224 in the general Missouri River section is the Happy Hollow Limestone. All of the beds just noted, together with the shale between the Silver Lake Coal and the Rulo bed, are in the Scranton Shale member, near the top, but the base of the Wabaunsee formation, which

² Missouri Bureau of Geol. and Mines, Vol. XIII, 2nd Series, p. 195, 1915.

should be at the top of the Silver Lake Shale overlying the Rulo Limestone, has not been definitely located in this part of the Missouri cross section, because the Burlingame Limestone, which marks the base of the Wabaunsee formation in Kansas and Nebraska, is not present here, or it has united with the Rulo bed (No. 28). The Rulo Limestone is at or near the Missouri River bottom land level in northern Holt County and southern Atchison County.

The cross section in Atchison County, correlated after Broadhead, is as follows:

CROSS SECTION OF ATCHISON COUNTY, MISSOURI

1. Admire-McKissick Grove Shale members, in descending order, more than 57' exposed:
 - (1). Shale, red (No. 3 of Broadhead's Atchison County section), 5'.
 - (2). Sandstone, greenish, irregularly bedded, micaceous (Broadhead's 4), 3'.
 - (3). Sandstone, brownish (Broadhead's 4), 8' to 10'.
 - (4). Shale and sandstone (Broadhead's 4), 35'.
 - (5). Dover Limestone, 5' 4".
 - a. Limestone, weathered brownish (Broadhead's 5), 10".
 - b. Limestone, earthy, fossiliferous (Broadhead's 6), 3' 2".
 - c. Limestone, bluish, concretionary (Broadhead's 7), 1' 4".
 - (6). Shale, argillaceous-sandy (Broadhead's 8), 2".
 - (7). Nyman Coal (Broadhead's 9), 2" to 3".
 - (8). Shale, arenaceous, ocherous (Broadhead's 10), 3' or less.
 - (9). Shale, sandy (Broadhead's 11), 22'.
2. Tarkio Limestone member, about 7':
 - (1). Limestone, dark blue, earthy (Broadhead's 12), 1' 6".
 - (2). Shale, greenish to reddish, with calcareous nodules (Broadhead's 13), 1' 6".
 - (3). Limestone, massive, with many *Fusulina* and *Osagea* incrustacea (Broadhead's 14), 4'.
3. Willard Shale member, blue and drab, argillaceous (Broadhead's 15), 28'.
4. Emporia Limestone member, bluish drab, with crinoid columns, bellerophons, etc. (Broadhead's 16), 2'.
5. Humphrey Shale member, 51' or more:
 - (1). Auburn Shale, about 14' or more:
 - a. Shale, blue, fossiliferous (Broadhead's 17), 10".
 - b. Sandstone, hard (Broadhead's 18), 2' 6".
 - c. Sandstone, soft (Broadhead's 19), 3'.
 - d. Sandstone, calcareous, with *Myalina subquadrata* and *Pinna peracuta* (Broadhead's 20), 10".
 - e. Shale, blue, argillaceous (Broadhead's 21), 6' to 12'.

- (2). Wakarusa Limestone, 3' or more:
 - a. Limestone, blue, fine grained, jointed, weathers brownish (Broadhead's 22), 1'.
 - b. Shale (Broadhead's 23), 1' 3".
 - c. Limestone, weathers buff and ocherous, quite fossiliferous (Broadhead's 24), 10".
- (3). Soldier Creek Shale, 34':
 - a. Shale, olive to buff (Broadhead's 25), 2'.
 - b. Shale, red (Broadhead's 26), 2'.
 - c. Shale, argillaceous to sandy, with layers of ferruginous sandstone (Broadhead's 27), 30'. This division may include the Silver Lake Shale at its base. If so, the Burlingame Limestone is absent.

6. Scranton Shale member:

- (1). Limestone, shaly, arenaceous at places, quite fossiliferous, thickness variable (Broadhead's 28), about 1' to 2'. This is the Rulo Limestone, or it is the pinched-out Rulo and Burlingame combined. It probably marks the boundary between the Shawnee and Wabaunsee formations in this part of Missouri, yet the contact of the formations should be about 8' higher at the base of the Burlingame Limestone if it occurs here.

The beds of Broadhead's section are quite well exposed between north of Craig and the Iowa-Missouri line. Most of the Soldier Creek Shale, the Wakarusa Limestone, Auburn Shale, Emporia Limestone, and the base of the Willard Shale are quite well shown in northern Holt County and southern Atchison County, dipping slowly northwestward. The Tarkio Limestone comes in east of Langdon and lowers to the coluvial slopes and bottom land west of Rockport. The middle and upper portions of the McKissick Grove Shale and the basal portion of the Admire member are exposed in the bluffs across most of Atchison County from near Rockport northward.

THE MCKISSICK GROVE SECTION

This is about 3 miles north of east of Hamburg, Iowa, in sections 13 and 24. The exposures here have attracted much attention. The general dip of the strata is southwestward.

1. Admire—McKissick Grove Shale member:

- (1). Aspinwall Shale, Brownville Limestone (?) and Pony Creek Shale:
 - a. Shale, recently exposed in gully and ravine south of iron bridge, dark gray, blocky, coarsely bedded, somewhat sandy,

- weathering yellowish, 4'. Beds yet higher may occur under the deep mantle of drift and loess.
- b. Shale, about 20'; upper 5' dark blue, massive and argillaceous; the remainder bluish or gray, argillaceous, bedded, and modified by sandy layers. The thickness is not easy to determine, because the beds are quite badly slumped. What may be the Brownville Limestone, although very sandy, occurs just below the middle of this division.
 - c. Nebraska City Limestone (?), about 1' 8"; top 5" to 1', dark gray, earthy, irregular, somewhat fossiliferous; basal 10" dark gray to bluish, fine grained, irregular, micaceous sandstone. This division forms a small waterfall in the south ravine in the northeast corner of section 24.
 - d. Shale, bluish, argillaceous, bedded to massive, with hard sandstone layers, some with ripple marks, about 16'. One of the hard layers forms a low waterfall. The stone is strewn far down the ravine into section 13.
- (2). Dover Limestone, 2' 6" to 3'. This forms a low waterfall under the iron bridge. Its upper portion is nearly eroded through except in the east bank of the creek. At places the bed is separated into a somewhat massive, dark gray, upper zone, which weathers brownish, and a more earthy basal zone. There are fossils in both zones. Most of the unweathered stone is bluish gray to dark gray. Fauna: Crinoid joints, fenestrated bryozoa, Rhombopora lepidodendroides, Ambocoelia planconvexa, Chonetes granulifer, Productus semireticulatus, and other species.
 - (3). Table Creek Shale, 23' or more:
 - a. Nyman Coal, and carbonaceous shale, well-shown under iron bridge, 1' 2" to 1' 4".
 - b. Shale, about 22'; top and base exposed along ravine in section 13, but middle portion covered. The shale just below the Nyman Coal is dark blue, irregular, quite massive, weathering yellowish to brownish. That near the base is bluish, argillaceous, bedded, with hard rusty flakes and sandy seams.
 - (4). Maple Hill Limestone, dark gray, earthy, quite fossiliferous, forms small waterfall in creek, 6" to 8". Fauna: Bellero-phons, pelecypods, brachiopods, and bryozoa.
 - (5). Pierson Point Shale, about 3' of the top exposed, the lower portion being covered. The Iowa Survey gives a thickness of 8' for this shale, which is bluish, bedded, and argillaceous to sandy.
2. Tarkio Limestone member, poorly exposed in creek bank about 250 yards southeast of the wooden bridge on road near the center of section 13, about 5'. Its upper 3' 6" to 4' is massive, dark blue, weathering brownish, with large Fusulina and a few crinoid joints. At the base of this massive bed is 6" to 1' of weathered or yellowish brown, rotted limestone.

3. Willard Shale member, probably 2' 6" exposed:

- (1). Shale, grayish, sandy to argillaceous, 6" to 1'.
- (2). Shale, mostly maroon, massive, argillaceous, 1' 8" shown to the creek bed. Formerly, according to the Iowa Survey, about 11' of this division was exposed here.

FROM HAMBURG TO THURMAN

There is an obscured exposure of the Pony Creek Shale, which includes the Nebraska City Limestone, below the school building at Hamburg, but north of this nothing of any consequence shows until two miles south of Thurman where the Nebraska City Limestone, overlain by about 10 feet of shale and underlain by 11 feet of shale with hard sandy concretions, outcrops in some farm lots east of the bluff-line road. There are badly obscured exposures on the creek just south-east of Thurman. The strata rise somewhat between Hamburg and north of Thurman.

SECTION ABOUT ONE MILE NORTH OF THURMAN, IOWA

1. Admire Shale member:

- (1). Aspinwall Shale, poorly exposed, 5' to 7'.
- (2). Brownville Limestone, yellowish, massive or badly weathered, forms large blocks; thickness about 2'; elevation 70' above the Missouri River bottom. This ledge has been quarried at two or three places south of the fault zone.

2. McKissick Grove Shale member:

- (1). Pony Creek Shale, 36' or more:
 - a. Shale, yellowish and red bands, mostly argillaceous, with bladed calcareous material above and nodular calcareous material and fossils below, 10' to 12'.
 - b. Nebraska City Limestone, one or two dark gray or mottled, shattered, fossiliferous beds, 1' to 2'. Fauna: Fenestrated bryozoa, Rhombopora lepidodendroides, Chonetes granulifer, Productus semireticulatus, Ambocoelia planoconvexa, etc.
 - c. Shale, grayish blue, argillaceous to sandy, with some calcareous debris, 4'. Fauna: Crinoid joints, brachiopods. This division is exposed in a ravine and at a barn lot.
 - d. Limestone, probably a lens, yellowish brown, shattered, no fossils observed, 8" to 10".
 - e. Shale, exposed in ravine and barn lot, 4' 10"; upper 1' to 2' yellowish; lower 2' 6" to 3' ash gray.
 - f. Sandstone, exposed at runway under road, bluish gray, micaceous, slabby, limy at places, 4" to 5".
 - g. Shale, bluish gray, silty, with micaceous layers, 5' 4".
 - h. Sandstone, bluish, fine textured, bedded, micaceous, weathers brownish, hard above, soft below, 6' 6".
 - i. Shale, bluish to buff, sandy, few fossils, 2' 6". The base of this is about 30' above the bottom land.

FROM RULO TO ASPINWALL FERRY

This stretch is west of the river, in Richardson and Nemaha counties, Nebraska. The top of the Scranton Shale is in the foot of the slopes from the spur south of Rulo northward to beyond Winnebago Creek. The Burlingame Limestone and other units of the Wabaunsee formation, up to the Willard Shale, form the core of the bluffs here and for several miles northward, going below the river as follows: Burlingame Limestone, north of Winnebago Creek, followed by the Soldier Creek Shale; Wakarusa Limestone, north of Fargo (Figure 20), followed by the Auburn Shale; Emporia Limestone, 4 miles north of Fargo, followed by the Willard Shale. The Tarkio Limestone is quite well shown from near Fargo northward and northwestward, dropping below the river southeast of St. Deroin (abandoned).



FIGURE 20.—The Wakarusa Limestone exposed in the Missouri River bluffs at Fargo, Richardson County, Nebraska.

Beds from the Tarkio Limestone up to the Falls City in the Admire member are shown at places between Indian Cave and the Aspinwall Ferry, dipping westward.

THE ASPINWALL FERRY SECTION

This is $2\frac{1}{2}$ miles south and $1\frac{1}{2}$ miles east of Nemaha City. It is based on exposures along the east-west road and in the Missouri River bluffs in sections 4, 19, and 20.

1. Admire Shale member, about 38' or 39' exposed:
 - (1). West Branch Shale, bluish, argillaceous, 6' to 7' of the base shown in small ravine southeast of ferry.
 - (2). Falls City Limestone, massive, forms large blocks, weathered brownish-mottled, exposed along roadside on hill southeast of ferry where its base is 75' above the river, 4' 3". Fauna: Pelecypod fragments quite abundant.
 - (3). Aspinwall Shale, about 26':
 - a. Shale, 4' or more; bluish and argillaceous above; slabby and calcareous below.
 - b. Limestone, bluish gray to dark gray, with some earthy material, shatters, 1' 1" or more. Fauna: *Derbya crassa*, *Ambocoelia planoconvexa*, *Rhombopora lepidodendroides*, etc.
 - c. Shale, bluish, argillaceous, 1'.
 - d. Shale, yellowish, with sandy plates or blades, 5'.
 - e. Shale, blue, massive, argillaceous, 8'.
 - f. Limestone, yellowish, about 1'.
 - g. Shale, mostly maroon, with calcareous material, 7'.
 - h. Shale, blue, quite fossiliferous, about 3'. Fauna: *Marginifera splendens*, *Chonetes granulifer*, *Spiriferina kentuckiensis*.
 - (4). Brownville Limestone, exposed in the ravines in section 19, in the bluffs west of the ferry, and southeast of the ferry, 2' or more:
 - a. Limestone, a thin fossiliferous seam or slab.
 - b. Shale seam.
 - c. Limestone, brownish, 1' 8". Fauna of whole division: *Marginifera splendens*, *Productus cora*, *Ambocoelia planoconvexa*, *Productus semireticulatus*, *Spiriferina kentuckiensis*, *Chonetes granulifer*, etc.
2. McKissick Grove Shale member, 58':
 - (1). Pony Creek Shale, 18' 2":
 - a. Shale, bluish, argillaceous to quite sandy, part bedded, about 6'.
 - b. Limestone, light bluish gray, fossiliferous, 1' 2".
 - c. Shale, mostly maroon and massive, part bluish, practically all argillaceous, about 11'.
 - (2). Dover Limestone, dark gray to buff, one or two beds, massive or weathered with shale parting, fossiliferous, 1' 3" to 2' or more. Fauna: *Productus semireticulatus*, *Derbya crassa* (small form), *Spirifer cameratus*, *Productus cora*. The small *Derbya*, *Ambocoelia planoconvexa* and *Chonetes granulifer* are very plentiful in the basal portion.

3. Table Creek Shale, about 36' exposed in foot of bluff south of mouth of the Little Nemaha and southeastward along the Missouri to beyond Aspinwall. In the bluff southeast of Nemaha City, its top is about 25' above the river (Big Nemaha), lifting to about 36' above the Missouri at the ferry. Although the upper portion of the Table Creek Shale varies greatly at places, it is comparatively uniform in parts of this section, being formed of broad bands of maroon, dark blue, and light to buff, argillaceous to silty shales, modified by limestone seams, two thin coals, and a fairly persistent limestone. It grades horizontally into non-persistent bodies of sand and sandstone. The zones of this division west of the ferry are:

- (1). Shale, bluish to dark, a few inches.
- (2). Nyman Coal, 3" to 1' or more.
- (3). Shale, bluish, argillaceous above, indurated below, 6' to 10'.
- (4). Limestone, dark gray, somewhat arenaceous, irregular, quite fossiliferous, with many *Myalina*, about 1' to 1' 6".
- (5). Shale, bluish to black, 2' to 4'. *Chonetes granulifer* abundant.
- (6). Coal, irregular, not persistent, 2" to 1' 6".
- (7). Shale, gray to buff, in bands of silt or fine sand, with many leaf fragments. This is well shown west of the ferry; thickness, 6' or more.
- (8). Shale, exposed at ferry, 10' to 15', massive to bedded, blue, argillaceous, with very thin seams of limestone which release many *Chonetes granulifer*, *Productus semireticulatus*, *Spirifer cameratus*, and *Rhombopora lepidodendroides*.
- (8). Calcareous bands, exposed near the river level a short distance west of the ferry, gray to mottled, yellowish, calcareous, irregular, fossiliferous, 2' or more.
- (9). Shale, bright red, 3' or more exposed to river level.

Below the ferry the beds dip eastward for about three-eighths mile. Here, four or five feet below the Dover Limestone, is a fossiliferous bed 1 to 3 feet thick. It forms a well-defined light colored band in the bluff. Lowering from this band is a very fossiliferous coquina lens. A coal lens, 1' 8" or more thick, occurs under the light colored ledge at one place, but only a short distance east it rises and pinches out below the Dover Limestone. At the foot of the bluffs here is 10 feet or more of dark carbonaceous shale underlain a little farther west by blue, argillaceous shale in which are pieces of pyritized wood. The yellowish mottled calcareous horizon and the bright red shale exposed at the foot of the section just west of the ferry are below the river level east of the ferry.

SECTION NORTHEAST OF NEMAHA CITY

1. Admire Shale member, 35' to 37' exposed:
 - (1). West Branch Shale, in road crossing bluff, blue, argillaceous, with thin rusty flakes, 6'.
 - (2). Falls City Limestone, bluish gray, jointed, fossiliferous, forms large blocks, weathers brownish and porous, 1' to 1' 2". Fauna: Many ostracods and pelecypods.
 - (3). Aspinwall Shale, 26' to 27':
 - a. Shale, blue, argillaceous, massive or bedded, 7'.
 - b. Limestone, dark gray, massive, weathers slabby, 4" to 6".
 - c. Shale, blue, massive, 5' 9".
 - d. Shale, maroon, 1'.
 - e. Shale, light blue, 1' 6".
 - f. Limestone and shales, thin layers, 3'; shales blue; limestone weathered, fossiliferous.
 - g. Shale, blue or mottled, argillaceous, with thin sandy-lime plates, 8'.
 - (4). Brownville Limestone, two limestone beds separated by 3" of fossiliferous shale, 2' 6". Stone dark gray, earthy at places, fairly dense and weathers buff to brown. Fauna: *Ambocoelia plancoconvexa*, *Marginifera splendens*, and other brachiopods in limestones and shale.
2. McKissick Grove Shale, about 24' 6" exposed:
 - (1). Pony Creek Shale, exposed in railroad cut and the spur of the bluff above:
 - a. Shale, light blue, bedded, 1' 6" or more.
 - b. Shale, maroon, 10' to 12'.
 - (2). Dover Limestone (?), dark gray, irregular, hard, earthy-sandy, shattered, quite fossiliferous, 6" or more exposed in railroad cut.
 - (3). Table Creek Shale, about 9' exposed in railroad cut:
 - a. Shale, blue, argillaceous, 6" to 1'.
 - b. Nyman Coal (?) and carbonaceous shale, 3" to 7".
 - c. Shale, blue, black and maroon, irregular, argillaceous to sandy, cross-bedded, part carbonaceous, about 8'. The base of this is 11' above the lowest Missouri River bottom land.

BROWNVILLE SECTION

1. Elmdale member, about 15' 8" exposed:
 - (1). Aspinwall Shale:
 - a. Limestone, poorly shown about 1¼ miles north of Brownville, blocky, about 8".
 - b. Shale slope, badly covered, about 15'.
2. Americus Limestone member (?), poorly shown in bluffs north of town, thickness (?).
3. Admire Shale member, about 62' 6":
 - (1). West Branch Shale, in poor exposure in bands of limy shale, claystone, blue shale, and limy-sandy beds, 30' or more.

- (2). Falls City Limestone, badly weathered or in two quite massive beds separated by shale parting, 4' to 5'. The outcrop is 1½ miles north of Brownville, about 41' above the railroad and 60' above the river.
 - (3). Aspinwall Shale, poorly shown in covered slopes north of Brownville, about 26'.
 - (4). Brownville Limestone, covered in section north of Brownville; and in section 3 south of town, 2' or more.
4. McKissick Grove Shale member, about 46' exposed:
- (1). Pony Creek Shale, loose, massive sandstone or argillaceous to sandy shale, 17' to 20'.
 - (2). Dover Limestone, in ravines back of stock yards below Brownville, elevation 10' or more above bottom land; not persistent in section north of town, but exposed across road 2 miles northwest, elevation 20' above bottom land; thickness about 2'.
 - (3). Table Creek Shale:
 - a. Nyman Coal, exposed across road 2 miles northwest of Brownville; not persistent; thickness 0" to 8".
 - b. Shale, sandy, irregular, exposed north of depot to near river level, 25' or more.

At places north of Brownville practically all of the section below the Falls City Limestone is either sandy shale, friable sandstone, or both.

WOOD SIDING SECTION

This is based on exposures between the mouth of Honey Creek and a ravine one mile south.

1. Elmdale Shale member, about 9':
 - (1). Hughes Creek Shale, 3'; upper 1' massive, the remainder yellowish and calcareous.
 - (2). Limestone, fossiliferous, 10"; upper 5" light gray, lower 5" weathered and shattered.
 - (3). Shale, poorly exposed, bluish, bedded, argillaceous, 5'.
2. Americus Limestone member, about 8' 6":
 - (1). Limestone, light gray, forms slabs, 9". This is quite fossiliferous, with crinoid joints, *Marginifera splendens*, *Meekopora prosseri*, and other fossils.
 - (2). Shale, blue, argillaceous, weathered yellowish, 5' 6".
 - (3). Limestone, gray, weathered yellowish, 9" or more.
3. Admire Shale member, about 61':
 - (1). West Branch Shale, 32' 2":
 - a. Shale, massive, argillaceous, with some induration; part of it covered; blue at base; thickness, 24' 6".
 - b. Limestone, yellowish, rotted, 1' 8".
 - c. Shale, hard, jointed, argillaceous, 4'.
 - d. Shale, blue, bedded, argillaceous, 2'.

- (2). Falls City Limestone, 2' 9"; upper portion dark gray, dense, massive, not much jointed, holds waterfall, 1' 5" to 1' 6"; lower 1' 3" yellowish, disintegrated. Fauna: Pelecypods and other fossils.
 - (3). Aspinwall Shale, about 24' 9":
 - a. Shale, 10' 3", top grayish blue, argillaceous; basal portion massive or loosely indurated in the part exposed.
 - b. Limestone, 8"; upper 2" to 4" dark gray with *Ambocoelia planoconvexa* and *Chonetes granulifer*; lower 4" to 5" dark gray, weathered, with crinoid joints, *Ambocoelia planoconvexa*, and *Chonetes*.
 - c. Shale, greenish gray, argillaceous, somewhat indurated, 1' 10".
 - d. Limestone, bluish gray, earthy, somewhat sandy, weathered yellowish, not very fossiliferous, 1'.
 - e. Shale, 12' 4"; upper 10" weathered yellowish; the remainder maroon, massive, argillaceous.
 - (4). Brownville Limestone, massive, yellowish brown, fossiliferous, 2' 4". Fauna: Crinoid joints, *Marginifera splendens*, *Productus semireticulatus*, *Spirifer cameratus*, etc.
4. McKissick Grove Shale member, about 47' exposed:
- (1). Pony Creek Shale, arenaceous to argillaceous, bedded to massive, poorly exposed south of Wood Siding, 22'.
 - (2). Dover Limestone, well shown in south of Honey Creek, southwest of Wood Siding, about 2'. Fauna: *Marginifera splendens*, *Chonetes granulifer*, etc.
 - (3). Table Creek Shale:
 - a. Nyman Coal, well shown in bluff south of the mouth of Honey Creek, maximum thickness 2' 6" in a small area.
 - b. Shale, about 20' exposed in the lower part of the Honey Creek Valley above the creek bed.

PERU SECTION

1. Americus Limestone (?), in bluff southeast of town, 95' above railroad and 110' above river; buff or yellow, not very fossiliferous, 4' to 6'. This forms large blocks which lower on the slope.
2. Covered slope, with some red shale exposed, probably 20' to 25'.
3. Sandstone, exposed along railroad below Peru, yellowish or light gray, soft, with some hard concretions, 50' or more. At the spur or bend in the bluff southeast of Peru, this sandstone grades southward into shale.
4. Dover Limestone (?), dark gray, hard, arenaceous, with some fossils, about 1'. This is about 11' above the railroad at the bend southeast of Peru and extends southward into the Table Creek horizon on Honey Creek, but does not seem to persist northward in the sandstone bluff.
5. Shale, bluish or gray, argillaceous to sandy, 9' to 11'; exposed above railroad at spur, where the Nyman Coal does not show at the top. This division seems to grade into sandstone on the north.

The Brownville Limestone is not thought to persist through division 3 of this section where it belongs. No doubt the Tarkio Limestone is several feet below the river level at Peru.

The beds rise slightly northward from this section past Barney and Minersville, maintaining about the same elevation with respect to the river, to about 2 miles southeast of Nebraska City, where they lift about 50 feet between this last point and the brick yard southeast of the city.

SECTION IN THE BLUFF AND CLAY PITS, SOUTHEAST OF NEBRASKA CITY

Beneath a heavy mantle of loess, sand, and some glacial drift, the exposed bed rock is as follows:

1. McKissick Grove Shale member, about 75':
 - (1). Pony Creek Shale, about 16' 6" exposed:
 - a. Nebraska City Limestone, high in the old pit, dark bluish gray, massive, quite hard, somewhat sandy and pebbly, forms large rectangular blocks, weathers buff to brownish and slabby, 2' to 2' 10". Fauna: Crinoid joints, Rhombopora lepidodendroides, and a few brachiopods.
 - b. Shale, exposed in old clay pit, about 14':
 - (a). Light bluish gray, mostly bedded and argillaceous, with thin limy seams and plates, 8'. Fauna: Fossils occur scattered throughout. Chonetes granulifer and Ambocoelia planoconvexa are quite plentiful.
 - (b). Dark blue, bedded to massive, and argillaceous, 6'. It is separated from (a) at places by a non-persistent micaceous sandy zone a few inches thick.
 - (2). Dover Limestone, one or two bluish gray or dark gray beds, weathers buff, with some chert at places, somewhat earthy in the lower portion in which the material gives a variegated appearance to broken surfaces, 1' 4" to 1' 8". Fauna: Marginifera splendens, Chonetes granulifer, and Spirifer cameratus quite common.
 - (3). Table Creek Shale (Figure 21), about 45':
 - a. Shale, a thin fossiliferous seam. Fauna: Chonetes granulifer, Spirifer cameratus, Meekopora prosseri, etc.
 - b. Nyman Coal, 4" to 8".
 - c. Shale, 38' to 40'; upper 28' to 30' exposed in the old pit; basal 10' in the new pit. This shale varies much in color and texture, grading between bluish gray clay and soft, yellowish, massive sandstone. Along the railroad south of the old pit and 12' or more below the top of the division is a heavy sandstone 5' to 6' thick. Near the south end of the old pit about 13' or 14' of sandy, argillaceous shale is exposed below this sandstone zone. North of the trestle and

- at a little lower level is friable sandstone. The basal zone of the shale exposed in the new pit is largely bluish, argillaceous, bedded, plastic shale.
- d. Limestone, exposed in new pit at an elevation of 10' to 11' below the level of railroad on the trestle; dark gray, earthy, one bed, disintegrated at places, fossiliferous, 8" to 1'.
 - e. Shale, bluish, mostly argillaceous, massive, 5' to 5' 6".
 - f. Shale, dark, argillaceous, 1' 2".
- (4). Maple Hill Limestone, about 1' 8":
- a. Limestone, dark gray, earthy, 4".
 - b. Shale, dark, somewhat carbonaceous in upper portion, 8" to 10".
 - c. Mudstone, very dark gray, earthy, nodular, somewhat calcareous, 7" in west part of pit, thicker in east part.
- (5). Pierson Point Shale, blue, mottled to maroon, argillaceous, massive, with some fossils, indurated at places, extends to floor of new clay pit, 9' to 11'. Its base at the east end of the clay pit is nearly black.
2. Tarkio Limestone member, exposed on floor of new pit, in ravine just north of floor of brick yard, and in river bank, about 11':
- (1). Limestone, forms floor of new clay pit, light blue to dark gray, fossiliferous, 4" to 6".
 - (2). Shale, bluish, argillaceous, fossiliferous, 8".
 - (3). Limestone, bluish gray, fossiliferous, 4" to 5".
 - (4). Shale, bluish, argillaceous, 4" to 6".
 - (5). Limestone, light gray, ranging between bluish gray and light gray, massive, jointed, 1' 6" or more. Fauna: Crinoid joints, brachiopods, bryozoa, etc.
 - (6). Shale, mostly bluish, argillaceous, bedded to massive, with thin seam of limestone, about 4' 6".
 - (7). Limestone, brownish, fossiliferous, 1' 10" to 2'. This is the lowest bed exposed in the ravine. In the river bank north of the Missouri River bridge are additional layers below, making a combined thickness of 3' to 3' 6" for this division.
3. Willard Shale member, about 16' or 17' exposed:
- (1). Shale, blue, argillaceous, 2'.
 - (2). Mudstone, dark gray, 5".
 - (3). Shale, blue, argillaceous, 1'.
 - (4). Limestone, impure, fossiliferous, 5".
 - (5). Shale, blue, argillaceous, about 1' 6".
 - (6). Limestone, fossiliferous, 1'.
 - (7). Shale, dark, 6" or more.
 - (8). Limestone, sandy, in two layers, weathered brownish, 10" to 1'.
 - (9). Shale, blocky, hard, bluish, argillaceous, with some calcareous material, about 2'.
 - (10). Shale, indurated, calcareous, weathered yellowish, very irregular, base uneven, resembles weathered or rotted limestone, 10" to 1'.
 - (11). Shale, greenish blue, massive, hard, 1' to 1' 6".
 - (12). Shale, red, massive, hard, 4' exposed above river at mean height.

Marcou separated the Nebraska City section into divisions A, B, C, and D, in ascending order. His designation was followed by Meek. The equivalents of Marcou's subdivisions are:

- D, Dover Limestone.
- C, Table Creek Shale.
- B, Tarkio Limestone and the upper portion of the Willard Shale.
- A, Middle portion of the Willard Shale.

The beds above the Dover Limestone were not exposed when Marcou and Meek studied this section. They were later uncovered in working clay for brick manufacture.



FIGURE 21.—The Table Creek Shale, Maple Hill Limestone, and Pierson Point Shale exposed in the Nebraska City clay pit. The Tarkio forms the floor of the pit.

SECTION IN RAVINE, FIVE-EIGHTHS MILE SOUTH OF THE MOUTH OF WALNUT CREEK

This is in the bluff north of Nebraska City.

1. McKissick Grove Shale member, about 22' exposed.
 - (1). Table Creek Shale:
 - a. Limestone, dark gray, earthy, fossiliferous, about 8". Fauna: *Entiletes carbonarius*, *Productus cora*, crinoid joints, *Derbya crassa*, *Schizodus*, etc.
 - b. Shale and covered slope, about 5', as follows: 3' light colored, bedded, argillaceous shale with some calcareous material; covered slope, 2'.
 - c. Limestone, light gray, brecciated, 8" to 10".
 - d. Slope, probably all shale, some of it maroon, 3' 6" to 4' 9".
 - (2). Maple Hill Limestone, massive, irregular, semi-crystalline, upper portion eroded, 1' 5".
 - (3). Pierson Point Shale, 8'; upper 1' olive colored; middle 4' maroon; basal 3' bluish.
2. Tarkio Limestone member, about 10' 6":
 - (1). Limestone, grayish or dark gray, 4" to 6".
 - (2). Shale, blue, 6" to 9".
 - (3). Limestone, light gray, 4" to 6".
 - (4). Shale, light blue, 4".
 - (5). Limestone, massive, hard, fossiliferous, 1' 9".
 - (6). Shale, bluish green, 3' to 4'.
 - (7). Limestone, 11".
 - (8). Weathered Limestone, 1' 2".
 - (9). Limestone, massive, 1' 8".
3. Willard Shale member, 24' to 25':
 - (1). Shale, 22' to 23'; upper 6' grayish; middle 8' to 9' maroon; lower 8' dark blue, argillaceous, and massive to bedded.
 - (2). Limestone, weathers yellowish, 8" to 10".
 - (3). Shale, dark blue, largely massive, argillaceous, and very fossiliferous, with many large specimens of *Productus semireticulatus*, 2'.
4. Emporia Limestone member ("Preston" Limestone), about 3' 8":
 - (1). Limestone, with shale seam in middle, 1' 4".
 - (2). Shale seam, 2".
 - (3). Limestone, forms large blocks, 7".
5. Humphrey Shale member:
 - (1). Auburn Shale, 4' 9" exposed:
 - a. Shale, blue, argillaceous, 2' 6".
 - b. Shale, blue, exposed to the high stage of river, 2' 3".

THIES FALLS SECTION IN THE LOWER PART OF WALNUT CREEK VALLEY

Location, about one-half mile east of Graham Falls.

1. Tarkio Limestone member, well exposed high in a ravine southeast of Thies Falls, where it is about the same as at Graham Falls.

2. Willard Shale member, about 23' to 24':
 - (1). Shale, mostly argillaceous, massive to bedded, upper 6' grayish; middle 8' or more maroon; lower 8' dark blue; combined thickness measured in the ravine and in banks of Walnut Creek, about 22'.
 - (2). Shale, shown near falls, light bluish, somewhat indurated and slabby at base, with large specimens of *Productus semireticulatus* and several other species, 1' 2".
3. Emporia Limestone member, 3' 6" to 4' or more:
 - (1). Limestone, grayish, weathers buff or gray, massive, with shale parting at places, 1' 4". This forms the bed of Walnut Creek above the upper Thies Fall. Fauna: *Productus semireticulatus* and other species.
 - (2). Shale, bluish, carbonaceous to argillaceous, 2".
 - (3). Limestone, weathers light gray to dark gray, fossiliferous, forms very large blocks, 6" to 8". This bed has well-defined joints extending east-west and northeast-southwest.
 - (4). Limestone, quite massive, weathers rusty, exposed under lower waterfall and in creek bank farther east, 1' 2".
4. Humphrey Shale member, 19' 6":
 - (1). Auburn Shale:
 - a. Shale, exposed in the south creek bank below the waterfall, greenish blue, argillaceous, 3' 6".
 - b. Limestone, weathered rusty, probably not very persistent, 1'.
 - c. Shale, 15' exposed in creek and river banks.
 - d. Greenish blue, argillaceous, 4'.
 - e. Maroon, argillaceous, about 1' 5".
 - f. Olive colored, argillaceous, massive, 1' 6".

There is a low northeast-southwest arch of the beds at the mouth of Walnut Creek. This is shown by a slight north dip at Thies Falls and by a drop of about 10 feet southward in the bluffs within a distance of a little more than one-half mile from Walnut Creek. The Emporia Limestone is exposed along the river three-fourths mile north of Walnut Creek, at Thies Falls and at the mouth of a ravine in the Missouri River bluffs five-eighths mile south of Walnut Creek.

GRAHAM FALL SECTION ON WALNUT CREEK

This is in Walnut Creek Valley about one mile above the mouth. There are two small waterfalls here — one under the wagon road bridge on the north branch and the other on the south branch between the wagon road and the Missouri Pacific Railroad. The height of the latter fall is between 3 and 4 feet. The section is:

1. Tarkio Limestone member, about 7' 6":
 - (1). Limestone seam, 3" to 4".
 - (2). Shale, argillaceous to calcareous, fossiliferous, 4" to 6".
 - (3). Limestone, bluish, weathers grayish, with some fossils, massive, 1' " to 1' 10".
 - (4). Shale, bluish, argillaceous, calcareous, contains thin, irregular limestone seams, 2' 6".
 - (5). Limestone, in a single massive bed or separated into a main central part and weathered upper and lower portions, 2' 6". There is some shale between the layers at places.
2. Willard Shale member, 9' exposed:
 - (1). Bluish, bedded, 7', part irregularly indurated and banded as gray to yellowish stone.
 - (2). Massive and maroon, about 2' exposed above creek bed.

SECTION IN THE BLUFF NEAR THE MOUTH OF WEEPING-WATER CREEK

The position of the mouth of Weeping Water Creek has changed much in the past few years. It is now about $1\frac{3}{4}$ miles south of the Otoe-Cass county line and close to the bluff. The upland is mantled with loess and drift, but not so deeply as at most of the other places. Section:

1. McKissick Grove Shale member, about 57':
 - (1). Pony Creek Shale, about 15':
 - a. Nebraska City Limestone, light gray to bluish gray, massive, granular, sandy, very hard, forms irregular blocks with sharp edges; thickness of bed probably 1' 3" or more, but the exposure is not in a condition to definitely determine.
 - b. Shale, with several layers of firm, sandy material, 12' to 15'.
 - (2). Dover Limestone, exposed in steep part of bluff three-eighths mile south of the Otoe-Cass county line, 2' or more; upper 1' weathered; lower 1' to 1' 3" massive, bluish, weathered rusty. *Marginifera splendens* is the most noticeable fossil.
 - (3). Table Creek Shale, 40':
 - a. Nyman Coal horizon, carbonaceous, a few inches.
 - b. Shale, arenaceous to micaceous, 27'. The best exposure of this is along an old trail leading to the mouth of a ravine one mile south of the county line. This shale weathers yellowish. It carries a good many rusty sandy plates, some of which are micaceous.
 - c. Limestone, somewhat sandy, badly weathered, fossiliferous, 6" or more. Fauna: Many *Productus cora* and several species of pelecypods.
 - d. Shale, weathers buff, 3'.
 - e. Limestone, a very fossiliferous seam 1" or more thick, with *Productus cora* and other species.

- f. Shale, bluish, with rusty plates, argillaceous to calcareous, 1' 9".
 - g. Limestone, buff, sandy with some mica, fossiliferous, badly weathered, 6" to 1' or more. *Productus cora* and pelecypods are quite common.
 - h. Shale, mostly maroon, grading into chocolate and bluish above, with small calcareous concretions; thickness, 6'.
2. Tarkio Limestone member, about 8' 6":
- (1). Limestone, dark gray, weathered nodular, fossiliferous, 4" to 10".
 - (2). Shale, light bluish green, somewhat calcareous, argillaceous, 4" to 6", with many fossil fragments and crinoid joints.
 - (3). Limestone, bluish, massive, weathers light gray at most places but locally brownish, forms large blocks which shatter badly, 1' 6". This is not very fossiliferous, but it carries some *fusulina* on the upper surface and crinoid joints throughout, also a few pelecypods and small gastropods. At places its lower 5" weathers brownish and separates as well-defined blocks.
 - (4). Shale, 2' 9", mostly greenish blue and argillaceous. It carries a buff to yellowish stone 1' or more thick at places. This condition, however, is not persistent.
 - (5). Limestone, bluish, massive, weathering light gray, yellowish or brownish, thickness 2' 6" to 3' 6". This is one bed or separated into two or three layers. It forms large blocks. At places 10" of the top is separated from the rest by 1" to 2" of greenish, argillaceous shale. The principal feature of this bed is its even joint planes, massive character, and rusty appearance. A slabby layer develops locally above; the base may thicken in the underlying shale. Fauna: The principal fossils are crinoid columns, *Productus cora*, *Derbya crassa*, *Rhombopora lepidodendroides*, *Allorisma terminale*, and *Chonetes granulifer*. The most noticeable fossils are the crinoid joints. This bed is quite well exposed for a mile or more along the bluff, but is best shown at the ravines.
3. Willard Shale member, 14' to 15' exposed above the flood plain of the creek and river:
- (1). Bluish, bedded, argillaceous, 5".
 - (2). Dark blue, mostly argillaceous, 6".
 - (3). Shale, with a seam of yellowish, irregular, non-persistent limestone, 1'.
 - (4). Greenish blue, bedded, argillaceous, 1' 6".
 - (5). Bluish, calcareous, 1'.
 - (6). Maroon, mostly massive and argillaceous with calcareous concretions and slabby material, about 9' exposed at the mouth of one ravine.
 - (7). Covered slope to bottom land and river, about 8' to 10'.

The beds of this section are nearly horizontal in north-south section, except in the northern part where they rise

northwestward. The Tarkio is exposed at places southward past Squaw Creek.

SECTION AT SAND POINT AND JONES POINT

This is in the Missouri River bluffs about four miles east of Union, Nebraska. The bed rock is deeply veneered with loess and drift, making the conditions unsatisfactory for study, however, river-cutting and landslides have at times exposed enough of the bedrock for observation. The beds rise quite rapidly but not uniformly northward through Sand Point and Jones Point, which are close together. The section from south to north, in descending order, is as follows:

I. Wabaunsee Formation

1. Humphrey Shale member, about 12' of the basal portion of the Soldier Creek Shale is exposed in the south part of Sand Point. The shale is reddish and argillaceous to sandy.
2. Burlingame Limestone member. This rises from below the river at the south side of Sand Point, becomes nearly flat in the next stretch, followed by a short rise which carries it high above the river at the middle part of Sand Point. It is one massive, bluish bed or separated as two or three beds, weathering brown, 3' to 3' 9". Fauna: Crinoid joints, Rhombopora lepidodendroides, Chonetes granulifer, Productus semireticulatus, etc.

II. Shawnee Formation

1. Scranton Shale members:
 - (1). Silver Lake Shale, exposed in Sand Point, bluish gray, mostly argillaceous, indurated at places, 2' 6" to 3'.
 - (2). Rulo Limestone, dark gray to yellowish brown, irregular, badly weathered, 8" to 1'. Fauna: A few gastropods and brachiopods.
 - (3). White Cloud Shale, exposed in the middle part of Sand Point; thickness probably 80'; top maroon and somewhat indurated; most of it is argillaceous to sandy with bodies of sandstone. The base of this is not exposed.

A narrow stretch between Sand Point and Jones Point is covered. There may be a few feet of displacement here by faulting, yet the dip of the beds in Sand Point and Jones Point accounts for nearly all of the interval. The section continued north of this covered stretch, i.e., at Jones Point, is as follows:

- (4). South Bend Limestone, badly covered but with some evidence of its presence in the south part of Jones Point; thickness (?), probably 5'.
- (5). Rock Lake Shale, badly covered; thickness probably 5'.
2. Howard Limestone member, in the south part of Jones Point, four bluish, massive beds weathered brownish, about 7'. At one point there is below the above a seam of shale underlain by a thin limestone, making a combined thickness of about 8' for the member. Fauna: Brachiopods, gastropods, bryozoa, and crinoid columns. Most of the fossils are fragmentary.
3. Severy Shale member, bluish, argillaceous, somewhat calcareous, with the Nodaway Coal near the middle, 8' to 9'.

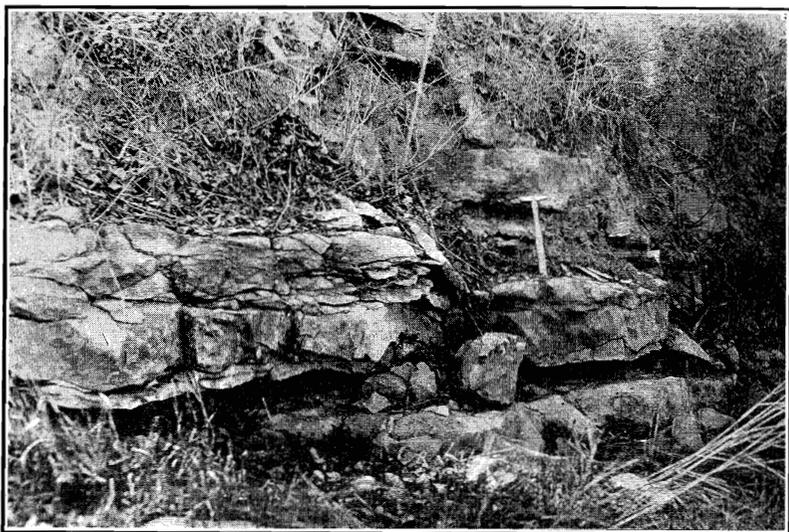


FIGURE 22.—Coal Creek Limestone at Jones Point.

4. Topeka Limestone member, about 8' 4":
 - (1). Coal Creek Limestone, 5' or more (Figure 22):
 - a. Limestone, blue, dense, brittle, with some dark chert and light colored fossils, 1' 6". Fauna: Many fenestrated bryozoa, brachiopods, pelecypods, and gastropods.
 - b. Shale seam, blue.
 - c. Limestone, in two or three wavy-bedded blue beds, with pelecypods, brachiopods, and other fossils, 2' 6".
 - d. Shale, 4" to 6".
 - e. Limestone, weathers buff, 6' to 8'.
 - (2). Holt Shale, 1' 2"; top bluish, argillaceous, fossiliferous; base dark, fissile.

- (3). Du Bois Limestone, two beds with a shale parting, 6" to 1'. Fauna: Many pelecypods, brachiopods, and some bryozoa largely in the lower portion.
5. Calhoun Shale member, about 18':
 - (1). Iowa Point Shale, bluish green, weathers yellowish, argillaceous, somewhat calcareous, 5' to 6'. The top 6" to 1' carries many *Derbya crassa* and other brachiopods, also some fenestrated bryozoa.
 - (2). Meadow Limestone, one massive bed or broken up, bluish gray, weathers buff or brownish, 3' 6". Fauna: Numerous *Allorisma* and fragments of other fossils; bryozoa common.
 - (3). Jones Point Shale, top portion bluish and argillaceous; basal portion somewhat calcareous and bedded to massive; combined thickness, 9'. Fauna: Many fenestrated bryozoa, some pelecypods, and brachiopods.
6. Deer Creek Limestone member, about 30', the divisions and thickness being about the same as at Rock Bluff. This member rises rapidly northward from below the river (Figure 23).
7. Tecumseh Shale member, blue to brownish clay and sand, 26'.
8. Lecompton Limestone member, about 20' exposed:
 - (1). Avoca Limestone, dark gray, one bed, 1' 6" to 2' 5".

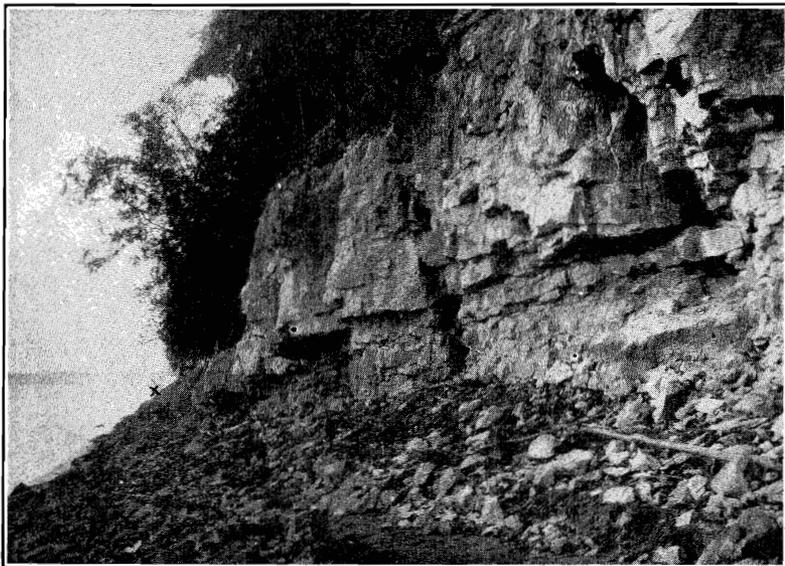


FIGURE 23.—Ervine Creek Limestone at Jones Point, dipping southward.

- (2). King Hill Shale, 7' to 8'; top portion light gray; basal portion greenish, argillaceous, bedded.
- (3). Cullom Limestone, 4' 7" or more.
- (4). Queen Hill Shale, exposed above river level at places from the north part of Jones Point to the mouth of Ervine Creek, 5' to 6'.

POSITION OF STRATA IN THE JONES POINT DEFORMATION

Between the mouth of Weepingwater Creek and Sand Point, a distance of about 4 miles, 40 feet or more of strata rise above the river level. The interval represented by these beds includes the lower portion of the Willard Shale, the Emporia Limestone, Auburn Shale, Wakarusa Limestone, and the top of the Soldier Creek Shale.

The following beds rise above the river from the south side of Sand Point northward:

1. Soldier Creek Shale, lifting gradually, about 12'.
2. Burlingame Limestone, rising slowly, then more rapidly, average thickness about 3' 6".
3. Silver Lake Shale, 2' 6" to 3'.
4. Rulo Limestone, 1' or less.
5. White Cloud Shale, top well shown, the lower portion covered in the north part of Sand Point, rising quite rapidly, thickness about 80'.
6. Covered slope on both sides of the ravine between Sand Point and Jones Point. The Plattford Shale, Cass Limestone, and other zones of the Scranton up to the base of the White Cloud Shale should occur in this interval of probably 32' to 36'.
7. Beds in the south part of Jones Point, representing the South Bend Limestone and Rock Lake Shale, about 10'.
8. The Howard, Severy, Topeka, and Colhoun members in Jones Point, rising slowly, then rapidly, thickness 40' to 43'.
9. The units of the Deer Creek member, rising rapidly, then lying nearly flat, about 30'.
10. Tecumseh Shale member and most of the Lecompton Limestone member in the north part of Jones Point, rising slowly followed by a nearly horizontal stretch and a low dip northward, about 46'.

The thickness of the strata lifting above the river between the mouth of Weepingwater Creek and Ervine Creek north of Jones Point, distance $6\frac{1}{2}$ to 7 miles, is about 300 feet. The river falls between 6 and 7 feet within this distance, which means, figuring from a given contour, that the strata drop southward about 293 feet between the north side of

Jones Point and the mouth of Weepingwater Creek. Nearly all of this change in the position of the beds is observable in the warping, yet there may be some faulting in the covered interval between Jones Point and Sand Point. However, as stated, if the beds dip at the same rate in the covered stretch as they do north and south of it, all of the deformation is due to warping.

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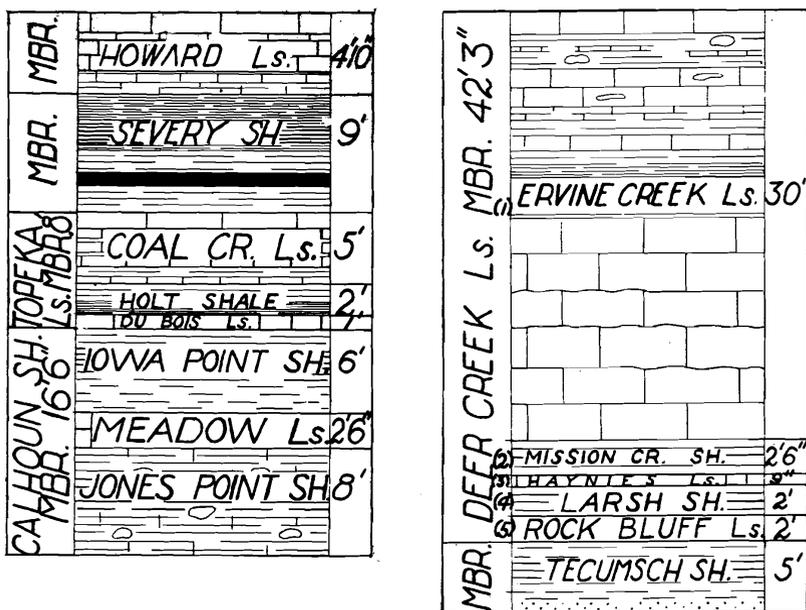


FIGURE 24.—Columnar section at the abandoned quarries two and one-half miles north of Thurman, Iowa.

SECTION AT THE ABANDONED QUARRY ON THE BALDWIN PLACE, 2½ MILES NORTHWEST OF THURMAN, IOWA

This is on the Redfield Anticline (Figure 24). The beds dip rapidly southeastward in the south part of the section, for the short distance exposed, and slowly northward in the north part. The most noticeable key beds are the Howard, Coal Creek, Meadow, and Ervine Creek limestones. The section, which is much like that at Jones Point, is as follows:

1. Howard Limestone member, exposed in Indian Creek valley, at one point north of the mouth of Indian Creek, and at the south side of section 23, about 4' 10":
 - (1). Limestone, dark blue, dense, quite fossiliferous in upper portion, weathers brownish and slabby below, about 3'.
 - (2). Shale, about 6".
 - (3). Limestone, two beds, separated by a shale seam, 1' 4".
2. Severy Shale member, quite well exposed in Indian Creek valley, 9' 6":
 - (1). Shale, yellowish, calcareous, 1'.
 - (2). Shale, black, 1' 10".
 - (3). Shale, bluish, argillaceous, fossiliferous, 1' 2".
 - (4). Shale, black, bedded, 1'.
 - (5). Shale, bluish gray, argillaceous, fossiliferous, 1' 6".
 - (6). Nodaway Coal, 1' or more.
 - (7). Shale, like No. (5), 2'.
3. Topeka Limestone member, well shown in foot of bluff south of the mouth of Indian Creek valley, about 8':
 - (1). Coal Creek Limestone, about 5', largely massive or separated as follows:
 - a. Limestone, dark blue, brittle, with conchoidal fracture, fossils light colored, 1' 10".
 - b. Shale seam, 1" to 2".
 - c. Limestone, blue, uneven, 6" to 1'.
 - d. Shale seam, 3".
 - e. Limestone, blue, 8".
 - f. Shale, 6" to 10".
 - g. Limestone, blue, earthy, 5" to 7".
 - (2). Holt Shale, 2' or more; upper 1' 3" bluish, poorly bedded, argillaceous; lower 1' black, finely bedded, becoming bluish at the base.
 - (3). Du Bois Limestone, blue, shattered, quite fossiliferous, about 1'. Fauna: *Derbya crassa* abundant in upper portion and *Myalina* in the lower.
4. Calhoun Shale member, about 16' 6":
 - (1). Iowa Point Shale, 6'; upper portion bluish green and somewhat indurated; lower portion more clayey.
 - (2). Meadow Limestone, dark gray, massive, with some chert, yellowish, weathers buff, forms large, rounded blocks, 2' 6". Fauna: *Fusulina*, crinoid joints, and brachiopods.
 - (3). Jones Point Shale, bluish, argillaceous to calcareous, with lime concretionary bodies, weathers gray, 8'. Fauna: Many fenestrated bryozoa, *Derbya crassa*, *Chonetes granulifer*, and pelecypods.
5. Deer Creek Limestone member, about 36':
 - (1). Ervine Creek Limestone, 28' 9":
 - a. Limestone, dark gray, dense, with some free calcite, irregularly joined, forms sharp blocks, 1' 6".

- b. Shale, bluish gray, argillaceous, with some calcareous bodies and seams, weathers yellowish, 2' 3".
 - c. Limestone, gray, fine textured, massive at places, part shattered, with some poorly developed yellowish brown flint, and few fossils; weathers yellowish, 2' 6" +.
 - d. Shale, bluish gray, with much calcareous material in upper portion, 2' or more.
 - e. Limestone, dark gray, dense, massive, forms blocks, 1'.
 - f. Shale, grayish above, dark at base, largely argillaceous, 1' 9". There are poorly preserved brachiopods in the upper portion.
 - g. Limestone, light gray, massive, oolitic, forms large rectangular blocks, 2' 10".
 - h. Shale seam, calcareous, 0" to 4".
 - i. Limestone, the main division of the Ervine Creek, massive to wavy-bedded, about 15'. The basal 2' carries many *Fistulipora nodulifera*.
- (2). Mission Creek Shale, bluish, shaly, 2' 6".
 - (3). Haynies Limestone, bluish, 9".
 - (4). Larsh Shale, bluish, clayey, now covered, 2'.
 - (5). Rock Bluff Limestone, bluish, covered, 2'.
6. Tecumseh Shale member, covered, formerly exposed as follows (after White):
- (1). Shale, bluish, clayey, 4'.
 - (2). Sandstone, fine grained, micaceous, 1'.

The beds dip northward from the crest of the Redfield Anticline to between Indian Creek and the mouth of Wabaunsee Creek valley, lowering about 50 feet in the Bartlett Syncline within 2½ miles. Beyond this there is a slow rise northward. The base of the Ervine Creek Limestone comes above the flood plain one mile north of the Mills-Fremont county line, beyond which there are many exposures of Ervine Creek, Meadow, and Coal Creek limestones to southeast of Haynies, Iowa.

SECTION NEAR HAYNIES, IOWA

This is near the old stone house southeast of Haynies. It is nearly identical with the upper portion of the section in the quarries east and northeast of Nehawka, Nebraska, as follows:

- 1. Topeka Limestone member. The Coal Creek Limestone and thin beds below it were formerly exposed high in the old quarry, thickness (?).

2. Calhoun Shale member, about 17' 6":
 - (1). Iowa Point Shale, formerly exposed, now covered, 6'.
 - (2). Meadow Limestone, bluish gray, massive, weathered gray or yellowish, forms large blocks, quite fossiliferous, 3' to 4'. This is well shown in the abandoned quarry.
 - (3). Jones Point Shale, 8' or more, bluish to gray, argillaceous to sandy, calcareous, with two thin, fossiliferous, calcareous seams and 1' 6" to 2' of irregular limestone-like material near the base. Fauna: *Chonetes granulifer*, *Derbya crassa*, *Spirifer cameratus*, large pelecypods, echinoid spines, *Septopora biserialis*, and *Rhombopora lepidodendroides*. Most of the pelecypods are in the lower calcareous seam.
 3. Deer Creek Limestone member, about 29':
 - (1). Ervine Creek Limestone, about 23':
 - a. Limestone, brittle, with considerable chert and many fossils, weathered yellowish, 2' 6".
 - b. Limestone and shale seams:
 - (a). Shale, gray, calcareous, 6".
 - (b). Limestone, 3" to 4".
 - (c). Shale, 5".
 - (d). Limestone, 3".
 - (e). Shale, bluish gray and argillaceous above, dark below, about 1'.
 - c. Limestone, dark gray, dense, with some calcite, forms angular blocks, 1' 3".
 - d. Shale, bluish gray, crumbly, fossiliferous, 1' or more.
 - e. Limestone, dark gray, massive to wavy-bedded, 15' to 16'.
The upper portion of this is exposed in the quarry near the stone house; the middle and basal zones are shown farther south.
 - (2). Mission Creek Shale, exposed along roadside south of the stone house, bluish to grayish, argillaceous, with one or two dark bands, 1' 4" or more (Figure 11).
 - (3). Haynies Limestone, bluish gray, compact, massive, with a good many crinoid joints, 9".
 - (4). Larsh Shale, 2'; upper portion bluish, argillaceous; basal portion quite dark, finely bedded, forms fissile debris at many places along the bluff.
 - (5). Rock Bluff Limestone, bluish gray, dense, massive, forms rectangular blocks, 1' 9" to 1' 10".
4. Tecumseh Shale member, about 7' exposed in gutter along road three-fourths mile south of the stone house; the top 1' to 2' is sandy, and the rest is bluish, argillaceous, and massive.

Northeast of Haynies the Deer Creek beds are high in the bluffs. Here the exposed section extends to below the Cullom Limestone, but the top of the Plattsmouth, though covered in the well-developed colluvial slopes, is above the level of the Missouri River bottom land.

EXPOSURES EAST OF PACIFIC JUNCTION, IOWA

Several years ago the top of the Plattsmouth Limestone was quarried at the bottom land level near the foot of the bluff east of Pacific Junction. This zone is now covered, but there is a fairly good exposure of the middle and lower zones in the bed and bank of Keg Creek just southeast of the above, the top being a few feet below the Burlington Railroad located a short distance north.

There are no exposures in the bluff north of those at Keg Creek until near Folsom. No doubt, however, the Plattsmouth occurs at places in the bluffs here covered by alluvial, loess, and drift materials.

EXPOSURES AT FOLSOM (HINTON STATION), IOWA

In the northwest quarter of Section 29, T. 73 N., R. 43 W.

There are outcrops in the foot of the bluff from north of the village southward about three-fourths mile. They have been described in various Iowa reports.³ Professor Tilton⁴ is of the opinion that the exposure is on beds below the Plattsmouth Limestone, probably in the horizon of the Weeping-water bed. His correlation is thought to be in error.

Highway excavations made below Folsom in 1926 exposed the Cullom Limestone and a few feet of underlying beds which are nearly identical with those at Rock Bluff and near Nehawka. The section includes layers from a few feet above the Cullom Limestone down to the base of the top zone of the Plattsmouth Limestone which outcrops just northeast of the station, rising northward. Excavation made here shows that zone B of the Plattsmouth is 7' or 8' thick.

EXPOSURES EAST OF COUNCIL BLUFFS, IOWA

Formerly there was an outcrop in the Mosquito Creek valley east of Council Bluffs. Udden⁵ gives the location

³ Udden, J. A., *Geol. of Mills and Fremont Counties: Iowa Geol. Survey, Vol. XIII, pp. 35-136, 1901.*

⁴ Tilton, John L., *Missouri Series of the Pennsylvania System of Southwestern Iowa: Iowa Geol. Survey, Vol. XXIX, p. 256.*

⁵ Udden, J. S., *Geology of Pottawattamie County, Iowa: Geol. Survey, Vol. XI, p. 230.*

of this as follows: "On the left bank of Mosquito Creek, near the center of the west line of Section 21, Township 75 North, Range 43 West." He agrees with White⁶ in correlating the beds here with those exposed south of Crescent, Iowa, which means that they seem to be the Plattsmouth Limestone at least in part.

EXPOSURES NEAR CRESCENT, IOWA

These are in the Missouri River bluffs 5 miles north of Council Bluffs. They are about 1½ miles southwest of Crescent, in sections 27 and 34. The beds probably are the same in whole or in part as at Rockport, Nebraska. According to the writer's investigations, they are not so low in the section as has been held by Professor Tilton. They seem to be the Plattsmouth Limestone or older.

Professors White, Udden,⁷ Tilton,⁸ and other geologists have described this section.

FROM JONES POINT TO NORTH OF OMAHA

This is on the Nebraska side of the river.

There is a low sag of the beds between Jones Point and King Hill, i.e., across the bartlett Syncline. The Deer Creek member (Figure 25) and strata up to the Iowa Point Shale outcrop in the lower course of Ervine Creek valley.

SECTION IN THE LOWER PART OF ERVINE CREEK VALLEY

This is at the Larsh place.

1. Calhoun Shale member, about 14':
 - (1). Iowa Point Shale, the basal portion, bluish, argillaceous, 3' to 4'.
 - (2). Meadow Limestone, about 2' 6".
 - (3). Jones Point Shale, in west bank of creek north of road at the Larsh place, about 8'.
2. Deer Creek Limestone member, about 22' to 23' exposed:
 - (1). Ervine Creek Limestone, full thickness in right valley side, part covered, 16' or more well shown.
 - (2). Mission Creek Shale, bluish, argillaceous, 1' to 1' 2".

⁶ White, C. A., *Geology of Iowa*, Vol. I, p. 379, 1870.

⁷ Udden, J. A., *Geology of Pottawattamie County, Iowa*: Geol. Survey, Vol. XI, p. 226.

⁸ Tilton, John L., *Missouri Series of the Pennsylvanian System in Southwestern Iowa*: Iowa Geol. Survey, Vol. XXIX, p. 257, 1920.

- (3). Haynies Limestone, one bed, 1'.
 - (4). Larsh Shale, 1' 6"; basal 6" dark, carbonaceous (Figure 24).
 - (5). Rock Bluff Limestone, about 2' 6"; quite fossiliferous in the basal 6".
3. Tecumseh Shale member, blue, argillaceous, 4' 3" exposed north of the spring on the Larsh place.



FIGURE 25.—Units of the Deer Creek Limestone member on the Larsh place near the mouth of Ervine Creek. The top of the Tecumseh is shown overlain by the Rock Bluff Limestone, Larsh Shale, Haynies Limestone, Mission Creek Shale, and the base of the Ervine Creek Limestone.

There are good exposures of the Cullom Limestone, Ervine Creek Limestone, and associated beds in Radke and Rock Creek valleys and in the bluffs between Ervine Creek and King Hill. Strata from the Cullom Limestone up to and including the Ervine Creek Limestone are shown at King Hill, southeast of Rock Bluff. They rise about 45 feet between this point and Queen Hill which is northeast of Rock Bluff. The Plattsmouth Limestone and the other units up to the Ervine Creek Limestone are well shown along Rock Creek, rising very perceptibly westward in the east flank of the Nehawka

Anticline. The Cullom Limestone outcrops along Rock Creek as far west as southwest of Murray.

QUEEN HILL SECTION NORTHEAST OF ROCK BLUFF

I. Shawnee Formation:

1. Deer Creek Limestone member, about 30':
 - (1). Ervine Creek Limestone, high in bluff, top eroded, 10' to 24' exposed.
 - (2). Mission Creek Shale, bluish gray, 1' 6".
 - (3). Haynies Limestone, gray, massive, 1'.
 - (4). Larsh Shale, bluish above, dark below, 2'.
 - (5). Rock Bluff Limestone, gray, dense, forms large blocks, 1' 6".
2. Tecumseh Shale member, argillaceous to sandy, about 25'.
3. Lecompton Limestone member, about 20' 6":
 - (1). Avoca Limestone, dark gray, forms large blocks, weathers yellowish at places, 2' or more.
 - (2). King Hill Shale, greenish blue, argillaceous to sandy, with some calcareous concretions, about 7'.
 - (3). Cullom Limestone, about 5':
 - a. Limestone, gray, massive, upper surface wavy and pitted in places, forming large blocks, 2' 4". Fusulina, brachiopods, and syringoporoid corals.
 - b. Shale, gray, calcareous, with Campophyllum torquium abundant, 6" to 1'.
 - c. Limestone, with Fusulina throughout and some cup corals in upper portion, 1' 7".
 - (4). Queen Hill Shale, 5' 6"; upper portion bluish, argillaceous; lower portion nearly black and fissile.
 - (5). Big Springs Limestone, cream colored, with many Chonetes granulifer, Productus cora, etc., about 1'.
4. Kanwaka Shale member, bluish, argillaceous, about 7'. This may prove to be the basal portion of the Lecompton and not the Kanwaka.

II. Douglas Formation:

1. Oread Limestone member, about 35' exposed:
 - (1). Plattsmouth Limestone, forms a prominent cliff in the lower part of the bluff, about 27':
 - a. Limestone, massive, weathered yellowish brown, with some chert, 7'.
 - b. Shale, yellowish, calcareous, about 4'.
 - c. Limestone, three divisions separated by shale partings, gray, fairly dense, quite fossiliferous, Fusulina abundant, 16'.
 - (2). Heebner Shale, formerly exposed in north part of section; now covered, 4'+:
 - a. Shale, bluish, argillaceous, 1' or more.
 - b. Shale, fissile, carbonaceous, 3' or more.

- (3). Leavenworth Limestone, blue, one or two beds; formerly exposed in north part of section, now covered, 1' 2".
- (4). Snyderville Shale, top portion formerly exposed in north part of the bluff.

There are numerous exposures between Queen Hill and Plattsmouth in which the strata rise a little faster northward than the river drops southward.

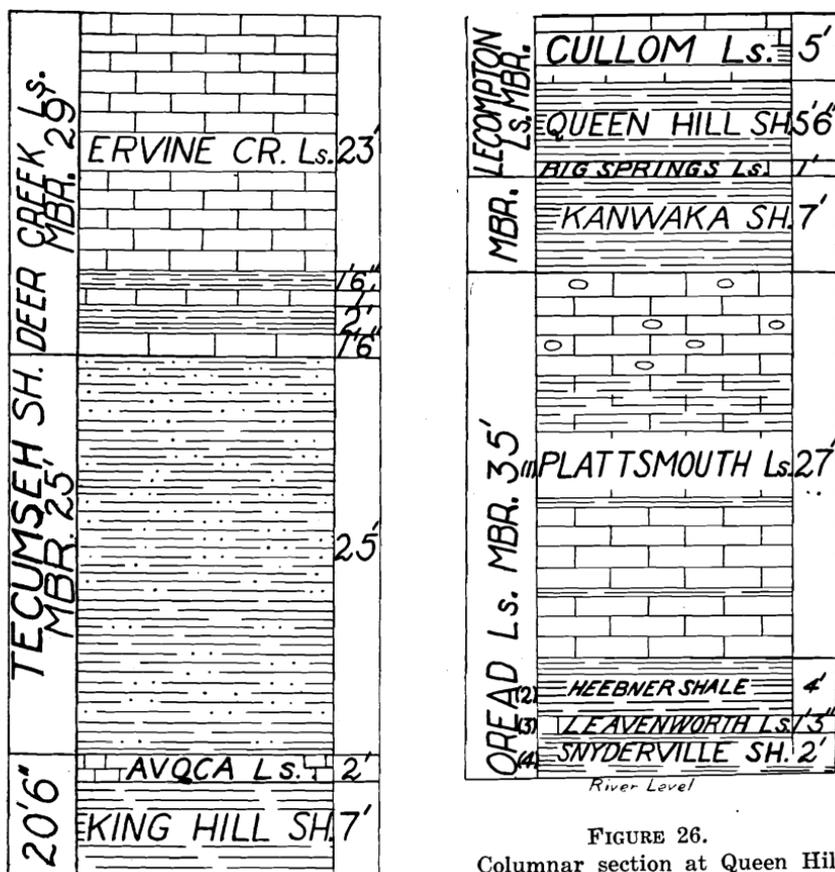


FIGURE 26.
Columnar section at Queen Hill
northeast of Rock Bluff.

SECTION AT PLATTSMOUTH

1. Oread Limestone member, about 45' exposed:
 - (1). Plattsmouth Limestone, well shown high in the bluffs north and south of city, the top eroded, leaving a thickness of 15' to 20' or more. There is a very dense, oolitic zone above the middle of this division.
 - (2). Heebner Shale, exposed below mouth of ravine southeast of the river bridge, but covered in most of the bluff. This is about 3' 6" thick. Its basal half or more is black and fissile.
 - (3). Leavenworth Limestone, two thin beds, exposed at river bridge and southward, dark bluish gray, dense, 1' 3".
 - (4). Snyderville Shale, exposed generally in lower part of bluffs, top bluish, with limestone seams; next lower zone, maroon; basal 3' bluish or greenish blue, argillaceous shale; combined thickness, 12' to 14' one-fourth mile south of bridge; less north of bridge.
 - (5). Weepingwater Limestone, near foot of bluff from south of the river bridge northward to beyond the city water works, about 7':
 - a. Shattered limestone, 6".
 - b. Massive, dense, irregular limestone, weathered buff, 4'.
 - c. Badly weathered, shaly, fossiliferous, limestone or nodular calcareous shale, 2' to 4'. Fauna: *Chonetes granulifer*, many *Ambocoelia planoconvexa*, crinoid joints, etc.
2. Lawrence Shale member, about 10' exposed at foot of bluff. The upper 1' to 2' is bluish gray and argillaceous to calcareous. Next below is a band of massive, reddish, argillaceous shale, thickness probably 4'. This is underlain by a few feet of bluish shale and the Iatan Limestone at or near the river level. Marcou, who made a section here at an early date when the river was very low, states that the reddish shale is underlain by bluish shaly clay with a ferruginous limestone near its top.

The Weepingwater Limestone rises northwestward in the bluffs north of Plattsmouth. It and the reddish shale below are well exposed along the railroad at the water works and north for about one-half mile, beyond which there are no outcrops until the spur of the bluffs is reached, where there is an exposure of doubtful correlation. This outcrop is alongside the railroad and at an elevation apparently below the red shale under the Weepingwater bed. The stone here seems to be in position dipping northeastward. It does not resemble the Weepingwater stone. It may be a mass of the Platts-mouth bed slumped from under the covered bluff above; otherwise it probably is in a horizon below the Weepingwater Limestone.

SECTION NORTHEAST OF BELLEVUE

The exposures here are badly covered. A modification of Meek's ⁹ section made when conditions were more favorable, is as follows:

1. Limestone, dark gray, dense, with some siliceous material and comparatively few fossils; about 2' exposed in bluff at or near the railroad level, from location of old landing and ferry northward about one mile.
2. Shale, bluish and drab, argillaceous, 6'.
3. Limestone, dark gray, siliceous, fossiliferous, 2'.
4. Shale, nearly black, bedded, with 2" seam of coal, 1' 3".
5. Unexposed, 5'.
6. Shale, gray, argillaceous to calcareous, separates into thin pieces, weathers yellowish, 2' 6".
7. Shale, 2' 6"; light gray above; dark gray and fissile below.
8. Shale, light gray to greenish, argillaceous, 2' 5".
8. Limestone, yellowish, soft, in layers, 2' 6".
10. Limestone, gray to bluish gray, massive, dense, earthy, with Fusulina and some embedded oolitic particles, 3'.
11. Limestone, light gray, brittle, quite fossiliferous, separated by shale, weathers yellowish. This division is below the river at mean water level but according to published reports, was observed by Meek and Hayden in 1859 during a very low water stage of the river. They reported its thickness to be 18'. This division occurs at a shallow depth under the river for a considerable distance from the west bank.

The stratigraphic position of these beds has not been determined beyond doubt. Meek correlated divisions 9 to 11 with certain divisions exposed west of La Platte, on a basis of the similarity of stone and fossils. This indicates that divisions 9 to 11 are in the Plattsmouth Limestone. Subdivisions 1 to 8 seem to be in the Lecompton Shale member or in this and the Tecumseh.

THE PAPILLION VALLEY EXPOSURE

In the northwest quarter of section 10, one mile southwest of
Fort Crook

About 4 feet of what seems to be the Plattsmouth Limestone is exposed here at an elevation of 20 feet above the bottom land. The stone is dense, hard, massive, and fossiliferous.

⁹ Meek, F. B., In the U. S. Geol. Survey of Nebr. and Adjacent Territories, p. 89.

ferous. There is evidence that softer layers are covered in the slope below.

Hayden's¹⁰ section, made here years ago, when the beds were better shown and some of them were quarried (modified), is as follows:

1. Limestone, in loose layers, 1' 6" to 2'.
2. Shale, light yellow, indurated, 3".
3. Shale, yellowish, indurated, calcareous, very fossiliferous, 10".
4. Limestone, dense, in layers, quite fossiliferous, 6'.
5. Shale, greenish yellow, 1' 8".
6. Limestone, yellowish, 1' 6".

EXPOSURES AT OMAHA

Soundings made by the Burlington Railroad encountered limestone and shale near the river level much of the distance between Omaha and Childs Point north of Bellevue.

Various wells at Omaha penetrate limestone at or near the river level. At an early date, what may be the Plattsmouth ledge, was exposed about three-fourths mile south of the Union Pacific bridge at Omaha. It is now covered. Hayden¹¹ correlated the beds at this place with those at old Rockport, a few miles northeast of Omaha.

Formerly there was an outcrop of bluish, fossiliferous shale in the foot of the bluffs northeast of Florence, now a suburb of Omaha. Below this shale, near the river level, is limestone probably the same as at Rockport. About 12 feet below the river is a heavy ledge which may be the Weepingwater Limestone.

EXPOSURES AT ROCKPORT

What is thought to be the Plattsmouth Limestone is poorly shown about six miles north of Omaha, at an abandoned place known as Rockport. The outcrop is in the foot of the bluff, between the river and 10 or 15 feet above the lowest bottom land. The stone is dense, dark gray, fossiliferous, and weathers yellowish. Its thickness and stratigraphic relations

¹⁰ Hayden, F. V., U. S. Geol. Survey of Nebr. and Adjacent Territories, p. 38.

¹¹ Hayden, F. V., Final Report on the Geology of the Territories, 1868.

cannot be determined definitely without excavation.

The earliest account of the Rockport exposure is by Major Long who encamped at this place during the winter of 1819-1820. Old residents say that lime has been burned here, part being used at Fort Atkinson, later called Fort Calhoun. Tumble-down kilns evidence the use of stone for this purpose.

Limestone, probably the Plattsmouth, occurs at a shallow depth along the bluff line from Rockport northwestward to Calhoun. This or other Pennsylvanian stone has been encountered in wells in the vicinity of Blair.

THE PLATTE VALLEY CROSS SECTION

This section (Plate III) is based on outcrops along the Platte, in Cass, Sarpy, and Saunders counties. It extends from the Missouri River section to Ashland.

The investigation of this cross section began at Louisville, and extended up-valley to Ashland and eastward to Cedar Creek without much difficulty, i.e., the beds were determined and mapped, however, their exact correlation was not worked out until after the Missouri and Weepingwater cross sections had been made for comparison. It was then observed that the Meadow and Ervine Creek Limestones persist in the Jones Point, Union, and Louisville sections, and correlation was soon made in the Platte section from these key-horizons up to the Howard Limestone and down to the Plattsmouth Limestone. Although this established the position of certain beds along the Platte, it did not account for the units above the Howard, i.e., for the Rock Lake Shale, South Bend Limestone, Cass Limestone, and Plattford Shale, which have not been found elsewhere in the general section, except that the lower ones occur at Jones Point. These higher beds, at the suggestions of the U. S. Geological Survey, are referred to the basal portion of the Scranton member.

The oldest strata of the Platte cross section are exposed in the Nehawka Anticline, the crest of which crosses the Platte valley between 2 or 3 miles west of LaPlatte and Oreapolis.

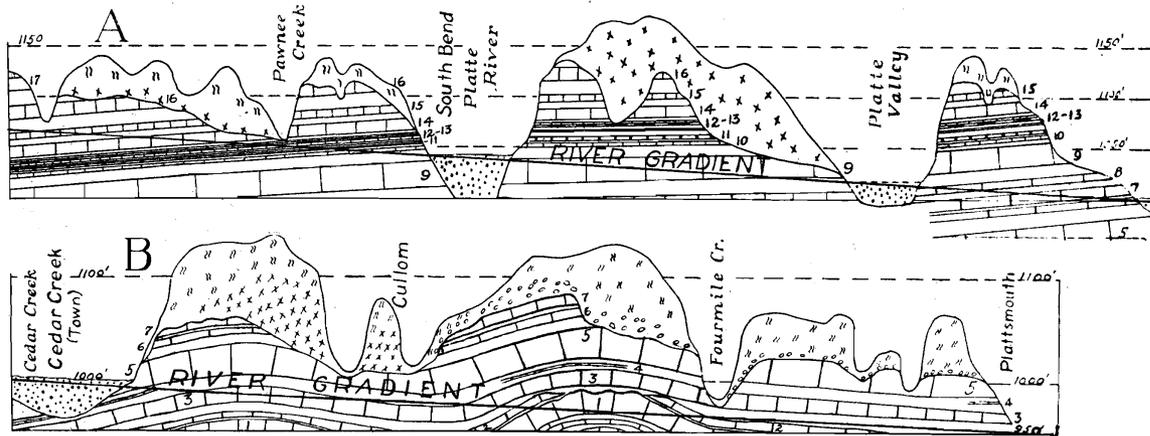


PLATE III.—The Platte Valley Cross Section. A, from south of Ashland to southwest of the town of Cedar Creek; B, from near Cedar Creek to north of Plattsmouth. Limestones: 1, Stanton; 2, Iatan; 3, Weepingwater; 4, Leavenworth; 5, Plattsmouth; 6, Cullom; 7, Avoca; 8, Cedar Creek; 9, Deer Creek beds; 10, Meadow; 11-13, Topeka beds; 14, Howard beds; 15, South Bend; 16, Cass Limestone; 17, Shale and a thin limestone in the White Cloud Shale.

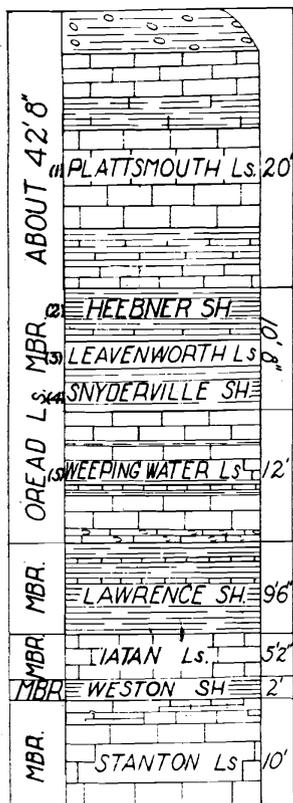


FIGURE 27. — Columnar section, Dyson Hollow, west of LaPlatte, Nebraska.

Anticline, the crest of which is west of Dyson Hollow.

The following sections, arranged in order up-valley, show the details of the Platte cross section.

DYSON HOLLOW SECTION

This is in the bluffs and along Dyson Hollow, north of the Platte, about $1\frac{1}{2}$ miles west of LaPlatte (Figure 27). The beds dip northeastward.

1. Oread Limestone member, about 42' shown:

- (1). Plattsmouth Limestone, about 19' of the middle and lower zones exposed:

The lowest member shown here probably is the Stanton Limestone, which is the Oreapolis Limestone of Condra and Bengtson.

The strata of the Platte section rise from LaPlatte to the crest of the Nehawka Anticline; lower westward for a distance of about 2 miles, then rise slowly to the Richfield Anticline, holding in this latter stretch about the same elevation above the river. There is a low dip from the crest of the Richfield Anticline, to near South Bend beyond which, with some modification, the beds are nearly level to Ashland.

South of the Platte, for a few miles west of its mouth, the valley side is deeply mantled with loess and drift. Recently, however, the basal zone of the Plattsmouth Limestone was exposed here in a highway excavation northwest of Plattsmouth, at an elevation of about 25 feet above the bottom land. The same zone is

shown on the north side of the valley beginning just west of LaPlatte and rising westward in the Nehawka

- a. Limestone, high in the bluff at the abandoned lime kiln, light gray, massive, hard, dense, oolitic with the spherules embedded in a calcareous base, 3' to 5'. Stone jointed, forms large rectangular blocks; upper surface planed smooth by glacial erosion. This stone has been quarried at several places. Its elevation at the highest point on the anticline in the vicinity of Dyson Hollow, is about 70' above the Platte flood plain. Fauna: Bryozoa, brachiopods, pelecypods, and a few corals. There are remnants of beds above this division at places.
 - b. Shale, bluish gray, calcareous, fossiliferous, and weathered limestone, all poorly exposed; thickness a few inches to 2' or more.
 - c. Limestone, light gray, dark gray, and yellowish, depending upon the stage of weathering; usually hard, dense, and massive; with some flint; weathers into subzones; fossiliferous, with *Fusulina*, bryozoa, and brachiopods; total thickness about 9'. The basal 7' is exposed at the upper fall in Dyson Hollow.
 - d. Calcareous shale and limestone layers, exposed under brink of upper fall in Dyson Hollow, quite fossiliferous, about 3' 6".
 - e. Limestone, two bluish beds separated by a thin wavy carbonaceous seam, fossiliferous, 1' 4" to 2'. This is exposed in the foot of the bluff west of LaPlatte and holds the lower part of the upper water fall in Dyson Hollow.
- (2). Heebner Shale, Leavenworth Limestone and Snyderville Shale, about 10' 8":
- a. Shale, 1' to 1' 8"; upper 1' 2" blue, argillaceous; lower 6" black, carbonaceous, with small worm burrows in top portion.
 - b. Limestone, dark blue, massive, 5" to 6".
 - c. Shale, fossiliferous, 1'; upper portion greenish blue, argillaceous; lower portion black; *Ambocoelia planoconvexa*, *Chonetes granulifer*, and *Rhombopora lepidodendroides* common.
 - d. Limestone, dark blue, dense, forms small waterfall, 6".
 - e. Shale, black, fissile, no fossils observed, 10".
 - f. Claystone, bluish, slate-like, jointed, 9".
 - g. Shale, dark, 5' 6"; bedded or slabby above; greenish blue, irregular, and argillaceous below.
- (3). Weeping-water Limestone, 12' or more:
- a. Limestone, gray, massive, 6'; upper surface uneven and weathered yellowish at places; separated by shale seam below middle. This division forms a double waterfall. Fauna: *Composita subtilita*, *producti*, *crinoid joints*, etc.
 - b. Shale, blue to black, bedded, with many *Chonetes granulifer* and *Derbya Crassa* (small), 5" to 6" in Dyson Hollow; thicker in bluffs southwest.
 - c. Limestone seam, dark gray, irregular, with many fenestrated bryozoa, 3" to 6".

- d. Shale, black with gray mottlings, bedded, carbonaceous to argillaceous, 4" to 5". Thicker in bluff southwest.
- e. Limestone, dark blue, massive, with concretionary forms in upper portion; conchoidal fracture; some dark chert at places; with dark shaly streaks along middle; forms large blocks; with crinoid joints, Myalina, and other fossils; thickness, 3' to 3' 6".
- f. Limestone, bluish, weathered nodular, becoming shaly in basal portion, with pelecypods, gastropods, and brachiopods, 1' 6" to 2'. This is the weathered base of "e."

~~2. Lawrence~~ Shale member, 9' 6":

- a. Shale, blue, bedded, mostly argillaceous, with *Derbya crassa* and bryozoa at top, 1'.
- b. Limestone or limy-sandy shale, bedded, not very uniform, 6".
- c. Shale, blue, massive, argillaceous, exposed in Dyson Hollow and bluff, 2'.
- d. Shale, exposed in bluff southwest of Dyson Hollow, reddish, argillaceous, 2'.
- e. Shale, greenish blue, argillaceous, 4'.

~~3. Latah~~ Limestone member, 5' 2":

- a. Limestone, impure, irregular, 4'.
- b. Limestone, dark gray, dense, granular, very hard, forms large blocks, lower surface rough, 1' 2". Fauna: *Fusulina*, bryozoa, pelecypods. This is the same as the basal zone [5(6)] of the member on the North Fork Weepingwater northwest of Nehawka.

4. ~~Weston~~ Shale member, bluish, argillaceous, with bryozoa and brachiopods at the top, 2'.

5. ~~Shanton~~ Limestone member, in ravines west of the mouth of Dyson Hollow, 10' or more exposed; top 2' weathered yellowish, slabby, and somewhat even; the rest is gray and massive, weathering light gray or light buff. The lowest portion exposed is about 12' above the Platte Valley floor.

Correlation. Meek¹ correlated the upper beds of the Dyson Hollow section with the lowest divisions of the Bellevue section, which seems to be well founded. He was not sure of the relation of the Dyson Hollow and Plattsmouth sections, as shown by the following: "With regard to the exact stratigraphic relations of the section seen on the north side of the Platte River, to that just below the town of Platts-

¹ U. S. Geol. Survey, Nebraska and Portions of the Adjacent Territories, p. 92, 1872.

mouth, of course we cannot speak very positively, as the beds cannot be traced into contact.

"Anyone, however, who will compare collections of fossils from these two localities must be at once convinced that the rocks belong to the same series, and must be closely related. Yet it is quite evident that the visible dip of the rocks seen along the north side of the Platte would take them somewhat beneath the Plattsmouth section, though not far below it, as the inclination of the strata here is to the northeastward, while the Plattsmouth exposure is south of east from those mentioned on the north side of the Platte."

Division 1(3) of the Dyson Hollow section is without much doubt the Weepingwater Limestone or basal bed of the Oread member. The lowest portion of it persists in several of the Platte sections, having developed in the transitional nodular shale just below the Weepingwater bed proper from Plattsmouth northwestward. The Lawrence Shale member is much thinner here than in the Weepingwater section, but is about the same as at Plattsmouth. Number 3 is either the Iatan Limestone or part of the Stanton, probably the former. Number 5 seems to be the main portion of the Stanton Limestone. It shows on unconformity at the top.

The exposure in the highway cut northwest of Plattsmouth is correlated as the basal zone of the Plattsmouth Limestone. It is about 25 feet above the Platte Valley floor and is the same as the basal beds exposed at the edge of the bottom land just west of LaPlatte, dipping northeastward.

West of Dyson Hollow and Oreapolis. There are nearly continuous outcrops of the Plattsmouth Limestone and lower beds from Dyson Hollow west for about $2\frac{1}{2}$ miles. In most of this distance, however, the exposures are too badly concealed by colluvial and drift material and the Dakota formation for detailed study.

South of the Platte, except at the spur north of Plattsmouth, in the highway cut northwest of the city, and on Eightmile Creek, there are no outcrops from near the Missouri to $1\frac{3}{4}$ miles west of Oreapolis Station.

SECTION BETWEEN OREAPOLIS AND CULLOM

This is in the bluffs just south of the Burlington Railroad, between $1\frac{3}{4}$ and $2\frac{3}{4}$ miles west of Oreapolis.

1. Tecumseh (?), Lecompton, and Kanwaka members:

- (1). Limestone, the highest ledge formerly quarried in the bluffs southeast of Cullom, about 5' exposed.
- (2). Shale, poorly exposed high in bluffs, greenish blue, argillaceous, about 6'.
- (3). Cullom Limestone, formerly quarried, now badly covered, weathered yellowish, quite fossiliferous, thickness probably 8' or more.
- (4). Slope to Plattsmouth Limestone, covered, 6' or more.

2. Oread Limestone member:

(1). Plattsmouth Limestone:

- a. Limestone, dark gray to light gray, dense, with some chert, fossiliferous, 6' to 22' exposed, the greater thickness being shown in the ravines farthest west where the stone holds small waterfalls.
- b. Shale, blue, argillaceous to calcareous, limy, weathers buff, fossiliferous, 3' 6".
- c. Limestone, dark bluish gray, dense, hard, fossiliferous, 8" to 9".
- d. Shale seam, wavy, dark colored, 0" to 1".
- e. Limestone, dark blue, dense, 5" to 6".

(2). Heebner Shale, Leavenworth Limestone, and Snyderville Shale, 9', more or less:

- a. Shale, blue, argillaceous except some fine sand at top, 2'.
- b. Limestone, weathered, with *Allorisma* and other fossils, 6".
- c. Shale, dark, bedded, part fissile, 8".
- d. Limestone, blue, massive, fossiliferous, with large pelecypods and other fossils, 8" to 9".
- e. Limestone, shaly, shattered, fossiliferous, 4". *Derbya crassa* is a common fossil.
- f. Shale, dark, bedded, weathers yellowish brown, 10" to 1'.
- g. Claystone-limestone, blue, massive, arenaceous, 6" to 7".
- h. Shale, sandy, with ostracods, 1'.
- i. Shale, dark, weathered, 1' 2".
- j. Shale, bluish, argillaceous, 1' 6" or more.

(3). Weepingwater Limestone, about 12':

- a. Limestone, light gray, massive, weathers buff, *Fusulina* common; 3' or more.
- b. Shale seam, argillaceous to calcareous, about 5".
- c. Limestone, massive, weathered yellowish, fossiliferous, 2' 10" or more.
- d. Shale, dark gray, massive, argillaceous to limy, with a thin layer of fossiliferous limestone, 1' 6" or more.
- e. Limestone, bluish, concretionary, massive, irregular, 4' to 5'.

3. Lawrence Shale member, shaly, dark gray above; greenish blue below, thickness about 7' in the east part of the section and about 3' farther west on the anticline. The Iatan Limestone has been eroded away if it was ever deposited here. There is an unconformity at the top of the Stanton.
4. Stanton Limestone member, about 19' exposed:
 - a. Limestone, weathered yellowish, slabby, and somewhat uneven, 2'; top about 21' above railroad and 29' or 30' above river at highest point on the anticline.
 - b. Limestone, massive, nearly solid, with thin shale seams, 14' to 16'.
 - c. Shale, calcareous, 1'.
 - d. Limestone, 9".
 - e. Shale, 4".
 - f. Limestone, 4".
4. Covered slope about 9' to river at a point 2½ miles west of Oreapolis.

The upper beds of this section are poorly shown westward in the bluffs to southeast of Cullom Station, beyond which, to about 2 miles west of the station, there is some topographic evidence of bed rock, probably the Dakota sandstone. From this on, the limestones and shales outcrop intermittently to the location of the following section.

SECTION AT THE SPUR OF THE BLUFF NORTHEAST OF CEDAR CREEK

1. Lecompton Limestone and Kanwaka Shale, 30' or more:
 - (1). Avoca Limestone, basal portion shown.
 - (2). King Hill Shale, badly concealed, a few feet.
 - (3). Limestone, becoming yellowish or sandy at base, about 10'. The upper portion of this is the Cullom bed.
 - (4). Shale, badly covered, 5' 6".
 - (5). Limestone, in seams, bluish, blocky, quite fossiliferous; with *Productus cora* and *Composita subtilita*, 5".
 - (6). Shale, black, fissile, 2'.
 - (7). Shale, bluish, argillaceous, 7' or more.
2. Oread Limestone member, about 30' exposed:
 - (1). Plattsmouth Limestone, about 25':
 - a. Limestone, gray, massive, with dark gray chert near base, about 9'.
 - b. Limestone, gray, in wavy beds, with thin shale partings, 14'.
 - c. Shale, bluish, 4" to 6".
 - d. Limestone, hard, 4".
 - e. Shale, bluish, calcareous, 6".
 - f. Limestone, dark blue, dense, hard, 10" to 1'.
 - (2). Heebner Shale, bluish, argillaceous above; black and fissile below, with thin limestone seams near middle, about 4'.

- (3). Leavenworth Limestone, in two thin bluish beds separated by a shale seam, about 8". The base of this, where best shown, is about 4' above the railroad.

The beds in this section dip perceptibly westward.

THE CARLILE QUARRY SECTION

This is north of the Platte, in Section 25, T. 12 N., R. 12 E. There is a deep mantle of drift and the Dakota formation, the latter being about 40 feet thick at some places. The rusty sandstone and gravel of the Dakota rest upon the eroded surface of the Pennsylvanian beds from above the middle of the Plattsmouth Limestone down to near the base of the Weepingwater Limestone. Section:

1. Oread Limestone member, 37' exposed:
 - (1). Plattsmouth Limestone, the middle and lower zones shown, about 14'. Stone, gray, in wavy beds separated by thin shale seams, with three flagstone layers at base, each 6" to 7" thick.
 - (2). Heebner Shale; top argillaceous; base black and fissile; total, 3' 6".
 - (3). Leavenworth Limestone, blue, about 1'.
 - (4). Snyderville Shale, bluish gray, with calcareous concretions and lime seams, 5' to 6'.
 - (5). Weepingwater Limestone, about 13':
 - a. Limestone, light gray, hard, apparently siliceous, weathers dark gray; top uneven; badly disintegrated at places; thickness, 1' to 4'.
 - b. Shale, nodular limestone and nearly solid limestone, 4¹ or more. This is too badly disintegrated for accurate measurement. Fauna: *Composita subtilita* and other brachiopods.
 - c. Limestone, gray to yellowish, fossiliferous, mostly hard, dense, and massive, 6' or more. This holds waterfalls in the ravines. Its base, altitude about 977', is about 4' above the Platte River.
2. Lawrence Shale member, about 2' exposed.

Between the Carlile Quarry section and the old quarries south of Richfield are a number of poorly defined outcrops on the Weepingwater limestone and beds up to the basal portion of the Plattsmouth limestone, the strata rising slowly westward most of the distance.

RICHFIELD QUARRY SECTION

This is in the Platte Valley bluffs and the abandoned quarries north of the river, in section 29.

1. Tecumseh Shale member, about 23' exposed:
 - (1). Limestone, poorly exposed above east end of the largest quarry, bluish, weathers yellowish, very fossiliferous, about 8". Fauna: *Productus cora*, *Derbya crassa*, etc. about 8'.
 - (2). Shale, badly concealed, bluish green, argillaceous, about 8'.
 - (3). Cedar Creek Limestone, about 8' 2":
 - a. Limestone, weathered yellowish, slabby, 1' 6".
 - b. Limestone, medium dark gray, dense, 4' 6".
 - c. Shale, bluish, 1' 3".
 - d. Limestone, exposed at top of main quarry, dark gray, dense, forms large blocks, 12'.
 - (4). Shale, bluish green, argillaceous, calcareous at top and base, 6'. There is a dark, somewhat carbonaceous band about 1' 6" below the top of this division.
2. Lecompton Limestone member, about 25' 6":
 - (1). Avoca Limestone, about 10' 6":
 - a. Limestone, massive, weathered yellowish, with dark limestone pebbles in top portion, 2'. Fauna: Fossil fragments of different species and several species of small gastropods quite well preserved.
 - b. Limestone, gray, massive or separated as thin irregular beds, 2' to 3'. Fauna: Dwarfed *Fusulina* in lower portion; *Myalina subquadrata* in middle portion.
 - c. Shale, blue, argillaceous to calcareous, fossil fragments, 0" to 6".
 - d. Limestone, dark gray, dense, resembles buhrstone, with poorly defined weathered vertical channels, 2'. Fauna: *Brachiopods*, pinna, etc.
 - e. Limestone, gray, massive, fossiliferous, 4'; shale seam near middle at places; forms large blocks; with many dwarfed *Fusulina*.
 - (2). King Hill Shale, 3' or more:
 - a. Shale, bluish, bedded, argillaceous, 1' 6". Fauna: Fenestrated bryozoa, crinoid joints, orbiculoidea, dwarfed *Chonetes granulifer*, etc.
 - b. Limestone, dark gray, irregular, earthy, 6" to 1'.
 - c. Shale, bluish green, massive, argillaceous, 1'.
 - (3). Cullom Limestone, light gray to medium dark gray, massive, oolitic, not very fossiliferous, forms large blocks, 3' 6" to 5'.
 - (4). Queen Hill Shale:
 - a. Stone, gray to buff, massive, forms large blocks; varies from claystone to very fine-grained sandstone and limestone; thickness about 4' 6".
 - b. Shale, black, fissile, flexible, 1' 10". The top 6" grades upward into (4)a.
 - (5). Big Springs Limestone, two earthy calcareous layers separated by a shale seam, 7". Fauna: *Brachiopods*.
3. Kanwaka Shale member, bluish, argillaceous, crumbly, 6' 6".

4. Oread Limestone member, about 36' exposed:

- (1). Plattsmouth Limestone, about 21':
 - a. Limestone, gray, very massive, forms large blocks, 6' to 7'. This is quite fossiliferous, with *Composita subtilita* as the most noticeable species.
 - b. Limestone, similar to above, but not so massive, with dark chert near the top, 6' or more.
 - c. Limestone, cream colored, soft, 3' or more.
 - d. Shale, calcareous, 5".
 - e. Limestone, cream colored, soft, 2'.
 - f. Shale, calcareous above, fossiliferous at base, 8" to 9".
 - g. Limestone, 7".
 - h. Shale, 6".
 - i. Limestone, dark blue, dense, hard, 10".
- (2). Heebner Shale, bluish and argillaceous at top; most of it black and fissile, 2' 6". This is well exposed in a ravine below the east end of the large quarry.
- (3). Leavenworth Limestone, 1' 6":
 - a. Limestone, dark blue, dense, shatters, with *Productus cora*, 3" to 4".
 - b. Shale, blue, argillaceous, 6".
 - c. Limestone, dark blue, dense, with *Productus cora*, 8".
- (4). Snyderville Shale, blue, argillaceous, 2' or more.
- (5). Weepingwater Limestone, in foot of bluff; best shown at the east side of section 29, about 8' 9" exposed:
 - a. Limestone, dark gray, massive, dense, brittle, 2' 9".
 - b. Shale, calcareous, concretionary, grades into limestone above and below, 2'.
 - c. Limestone, bluish gray, massive, irregular, not very fossiliferous, 2' 6". Altitude of base about 1,009'. This is the same as the zone found at the base of the Weepingwater bed proper west of LaPlatte and Oreapolis.
 - d. Weathered limestone or nodular shale, 1' 6" exposed just above the Platte bottom land. The nodules are bluish limestone, as they are at Plattsmouth and west of LaPlatte and Oreapolis.

Although division 2 seems to represent the Lecompton member, its units are not typical. Number 2 (3) is thought to be the Cullom Limestone in which the middle and lower zones are replaced by sandy-lime rock here referred to the top of the Queen Hill Shale. Number 4 (1) is the Platts-mouth Limestone, yet it is less fossiliferous than at most places. Number 4 (5) is the Weepingwater unit, about the same as at Dyson Hollow.

COMBINED SECTION AT THE ATWOOD QUARRIES ON CEDAR
CREEK ABOUT TWO MILES EAST OF LOUISVILLE

In sections 7 and 18, T. 12 N., R. 12 E. (Figure 28)

1. Scranton Shale member, above quarry in southwest quarter of section 18, T. 12 N., R. 12 E., thickness 24' 6":
 - (1). Plattford Shale, bluish and reddish argillaceous zones, with two fossiliferous limestone layers, 10' to 12' exposed.
 - (2). South Bend Limestone, the upper bed formerly worked in quarry farthest south on Cedar Creek, about 8' 6":
 - a. Limestone, grayish, the flint-bearing zone; fossiliferous, with *Fusulina* and *Rhombopora lepidodendroides* as the main fossils; thickness 1' 4" to 1' 8".
 - b. Shale, bluish, bedded, 1' 8 to 1' 10".
 - c. Limestone, grayish, massive, separated by weathering, with many *Fusulina* and crinoid joints, 3' 4".
 - d. Shale, light to bluish, calcareous, with some weathered seams of limestone, 1' 2".
 - e. Limestone, light gray, one bed, 8".
 - (3). Rock Lake Shale, argillaceous, maroon except a 6" bluish, calcareous band at the top, about 5'.
2. Howard Limestone member, about 15' 6":
 - (1). "Louisville" Limestone, formerly worked in several high-lying quarries, about 11'.
 - (2). Kiewitz Shale, argillaceous to calcareous, quite fossiliferous, 3' 9". This is exposed in the big quarry southwest of the town of Cedar Creek.
 - (3). Church Limestone, blue, dense, fossiliferous, separated as two beds, 1' 4".
3. Severy Shale member, bluish, argillaceous, with a carbonaceous band, quite fossiliferous, 2' to 4'.
4. Topeka Limestone member, 9' to 10':
 - (1). Coal Creek Limestone, blue, forms large blocks, 6" to 7". This has a good many small bellerophons.
 - (2). Holt Shale, bluish, argillaceous to carbonaceous, many fossil fragments in upper portion, 1' 2".
 - (3). DuBois Limestone, bluish, blocky, earthy, 4" to 6".
 - (4). Turner Creek Shale, bluish, fossiliferous, 3' to 4'.
 - (5). Curzon Limestone, buff, in irregular zones, separated by shale seams; fossiliferous; 4' or more.
5. Calhoun Shale member, about 14' 6":
 - (1). Iowa Point Shale, argillaceous to calcareous, very uneven in thickness, 3' or more.
 - (2). Meadow Limestone, massive to slabby, weathered yellowish, about 3' 6".
 - (3). Jones Point Shale, mostly argillaceous, with slabby seams of very fossiliferous limestone in upper portion, 8'.
6. Deer Creek Limestone member, 29' 6":

- (1). Ervine Creek Limestone, top 7' massive; next 2' bluish shale; main portion massive; basal portion with wavy layers separated by thin shale partings; combined thickness about 26'.
- (2). Mission Creek Shale, poorly shown in cut-bank on Cedar Creek, 6".
- (3). Haynies Limestone, about 6" to 8".
- (4). Larsh Shale, bluish gray, 1' 6".
- (5). Rock Bluff Limestone, about 10".

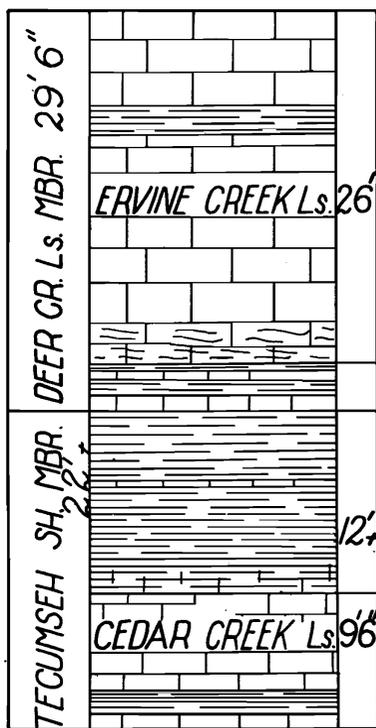
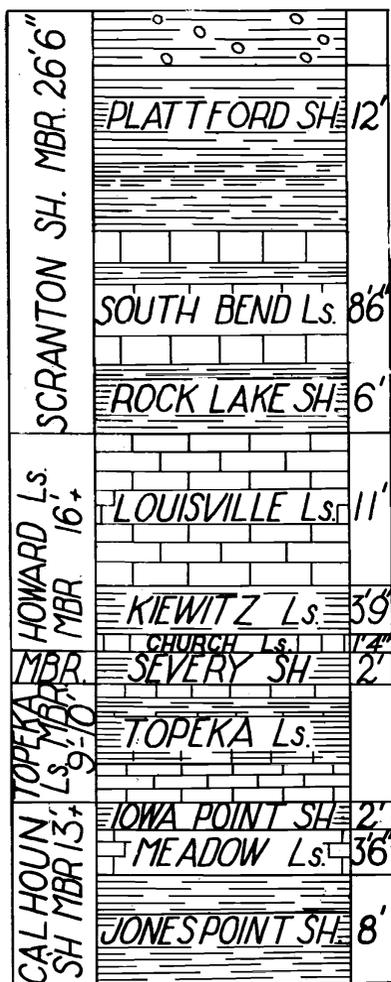


FIGURE 28

Columnar section at the abandoned quarries two miles east of Louisville. The basal shale of the Tecumseh and the Avoca Limestone at the top of the Lecompton are exposed in the creek bank just east of the bridge on the north-south road.

7. Tecumseh Shale member, exposed in cut-bank on Cedar Creek in the southwest quarter of section 7, T. 12 N., R. 12 E., about 29':
- (1). Shale, 12' to 13':
 - a. Shale, argillaceous, with limy seams, about 5'.
 - b. Limestone seam, disintegrated.
 - c. Shale, bluish, argillaceous, jointed, nodular at places, 6'.
 - d. Shale, buff, limy, 2'.
 - (2). Cedar Creek Limestone, at type locality in the southwest quarter of section 7, about 9' 6":
 - a. Limestone, weathered yellowish and slabby, 2' or more.
 - b. Limestone, medium dark gray, dense, massive, not very fossiliferous, 5' or more.
 - c. Shale, bluish, argillaceous, 5".
 - d. Limestone, 4".
 - e. Shale, bluish, argillaceous, 7".
 - f. Limestone, gray, dense, 10" to 1'. This is on the creek bed.
 - (3). Shale, in concealed slope, 6' to 7'.
8. Lecompton Limestone member, the top of the Avoca Limestone unit being exposed in the cut-bank east of bridge on north-south road.

NATIONAL STONE COMPANY QUARRY SECTION

This is south of the Platte, alongside the Burlington Railroad and about 2 miles northeast of Louisville (Figure 29):

1. Calhoun Shale member, about 13' 6" exposed:
 - (1). Iowa Point Shale, base shown at places, bluish, argillaceous, 3' or more.
 - (2). Meadow Limestone, bluish to dark gray, weathering buff to yellowish; forms large blocks, 2' to 3'. This has a good many fossils throughout, and many *Polypora elliptica* on the upper surface.
 - (3). Jones Point Shale, bluish, argillaceous, massive to bedded, with some fossiliferous limy seams, 8'. Fauna: *Derbya crassa*, *Rhombopora lepidodendroides*, *Septopora biserialis*, and other species.
2. Deer Creek Limestone member, 31' or more:
 - (1). Irvine Creek Limestone, about 28':
 - a. Limestone, gray, massive, weathers yellowish brown, 6' to 7'.
 - b. Shale, bluish gray, argillaceous, 1' to 1' 6".
 - c. Limestone, 20' or more; upper portion medium dark gray, dense, with conchoidal fracture, oolitic at top; lower portion dark gray, somewhat earthy, and softer.
 - d. Shale, dark, fissile, 2" to 3".
 - e. Limestone, gray, 10" to 1' or more.
 - (2). Mission Creek Shale, olive colored, fossiliferous, 6" to 8".
 - (3). Haynies Limestone, gray, fossiliferous, 6" to 8".
 - (4). Larsh Shale, 1' 8" to 2'; upper portion bluish, argillaceous; lower portion black, carbonaceous, fissile.
 - (5). Rock Bluff Limestone, gray, with *Derbya crassa* common at the base, 8".

3. Tecumseh Shale member, about 29':
- (1). Mostly shale, 14':
 - a. Shale, bluish, argillaceous, 8" to 10".
 - b. Claystone, light gray-mottled, calcareous, 6".
 - c. Shale and thin claystone seams, 2' 6".
 - d. Claystone, gray, mottled, calcareous, 10".
 - e. Shale, gray, argillaceous, 3' 6".
 - f. Limestone, gray, very fossiliferous, with *Derbya crassa* common, 6" or more.
 - g. Shale, olive green, with yellowish brown mottlings in lower portion, 5' 6".
 - (2). Cedar Creek Limestone, about 9':
 - a. Limestone, bedded, weathered yellowish, 1' 6" or more.
 - b. Limestone, gray, massive, dense, 5'.
 - c. Shale, calcareous, about 4".
 - d. Limestone, 4".
 - e. Shale, calcareous, 8" or more.
 - f. Limestone, dense, forms large blocks, 10" to 1'.
 - (3). Shale, about 6':
 - a. Olive green, argillaceous, a few fossils, 10".
 - b. Black, argillaceous to carbonaceous, 1'.
 - c. Dark gray, 4".
 - d. Bluish green, argillaceous, mottled, 4' or more.
4. Lecompton Limestone member, 12' or more exposed:
- (1). Avoca Limestone, about 12':
 - a. Limestone, dark gray, massive, irregular, with a few limestone pebbles near top, 6".
 - b. Shale, 4".
 - c. Limestone, uncovered in an excavation, gray, weathers buff, 5' 8" or more.
- Division 4(1) here is the same as 2(1) at the Richfield Quarry.

Mr. F. H. Brammer, foreman of the National Stone Co. Quarry, from whom most of the measurements of this section were secured, reports the top of the Cullom Limestone to occur here near the level of the river just north of the quarry.

The upper strata of this section are exposed nearly continuously westward to Louisville. They dip slowly to near the east end of what was called the Stout Quarry, beyond which they are about horizontal to the Murphy Quarry. The base of the Ervine Creek bed is about 28 feet above the railroad at the National Stone Co. Quarry and a little below the track level at the Murphy Quarry.

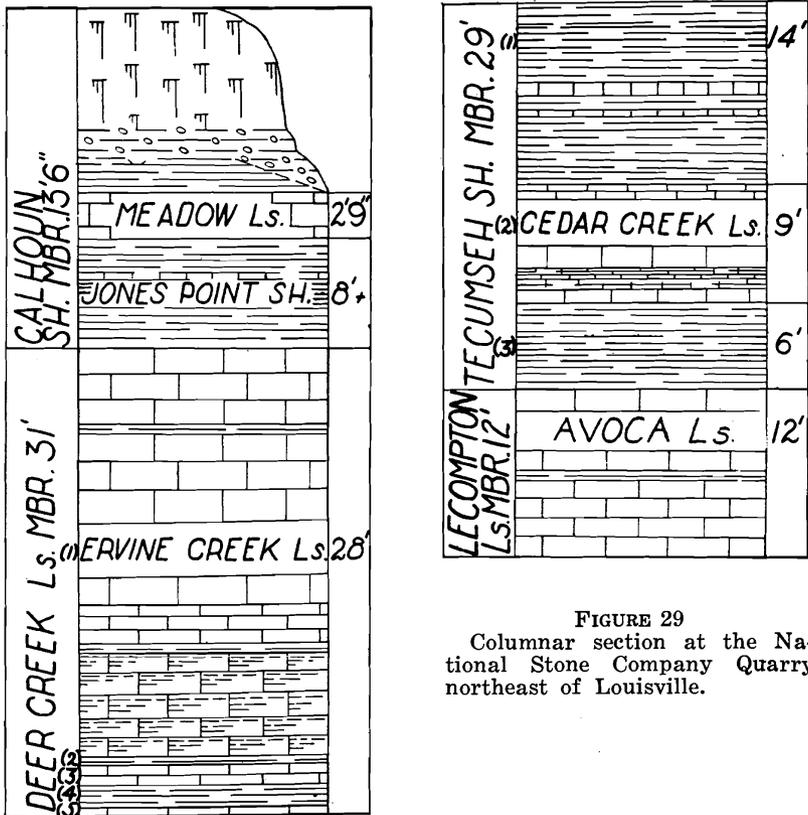


FIGURE 29
Columnar section at the National Stone Company Quarry northeast of Louisville.

SECTION WEST OF MEADOW STATION

This is north of the Platte and alongside the Rock Island Railroad (Figure 30). Section:

1. Scranton Shale member, about 33' exposed:
 - (1). Cass Limestone, poorly exposed in the vicinity of the abandoned Green Quarry, a short distance west of the Kiewitz Quarry.
 - (2). Plattford Shale, formerly exposed, now covered in slope beneath the Cass Limestone, thickness about 14'.
 - (3). South Bend Limestone, formerly quarried in the Green Quarry, about 8' 6".
 - (4). Rock Lake Shale, exposed from top of Kiewitz Quarry westward, 5' 6".

2. Howard Limestone member, 16':
 - (1). "Louisville" Limestone, light gray, slabby in upper 2' 6" to 3'; massive in middle and lower 9'; combined thickness 11' 6".
 - (2). Kiewitz Shale, largely argillaceous, with some calcareous material and many fossils, 2' 10".
 - (3). Church Limestone, weathered brownish, in two layers, the upper portion slabby, 1' 8" to 1' 10".
3. Severy Shale, argillaceous, 2'; lower 7" carbonaceous or coal-like; the rest somewhat arenaceous.
4. Topeka Limestone member, 9' 6":
 - (1). Coal Creek Limestone, blue, one or two beds, weathers rusty, 7" or more.
 - (2). Holt Shale, blue to black, bedded, argillaceous, 1'.
 - (3). Du Bois Limestone seam, 4" to 1'+. Separated by shale seams at places.
 - (4). Turner Creek Shale, blue, with some reddish material in lower portion, argillaceous, bedded, with uneven base, 3' 6".
 - (5). Curzon Limestone and Shale, yellowish rock resembling the Meadow ledge but irregular in thickness and character, 3' to 4'.
5. Calhoun Shale member, about 10':
 - (1). Iowa Point Shale, blue, argillaceous, thickness in west part of Kiewitz Quarry, 1' to 3'.
 - (2). Meadow Limestone, weathers yellowish to brownish, 2' 6" to 3'.
 - (3). Jones Point Shale, blue, 5' 6", with seams of limestone 1' to 1' 2" below the top.
6. Deer Creek Limestone member, 28' exposed:
 - (1). Ervine Creek Limestone, 28':
 - a. Limestone, massive in upper two-thirds; weathers shelly in lower one-third, 5' This division forms the roof of the tunnels used in mining the stone.
 - b. Shale, massive, argillaceous, grayish blue, 1' 6".
 - c. Limestone, gray, massive, 21' 6" quarried. The floor of the quarry which is at the base of the Ervine Creek Limestone is about 11' above the Rock Island Railroad on the bottom land of the Platte.

From not far west of the location of the above section to across the bend in the valley opposite South Bend, the Pennsylvanian beds have been eroded and the Dakota sandstone rests upon their uneven surface down to a few feet above the bottom land. On the south side of the valley, the Ervine Creek Limestone and higher beds continue exposed at places from west of Louisville to near South Bend, the Ervine Creek bed going below the river near the Rock Island bridge on the Platte.

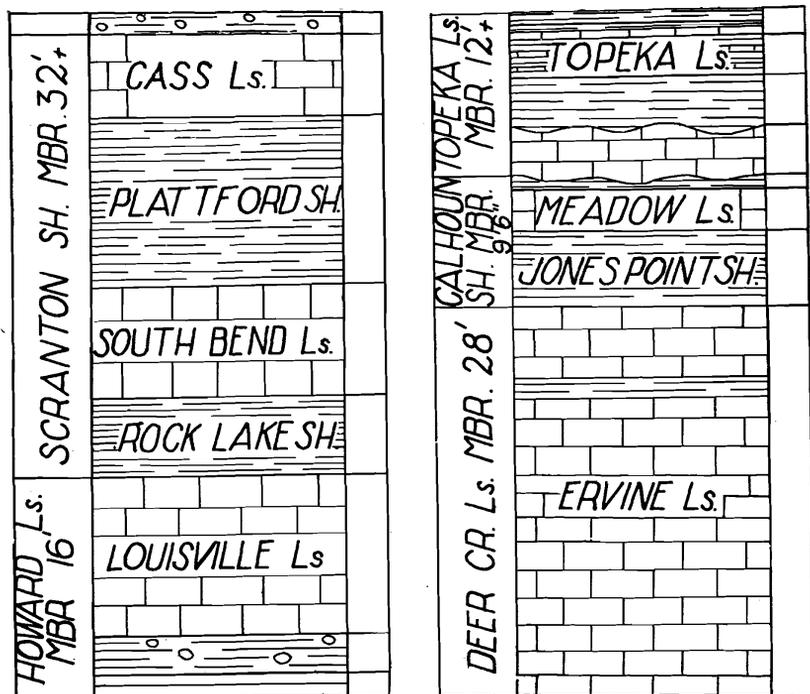


FIGURE 30.—Columnar section at the Kiewitz quarry west of Meadow, Nebraska.

SECTION SOUTH OF THE STATE FISH HATCHERIES

This is across the river northeast from South Bend. There is an uneven mantle of drift and the Dakota formation.

1. Scranton Shale member, 34' or more exposed:
 - (1). Cass Limestone, poorly exposed in part of its thickness from the first ravine southeast of the State Fish Hatcheries southward to near the abandoned quarries. It has free calcite in small fractures and forms large blocks which weather rounded, and lower on the slopes.
 - (2). Plattford Shale, badly covered, mostly maroon and argillaceous. The basal portion is bluish and carries thin seams of calcareous, fossiliferous limestone. The thickness of the division is about the same as at the South Bend Quarry. There are many specimens of *Rhombopora lepidodendroides* in the basal portion.

- (3). South Bend Limestone, about 9'. This extends from near the Fish Hatcheries southward to and through the old quarry. Its upper zone is massive, with many *Fusulina* and cherty concretions. Next below is a calcareous shaly zone. This is underlain by a heavy grayish, oolitic fossiliferous limestone which was the main quarry ledge. Most of the fossils in this zone are fragmentary. The next or basal zone is somewhat slabby. It has many *Ambocoelia planoconvexa* on its upper surface. Among the associated species are *Spirifer kentuckiensis*, *Pugnax osagensis*, *Hustedia mormoni*, *Rhipidomella pecosi* and *Pustula nebraskensis*.
- (4). Rock Lake Shale, 6'; upper 1' bluish; the rest maroon; all argillaceous.
2. Howard Limestone member, practically the same as at the Kiewitz Quarry, 16'. The upper bed, called the "Louisville" ledge, has the biscuit-formed concretions at the top so typical of this zone. The ledge is exposed from the south end of the old quarry northward past the State Fish Hatcheries and Rock Lake. The middle and lower units of the Howard are covered at most places.
3. Slope to the river. Divisions down to below the Meadow Limestone are in this interval, but badly obscured by talus from above. The top of the Ervine Creek Limestone of the Deer Creek member is near the river level at the south end of the section.

ROCK LAKE SECTION

Based on outcrops in the ravines and bluffs at Rock Lake in Section 3, T. 12 N., R. 10 E.

1. Scranton Shale member, 7' shown:
- (1). South Bend Limestone, 1' of the base exposed in a ravine.
 - (2). Rock Lake Shale, about 6':
 - a. Bluish, argillaceous, 2'.
 - b. Dark maroon, 1'.
 - c. Greenish, sandy, 6".
 - d. Maroon, 8".
 - e. Calcareous, about 2'.
2. Howard Limestone member, outcrops in the main ravine north of Rock Lake and northward; also at places southeastward to beyond the State Fish Hatcheries, about 14' 6":
- (1). "Louisville" Limestone, 9' 8"; top 2' 8" light gray, slabby, thin bedded, grading upward into limy shale; main portion light bluish gray, firm, massive, separated into beds, thickness about 7'. This forms a small waterfall in a ravine. Fauna: *Composita subtilita*, *Fusulina*, *Marginifera splendens*, and many other species.
 - (2). Kiewitz Shale, greenish blue, with calcareous nodules and many fossils; weathers clayey, 2' 6" to 3'. This is characterized by the abundance of *Chonetes verneuillianus* and the presence of

Lophophylum profundum. There are a good many crinoid joints, several bryozoa, and brachiopods, including *Spirifera cameratus* and *Productus semireticulatus*.

- (3). Church Limestone, dark bluish gray, weathers light gray and uneven; quite fossiliferous, showing fenestrated bryozoa, *Chonetes verneuillianus*, *Composita subtilita* (large form), and other brachiopods, 1' 6".
3. Severy Shale member, 2' 9":
 - (1). Shale, grayish blue, bedded and argillaceous, 2'.
 - (2). Shale, carbonaceous, coal-like, 9".
4. Topeka Limestone member, 5' 8" exposed:
 - (1). Coal Creek Limestone, 1' 8", zones:
 - a. Limestone, blue, weathers dark gray, hard, tough, brittle, dense, 6" to 7".
 - b. Shale, bedded, 6".
 - c. Limestone, dark blue, with some earthy material, 8"; weathers gray; fossils white, mostly crinoid stems and brachiopods.
 - (2). Holt Shale, about 4' exposed:
 - a. Bluish, fissile, weathers brownish, 1' to 1' 2".
 - b. Sandy, weathers light brown, 10" to 1'.
 - c. Blue, argillaceous, bedded, 2' exposed. The top of this is 3' or 4' above the surface of Rock Lake.

The beds at Rock Lake have a low dip southward, lowering about 7 feet within one-half mile, beyond which they are nearly level to the State Fish Hatcheries.

THE SOUTH BEND QUARRY SECTION

This is 1¼ miles northwest of South Bend, in the southwest quarter of Section 9, T. 12 N., R. 12 E. The Burlington Railroad operates this quarry on the Howard, South Bend (Figure 31), and Cass limestones which are exposed northward to Pawnee Creek valley and southward towards South Bend.

1. Scranton Shale member, 42' 8" exposed:
 - (1). Cass Limestone, "Ashland Limestone," 11' to 12':
 - a. Massive, bluish, 1'.
 - b. Weathered and shaly, 6" to 1'.
 - c. Bluish, resembling lithographic stone, bedding irregular, 3' to 4'.
 - d. Bluish gray, hard, compact, with calcite, bedding not very distinct, about 6'. The basal 5" of the ledge, which is dark blue, separates quite uniformly. The Cass is quite fossiliferous throughout, but good specimens are not easily obtained.

- (2). **Plattford Shale, 15' to 16':**
- a. Shale, 1' 6"; upper portion blue, argillaceous; middle 3" to 6" or more carbonaceous, becoming fissile when dry; lower portion blue and very fossiliferous. Fauna: *Composita subtilita*, *Spirifer cameratus*, crinoid joints, *Rhombopora lepidodendroides*, several species of fenestrated bryozoa and other species.
 - b. Limestone, dark blue, brittle, fossiliferous, breaks into small blocks which shatter, 2" to 4".
 - c. Shale, very fossiliferous, 0" to 2".
 - d. Limestone, massive, dark blue, forms small blocks which shatter into fine debris, 8" to 10". Fossils light colored. At places this limestone unites with the thin bed above forming one ledge.
 - e. Shale, or slabby stone with a few pebbles; weathers rusty, probably not very persistent, 6".
 - f. Shale, bluish to bluish gray, argillaceous, 2' to 2' 6".
 - g. Shale, maroon, massive, quite calcareous, 7' to 8'.
 - h. Shale, purple, massive, with two or more limestone seams, 3' to 4'. There are many *Rhombopora lepidodendroides* in a bluish band at the base of this division.
- (3). **South Bend Limestone, 9' 8" or more:**
- a. Limestone, massive, with large chert bodies; forms large blocks, 2' 10". Chert bodies, 2" to 5" across, forming a zone 6" to 8" below the top of the bed. Fauna: Many *Rhombopora lepidodendroides* occur on the upper surface. *Fusulina* and brachiopods are scattered throughout.
 - b. Shale, bluish to bluish gray; average thickness, 10" to 1'.
 - c. Limestone, oolitic, the building stone division, 5'. This weathers along the middle, forming a shale seam 2" to 4" thick at places, but the freshly quarried rock is solid.
 - d. Shale, a seam on weathered surfaces, but not shown in new openings, 3".
 - e. Limestone, massive, quite fossiliferous, not very hard, 8" to 10".
- (4). **Rock Lake Shale, 6':**
- a. Bluish, argillaceous, 1'.
 - b. Maroon, tough, argillaceous, with some calcareous bodies in the basal portion, 5'.
2. **Howard Limestone member, 12' or more exposed:**
- (1). "Louisville" Limestone, 10' or more; top 1' 6" to 2' light gray, with some clay and wavy bedding; the remainder bluish, gray, massive, dense, with free calcite, weathers light gray, 8' 6". This is the main quarry stone. Its base is at the level of the railroad which is about 14' above the Platte River.
 - (2). Kiewitz Shale, blue, about 2' shown in the railroad gutter.

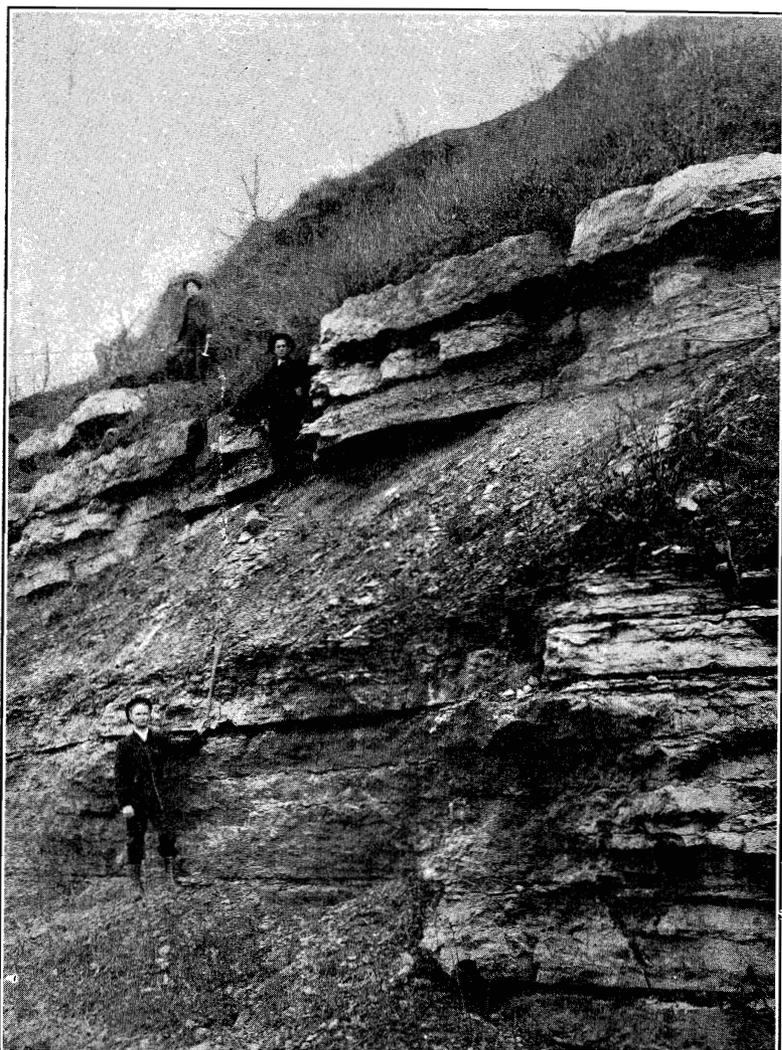


FIGURE 31.—The South Bend Limestone, Rock Lake Shale, and “Louisville” Limestone at the South Bend quarry, named downward.

Between Pawnee Creek and the spur east of Ashland, except at the mouth of Salt Creek where the South Bend ledge is exposed at the railroad level, the Dakota Sandstone occupies

a low position in the bluffs and there are no exposures of the Pennsylvanian beds. The Cass Limestone outcrops in the ravines south of Salt Creek about one mile east of Ashland. This is south of the main line of the Burlington Railroad.

ASHLAND SECTION

This is made on exposures in a ravine and the railroad cut southwest of the Burlington station. There is a heavy mantle of drift and the Dakota sandstone.

1. **Scranton Shale member**, 41' or more of the lower portion exposed:
 - (1). Shale, dark, fissile, with some very fine sand, weathering brownish, 4' 6". Formerly this was well shown in the south bank of the abandoned railroad cut, but it is now covered at most places. Yet higher Scranton strata probably occur under the Dakota in the hills above.
 - (2). Limestone, in railroad cut, dark bluish gray, massive, jointed at right angles, compact, with some free calcite and pyrites of iron, weathers light gray, 1' 2" to 1' 6". This has a low dip westward. Fauna: Small *Fusulina*, *Chonetes granulifer*, *Spirifer cameratus*, gastropods, and pelecypods.
 - (3). Shale, poorly shown in base of abandoned railroad cut and in the ravines, largely argillaceous, 12'. The upper 2' to 3' is bluish. About 8" to 10" at the base is bluish green and the remainder is maroon.
 - (4). **Cass Limestone**, "Ashland Limestone," exposed in ravine, weathered into zones, 10':
 - a. Limestone, weathered slabby and dark buff, 9". Fauna: *Productus cora*, *Ambocoelia planoconvexa*, and *Astartella*.
 - b. Limestone, grayish, 4' 3"; upper 10" to 1' blocky; middle massive; basal portion weathered into platy lenses. Fauna: Many *Fusulina* and a few specimens of *Spirifer cameratus*.
 - c. Limestone, weathered light gray and shaly, 1' 8". Fauna: *Spiriferina kentuckiensis* at top; a zone of *Ambocoelia planoconvexa* 6" from top. *Spirifer cameratus* and *Chonetes granulifer* common.
 - d. Limestone, bluish gray, with thin shale partings, 1' 9". Fauna: Bryozoa quite plentiful.
 - e. Shale, lavender, 6". Fauna: *Marginifera splendens*, *Chonetes granulifer*, *Spirifer cameratus*, *Productus cora*, *Hustedia mormoni*, and many crinoid joints.
 - f. Limestone, shaly to nodular, thin bedded, with few fossils, 10".
 - (5). **Plattford Shale**, in the ravine, about 12', with the basal 1' to 2' covered. Much of this shale is maroon, massive, and argillaceous, modified by arenaceous-calcareous seams and calcareous bodies arranged more or less in horizontal layers.

- (6). South Bend Limestone, top exposed on the bed of Salt Creek at the abandoned mill site and northeast of the Burlington Railroad station.

THE WEEPINGWATER CROSS SECTION

This extends through southern Cass County and part of northern Otoe County. There are many favorable outcrops for study. The valley crosses the Nehawka Anticline, Bartlett Syncline, Redfield Anticline, and the Thurman-Wilson Fault if it extends this far southwest. Strata from the Stanton Limestone to the base of the Admire member outcrop, making the greatest stratigraphic range of any small area in Nebraska. The oldest beds exposed are on the Nehawka Anticline, and the youngest occur south of Weepingwater Valley southeast of Union.

The strata rise northwestward on the Redfield Anticline which passes through Jones Point and Union, drop a little in the Bartlett Syncline west of Union, lift very perceptibly just east of Nehawka, and yet higher on the crest of the anticline northwest of Nehawka, beyond which they lower gradually to Wabash.

The key limestones are exposed as follows: The Dover, Tarkio, and Emporia along the south side of the Weepingwater Valley southeast of Union; Coal Creek, Meadow, and the top of the Ervine Creek at Union; Howard, Coal Creek, Meadow, and the top of Ervine Creek on Coal Creek north of Union; Deer Creek beds and the Cullom northeast of Nehawka; Plattsmouth, Leavenworth, Weepingwater, Iatan, and the top of the Stanton on the North Branch Weepingwater northwest of Nehawka; Cullom, Plattsmouth, Leavenworth, and the Weepingwater at the Snyderville Quarry west of Nehawka; Deer Creek beds and the Cedar Creek Limestone, two to four miles east of Avoca; Deer Creek beds, Cullom, and the Plattsmouth Limestone in the vicinity of Weepingwater; Coal Creek, Meadow, and the top of the Ervine Creek southeast of Wabash.

The Weepingwater Valley cross section is shown by Plate IV. Following are descriptions of detailed sections of some of the principal outcrops from west to east on the cross section.

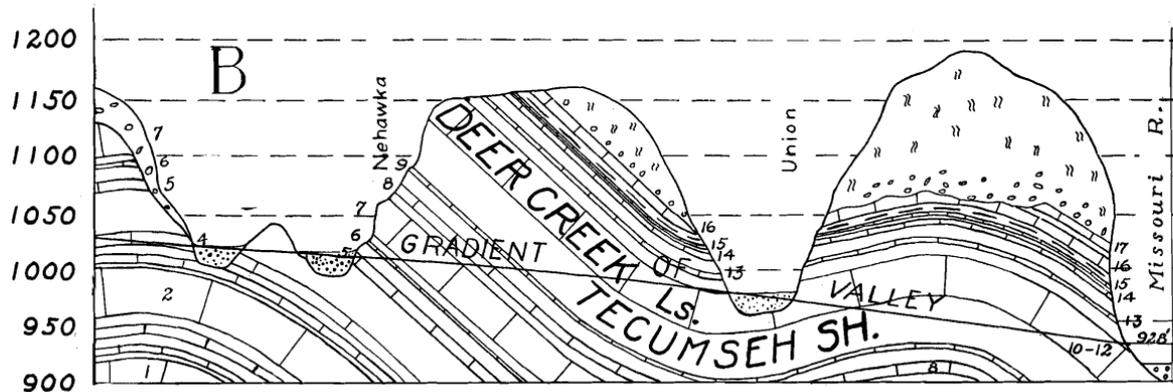
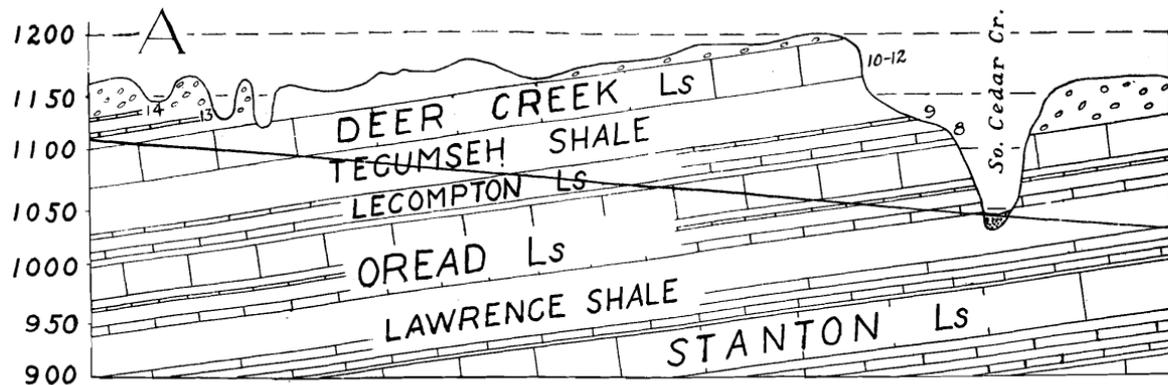


PLATE IV.—The Weepingwater Valley cross section from south of Wabash to the Missouri. Limestones: 2, Stanton; 3, Iatan (not numbered); 4, Shoemaker; 5, Weepingwater; 6, Leavenworth; 7, Plattsmouth; 8, Cullom; 9, Avoca; 10-12, Deer Creek beds; 13, Meadow; 14-15, Topeka beds; 16, Howard; 17, South Bend.

ELMWOOD EXPOSURE

There is an obscured outcrop of limestone and shale in the lower part of a cut-bank of the creek just north of the road leading east from Elmwood. The limestone of this is about five feet above the creek bed at an elevation of 15 feet or more below the depot at Elmwood. It is bluish, dense, and weathers yellowish brown. The shale below the limestone is bluish and argillaceous. The exposure seems to be in the lower Scranton.

No well-defined outcrops have been found between Elmwood and Wabash, yet there is topographic evidence of the presence of Pennsylvanian bed rock at places.

COMBINED SECTION SOUTHEAST OF WABASH

(Based on exposures in the cut-banks and ravines.)

1. Topeka Limestone member:

- (1). Coal Creek Limestone, exposed at the forks of a ravine near west side of section 36. Debris of this ledge is found in the slopes at a few places. The stone weathers yellowish and shatters; thickness exposed, 1' to 2'. Other units of the Topeka member may occur in the covered slope.

2. Calhoun Shale member, 21' exposed:

- (1). Iowa Point Shale, in the ravines south of Weepingwater Creek, bluish, argillaceous, about 10'.
- (2). Meadow Limestone, under wagon road bridge south of Wabash (top 18' below railroad station), at cut-bank farther east, and in ravines, 5' or more including the transition beds and a non-persistent bed:
 - a. Limestone, dark gray, rotted, slabby, very fossiliferous, 2'. Fauna: *Polypora elliptica*, *Polypora submarginata*, *Chonetes granulifer*, *Rhombopora lepidodendroides*, and other species.
 - b. Limestone, bluish, massive, weathers buff to gray, shatters, contains some free calcite; forms small fall in ravine, 1' 10" to 2' 2". Fauna: Crinoid joints, a few pinna and brachiopods.
 - c. Shale or rotted limestone, weathers buff, probably not persistent, with some fossils, 8".
 - d. Limestone, weathers brownish, impure, massive, not persistent, 1' 10" at one place.
- (3). Jones Point Shale, 6' in cut-bank, bluish, bedded, argillaceous, with about 6" or more of dark, fissile material 2' below top.

Limestones and shales are exposed in the south banks and slopes of the Weepingwater from the cut-bank southeast of

Wabash eastward about one-half mile. Next is a stretch of covered slope in which the bench-form of the valley side indicates the presence of rock. About one-quarter mile west of the east side of section 35 is a small exposure low in the bank of Weepingwater Creek. The section based on this and an outcrop in a ravine south is as follows:

1. Calhoun Shale member, 13' 4" exposed:
 - (1). Meadow Limestone, bluish, massive, brittle, weathering rusty and shaly, forms large blocks, 2' 4". Fauna: *Fusulina*, *Polypora elliptica*, *Polypora crassa*, crinoid joints, etc.
 - (2). Jones Point Shale, about 11':
 - a. Bluish, argillaceous, 2' 9".
 - b. Nearly black, fissile, blocky, 1'.
 - c. Dark bluish, bedded, argillaceous, fossiliferous, 8'.
2. Deer Creek Limestone member:
 - (1). Ervine Creek Limestone, 5' 10" exposed:
 - a. Limestone, forms small waterfall in ravine; dark gray, weathers into three beds with shale-like partings, fossiliferous, jointed north-south, east-west, and north-west-south-east, thickness about 4'.
 - b. Shale, bluish to black, fossiliferous, about 2'; upper portion argillaceous; basal 6" black.
 - c. Limestone, in bank of Weepingwater north of the small water fall, bluish, bedded, massive, forms large blocks, fossiliferous, 8".
 - d. Limestone, 1' 2"; yellowish, forms large blocks 4" to 6" thick. The blocks have a ringing sound when struck with a hammer. The stone is quite fossiliferous. This division, which is on the bed of Weepingwater Creek, grades downward into yellowish disintegrated limestone.

Eastward from the Wabash section, the Ervine Creek Limestone forms rather prominent rock benches to one mile beyond Weepingwater on the north side of the valley, and to about 2½ miles west of Nehawka on the south side of the valley, beyond which, to Nehawka, it has been eroded away on the crest of the Nehawka Anticline. The Ervine Creek bed is the high rim rock well shown and extensively quarried in the vicinity of Weepingwater where its top zones have been removed by glacial erosion. The middle zone is dense. It produces very large blocks on the steep valley sides (Figure 32).



FIGURE 32.—Blocks of the Ervine Creek Limestone at Weepingwater.

The Avoca Shale, Cedar Creek Limestone, King Hill Shale, Cullom Limestone, and Big Springs Shale are in the slopes at Weepingwater, between the Deer Creek and Oread members and show eastward for a distance of 4 or 5 miles. The Plattsmouth Limestone forms the rapids southwest of Weepingwater and becomes prominently exposed in both sides of the valley to Nehawka where it dips eastward under the younger beds in the east flank of the Nehawka Anticline.

CASCADE CREEK SECTION ONE MILE SOUTHEAST OF WEEPINGWATER

1. Deer Creek Limestone member, the rim-rock, well shown at quarry in the north half of section 12:
 - (1). Ervine Creek Limestone, about 19' exposed in the following zones:
 - a. Limestone, light gray; forms small rounded wedge-edged blocks; quite fossiliferous; crinoid joints common. Part of this bed has been removed by erosion; thickness remaining, 1' to 2'.
 - b. Limestone, weathered yellowish, disintegrated, 1'.
 - c. Shale, bluish, argillaceous, 5" to 7".
 - d. Limestone, gray, badly weathered above and below, part oolitic; with irregular cherty concretions in upper portion, 1' 6".

- e. Limestone, yellowish, badly weathered, fossiliferous, with shale partings, 5' 6".
 - f. Limestone, dark gray, one bed, brittle, with cream colored chert, 9" to 1' 1".
 - g. Shale, light blue, argillaceous, with poorly preserved fragmentary fossils such as *Spirifer cameratus* and *Rhombopora lepidodendroides*, 4" to 6".
 - h. Limestone, dark gray, compact, with some free calcite; chert at top; 7' to 8' quarried. This division is a few feet above the base of the Ervine Creek Limestone, the lower zones being covered.
2. Tecumseh Shale member, in cut-bank south side of Cascade Creek, in bluish gray and maroon bands, part sandy, about 32'. The Cedar Creek Limestone, 8' above the base, is 2' to 3' thick.
 3. Lecompton Limestone member, 19' 9":
 - (1). Avoca Limestone, poorly exposed, 1' +.
 - (2). King Hill Shale, in greenish and maroon bands, about 8'.
 - (3). Cullom Limestone, gray with buff stains; shaly along middle which has many specimens of *Campophyllum torquium*, 5' 9".
 - (4). Queen Hill Shale, blue above, black below, 4' or more.
 - (5). Big Springs Limestone, 1' +.
 - (6). Doniphan, or Kanwaka Shale (?), 4' to 5'.
 4. Oread Limestone member:
 - (1). Plattsmouth Limestone, 4' exposed above creek bed, but a much greater thickness is shown farther east near the mouth of the creek.

The Cullom Limestone is closer to the Plattsmouth in this section than at most places, and the Kanwaka Shale is either very thin or absent.

SOUTH CEDAR CREEK SECTION

This is two miles northeast of Weepingwater, in sections 29, 30, 31, and 32.

1. Lecompton Limestone member, position indicated by debris in ravine in the east half of section 30; thickness (?).
2. Oread Limestone member, 40' or more exposed:
 - (1). Plattsmouth Limestone, upper portion eroded along valley, the zones remaining well shown, 18' to 20'.
 - (2). Heebner Shale, in northeast quarter of section 31, thickness 4' 6" to 5'; upper 1' 6" bluish, calcareous; basal portion black, fissile.
 - (3). Leavenworth Limestone, blue, massive, blocky, brittle, weathers gray, 1' 8".
 - (4). Snyderville Shale, in the northwest quarter of section 32, thickness 11'; upper portion bluish, argillaceous, calcareous; lower portion maroon, argillaceous.
 - (5). Weepingwater Limestone, well shown above creek bed at foot of cut-bank in section 32; grayish, massive, forms large irregular

blocks, 5' or more; basal portion weathered, showing many specimens of *Ambocoelia planoconvexa*.

3. Lawrence Shale member, 4' exposed; top argillaceous to calcareous, weathered grayish; lower portion maroon, argillaceous.

On the north side of the valley, extending from a little more than one mile east of Weepingwater to near Nehawka, is a poorly defined rock bench developed on the Plattsmouth Limestone, but eroded through to the Weepingwater and older strata at places. The Plattsmouth Limestone has been worked at the Swede Quarry west of the mouth of South Cedar Creek, at the Snyderville Quarry in Section 10, T. 10 N., R. 12 E., and at a few other points.

SNYDERVILLE QUARRY SECTION

In the southeast quarter of Section 10, about 3 miles west and 1 mile north of Nehawka.

1. Lecompton Limestone member, 7' or more exposed:
 - (1). Cullom Limestone, poorly shown at one point above the quarry opening. Stone light gray; thickness (?), specimens of *Camphylum torquium* are common.
 - (2). Queen Hill Shale, not well exposed, grayish, calcareous, with bands of blue, maroon, and yellow, 4' 4".
 - (3). Big Springs Limestone, light gray, weathers buff, forms fine debris, quite fossiliferous, 6" to 1'.
2. Kanwaka Shale (?), with three thin seams of impure limestone near the middle, 5'. This shale is bluish and argillaceous. The stone weathers buff to yellowish. The upper seam has abundant specimens of *Productus cora*, and other brachiopods, and some gastropods. The middle zone has several kinds of fossils and the basal one is rich in pelecypods. This division may prove to be the Doniphan Shale in the Lecompton rather than the Kanwaka.
3. Oread Limestone member, 50' or more:
 - (1). Plattsmouth Limestone, forms main part of the quarry face, 26' 6":
 - a. Limestone, average thickness 4' or more:
 - (a). Limestone, dark gray, weathered into many nodular forms which resemble concretions, 6". The nodules are one-fourth inch or more in diameter. Fauna: Several genera of small gastropods.
 - (b). Limestone, bluish gray, massive, weathers buff; with dark cherty concretions in upper portion; forms large blocks; 3' to 4' 7"; lower portion weathered slabby at

places. Fauna: Crinoid joints, *Ambocoelia planconvexa*, *Composita subtilita*, *Allorisma terminale*, *Pinna* sp., and other fossils.

- b. Weathered limestone and shale, dark gray to buff, upper surface uneven, exposed edge irregular, forming re-entrant on weathered quarried surface, 4' 7"; upper portion, calcareous and quite fossiliferous; middle portion with some carbonaceous material at places; basal portion brownish to black, carbonaceous shale. On nearly fresh exposures much of division (b) probably would be nearly solid rock. Fauna: Many species of brachiopods, mollusca, and bryozoa. *Ambocoelia planconvexa* very common in the upper portion; *Composita subtilita* occurs throughout. *Pugnax osagensis* and *Dielasma bovidens* occur in good numbers well preserved. Some *Fusulina*, *Hustedia mormoni*, *Derbya bennetti*, and *Derbya crassa* are found. A thin crust of the base carries many ostracods.
- c. Limestone, dark gray, massive, dense, semi-crystalline, with conchoidal fracture, 2' 2", more or less. Fauna: *Fusulina*, crinoid joints, Echinoid spines, and *Spirifer cameratus* common.
- d. Shale, bluish or gray, mostly argillaceous, fossiliferous, 1' 8". The fossils are crushed. Crinoid columns are common in the upper portion.
- e. Limestone, light gray, massive, with chalky appearance, forms very large blocks, 4' to 4' 5". Fauna: Many *Fusulina*.
- f. Shale and weathered limestone, mostly dark gray, argillaceous to calcareous, 6" to 1'. Fauna: *Spirifer cameratus* (common); *Marginifera kansasensis* and *Fusulina* very common.
- g. Limestone, dark gray, massive to unevenly bedded, irregularly jointed, compact, brittle, with considerable free calcite, 9'; upper 3' with two zones of chert. Thin seams of clay may occur at places in the stone below the chert. Fauna: Many horn corals in basal portion; *Fusulina* rare and more slender than those in the higher zones; brachiopods common. There are a few specimens of *Entiletes hemiplicata*.

The lowest portion of the Plattsmouth Limestone exposed in the quarry, is at an altitude of about 1,050'. The base of the unit is shown at an elevation of 1,040' in a ravine to the east where the beds have slumped.

- (2). Heebner Shale, along Heebner Creek east of quarry, 6'; upper 3' bluish with a thin band of maroon; basal 3' black and fissle.
- (3). Leavenworth Limestone, along Heebner Creek, blue, brittle, massive, one or two beds, forms rectangular blocks, 1' 4".
- (4). Snyderville Shale, along Heebner Creek, bluish above, maroon below, massive, argillaceous, 11' to 12'.
- (5). Weepingwater Limestone, forms small waterfall in Heebner Creek, 5' or more. Stone light bluish gray, massive in upper

portion, slabby below, and somewhat shaly along the middle; altitude of top about 1,020'. Fauna: Crinoid joints, brachiopods, bryozoa, etc.

4. Lawrence Shale member, 4' to 5' shown along Heebner Creek, below which is a covered slope to Weepingwater Creek.

The Deer Creek beds outcrop high in the upland southwest of the Snyderville Quarry where they turn southward and westward into the valley of the South Branch Weepingwater Creek to near Avoca.

SECTION ON SOUTH BRANCH WEEPINGWATER CREEK
BETWEEN TWO AND FOUR MILES EAST OF AVOCA

1. Deer Creek Limestone member, 25' or more exposed:
 - (1). Ervine Creek Limestone, quite well shown at the bridge crossing the South Branch Weepingwater two miles east of Avoca where its base is 25' above the creek bed. Here and at places east for a distance of three miles the upper and middle zones are eroded away, yet, enough of the division remains to form a well defined rock bench in the valley. Some of the best exposures are along the valley in sections 33, 34, and 35, and for about one-half mile into Otoe County.
 - (2). Mission Creek Shale, poorly exposed, 1' or more.
 - (3). Haynies Limestone, one bed, 1'.
 - (4). Larsh Shale, blue to dark, argillaceous above, carbonaceous below, about 2'.
 - (5). Rock Bluff Limestone, bluish gray, one or two massive beds, 1' 6".
2. Tecumseh Shale member, 38' or more exposed:
 - (1). Shale, about 20' exposed 2 miles east of Avoca; the full thickness, about 40', is shown in section 35 as follows:
 - a. Shale, grayish, sandy, massive, weathers yellowish, 15' to 20'.
 - b. Shale, slabby, calcareous, 10".
 - c. Shale, a yellowish band, 4' 6".
 - d. Shale, argillaceous, bluish to ashy, 1' 6".
 - e. Shale, reddish, argillaceous, 3' 6".
 - f. Cedar Creek Limestone, light bluish gray, shaly, 2'.
 - g. Shale, badly covered, argillaceous, blue and red bands, 7' to 8'; basal 6" or more blue and quite fossiliferous. Fauna: *Ambocoelia planoconvexa* and crinoid joints common.
3. Lecompton Limestone member, 2' 4" exposed:
 - (1). Avoca Limestone, in layers, about 2' to 3'.
 - (2). Queen Hill Shale, blue and red bands, 7' 6".
 - (3). Cullom Limestone, top shown on creek bed below one cut-bank. The beds here dip eastward.

There are a few exposures of uncorrelated beds in Otoe County, on Flood Creek about 4 miles northeast of the town of Otoe. Beds between the Avoca and Plattsmouth limestones come in farther east, in Otoe County, at a point 4 miles south and $1\frac{1}{2}$ miles west of Nehawka.

EXPOSURE OF THE PLATTSMOUTH LIMESTONE ON THE
SOUTH BRANCH WEEPINGWATER CREEK

This is in a cut-bank west of the north-south road about $3\frac{1}{2}$ miles south and one mile west of Nehawka. It is in Otoe County, in the east half of section 1 and the west half of section 6. Here the Plattsmouth Limestone holds a low bench and is exposed for most of its thickness. The identification of this as the Plattsmouth is based on the fauna, chert, and general features of the stone. Evidently this exposure is on the Nehawka Anticline, but just how far the Plattsmouth extends southwestward near the surface in Otoe County, is not known. Strata higher in the section occur between this point and the town of Otoe.

SECTION ON THE SOUTH BRANCH WEEPINGWATER CREEK,
BETWEEN TWO AND THREE MILES SOUTH
OF NEHAWKA

East of the creek in the west half of section 32.

1. Deer Creek Limestone member, quite high in the bluff and practically the same as at other exposures along the Weepingwater, thickness (?).
2. Tecumseh Shale member, represented by friable sandstone and argillaceous to sandy shale, about 34'.
3. Lecompton Limestone member, 22' or more:
 - (1). Avoca Limestone, poorly exposed, thickness (?).
 - (2). Queen Hill Shale, 8' to 10'.
 - (3). Cullom Limestone, well shown in three or four cut-banks and southward to the Otoe County line, 6'; upper 3' weathered yellowish, is fossiliferous and forms quite large blocks; middle 1' badly weathered, shaly, with *Campophyllum torquium* abundant; lower portion grayish, wavy bedded near top, and 1' 8" to 2' thick.
 - (4). King Hill Shale, 5' 6"; upper 1' 6" to 2' bluish, argillaceous; lower 3' to 4' black, fissile, jointed.
 - (5). Big Springs Limestone, blue, blocky, one bed, fossiliferous, 1' 4".

4. Kanwaka Shale member (?), or part of the Lecompton, bluish, argillaceous, with two limestone seams in upper portion, 4' or more.
5. Oread Limestone member, about 4' of the Plattsmouth Limestone exposed above creek at one cut-bank.

The divisions of this section are nearly identical with those of the Cascade Creek section southeast of Weepingwater. They dip eastward as at Nehawka.

There are a number of interesting exposures in the various valleys of the North Branch Weepingwater Creek extending from Nehawka northward and northwestward 4 or 5 miles. They represent a vertical section of about 200 feet of strata from the top of the Deer Creek down to the Stanton Limestone.

COMBINED SECTION ON THE NORTH BRANCH WEEPING-WATER CREEK

(Figure 33 is a columnar section of the older beds.)

1. Deer Creek Limestone member, in upland north and northeast of Nehawka, dipping southeastward. The Ervine Creek Limestone of this member forms an obscured escarpment north of Nehawka, turning northeastward in the direction of Murray.
2. Tecumseh, Lecompton, and Kanwaka members, poorly exposed in the east valley-side and ravines from Nehawka northward two miles, about 60'.
3. Oread Limestone member, 56':
 - (1). Plattsmouth Limestone, on both sides of the North Branch Weepingwater at Nehawka and gradually higher northward on the east side for a distance of three miles. Some of the best outcrops are in the northwest quarter of Section 18, in the center and northeast of Section 7, and east by north therefrom to the middle of Section 29, T. 11, N., R. 13 E., thickness about 30'. Many horn corals occur in the basal portion of this division.
 - (2). Heebner Shale, at various places north and northwest of Nehawka, 5' to 6'.
 - (3). Leavenworth Limestone, well shown a few places along the creek in the north half of Section 32, T. 11 N., R. 13 E., thickness 1' 4".
 - (4). Snyderville Shale, in slope west of creek on the Pollard farm northwest of Nehawka, and at points between this and three miles north of Nehawka, about 14'; upper portion blue; basal portion maroon.
 - (5). Weepingwater Limestone, poorly exposed in the west valley-side across the northwest quarter of section 18 and northwest-

ward therefrom as far as the northwest quarter of Section 30, T. 11 N., R. 13 E., thickness 5' or more.

4. Lawrence Shale member, 55':

- (1). Shale, in lower part of west valley side, one-half mile to one mile northwest of Nehawka and northeastward, 42' to 43':
 - a. Blue, argillaceous, 3'.
 - b. Maroon, with hard rusty flakes, 10' to 11'.
 - c. Blue, argillaceous, part bedded, with some fossils, 12' or more.
 - d. Dark, calcareous to carbonaceous, 4'; Myalina and other fossils in upper portion.
 - e. Coal, 6".
 - f. Blue, argillaceous, about 12'.

These beds rise gradually northwestward through sections 18, 7, and 12.

- (2). Shoemaker Limestone, 7' or more, well shown in the center and northeast quarter of section 6 two miles north of Nehawka and as follows in the northeast quarter of section 12 about 2¼ miles northwest of Nehawka:
 - a. Limestone, three or four massive bluish-gray beds separated by dark blue clay seams, 4' 3". Fauna: *Chonetes granulifer*, *Spirifer cameratus*, some bryozoa, and crinoid joints.
 - b. Shale, light blue, argillaceous, 8" to 10".
 - c. Shale, coal-like, with orbiculoidea, 3" to 5".
 - d. Shale, dark, granular, fossiliferous, with *Ambocoelia planoconvexa*, 3" to 4".
 - e. Limestone, bluish, dense, 1" to 2".
 - f. Shale, blue to black, 4" to 6".
 - g. Limestone, light gray, 6" to 11".

- (3). Shale, bluish green, argillaceous with small calcareous concretions and pebbles in middle and lower portions, 5' to 6'.

5. Iatan Limestone member, about 12':

- (1). Limestone, dark gray, massive or shattered, with "pellett" structure, forms large rough blocks, *Productus cora* common, about 5'.
- (2). Shale, concretionary, calcareous, 1' 4" +.
- (3). Limestone, gray, weathers buff, massive, quite fossiliferous, with *Fusulina*, bryozoa, brachiopods, bellurphons, and crinoid joints, 1' 2".
- (4). Shale, bluish gray, argillaceous to calcareous, with many free *Fusulina*, 1'.
- (5). Limestone, gray, weathered or shattered, part oolitic, with dwarfed *Fusulina*, 1' 6".
- (6). Limestone, gray, dense, massive, with fucoid-like forms on under surface, forms large rectangular blocks, 2' 3", more or less. Fauna: *Fusulina*, *Polypora*, *Septopora biserialis*, *Rhombopora*, *lepidodendroides*, *Composita subtilita*, *Myalina subquadrata*, and other fossils best shown on the lower surface.

- 6. Weston Shale member, calcareous, fossiliferous, with *Lophophyllum profundum*, crinoid joints, *Composita subtilita*, *Spirifer cameratus*, gastropods, etc., 2' 3".
- 7. Stanton Limestone member, upper 2' exposed on creek bed. Stone medium dark gray and not very fossiliferous.

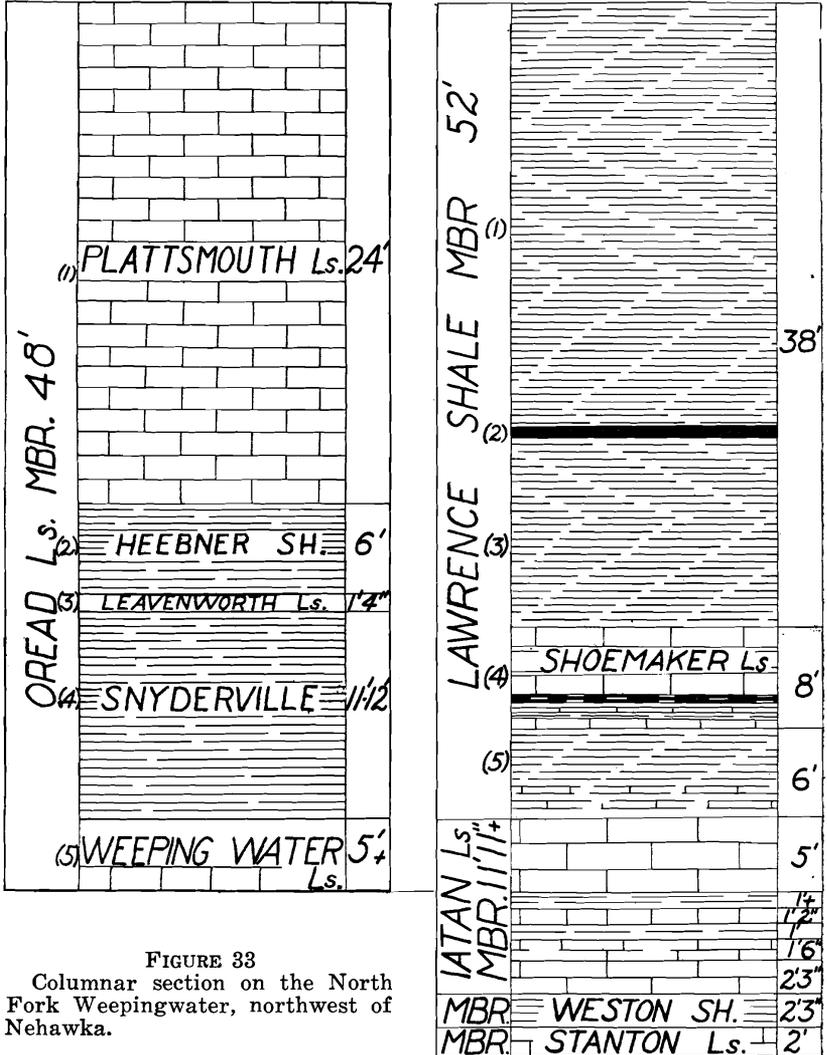


FIGURE 33

Columnar section on the North Fork Weepingwater, northwest of Nehawka.

The Iatan Limestone and associated beds rise northwestward in section 36 beyond which they flatten out for an unknown distance.

There are poor exposures of doubtful relations along the bed of the middle branch of the North Fork Weepingwater in sections 24, 25, and 31. The key bed seems to rise northwestward about as fast as the valley floor. It resembles the Iatan in some respects, but is probably higher in the section, may be either the Weepingwater or Plattsmouth.

SECTION AT THE VAN COURT QUARRY NORTHEAST OF NEHAWKA

1. Deer Creek Limestone member, 31' to 32':
 - (1). Ervine Creek Limestone, 26' 5" or more:
 - a. Limestone, gray, weathers yellowish brown, with some chert, 1' 4" +.
 - b. Shale and calcareous material, 3' 6".
 - c. Limestone, massive, fossiliferous, 1'.
 - d. Shale, argillaceous, fossiliferous, 8" +.
 - e. Limestone seam, with many crinoid joints, 4" to 5".
 - f. Limestone, gray, massive with few joints, upper surface uneven with shallow, saucer-like depressions and elevations made by colonies of *Fistulipora nodulifera*, 19' 6". The top of this ledge is 98' (Bar.) above the railroad station at Nehawka.
 - (2). Mission Creek Shale, blue, argillaceous, with some carbonaceous material, 1' 2".
 - (3). Haynies Limestone, gray, 1'.
 - (4). Larsh Shale, blue to gray, argillaceous, part black and fissile, 1' 3".
 - (5). Rock Bluff Limestone, dark gray, dense, massive, forms rectangular blocks, 2'.
2. Tecumseh Shale member, clay above, sandy below, 3' 6" exposed. Below this is a covered slope for about 40'.
3. Lecompton Limestone member, badly covered, the Cullom Limestone being exposed in the ravine west of the quarry.

NEHAWKA STONE COMPANY QUARRY SECTION

One mile east of Nehawka, near the southeast corner of Section 17, T. 10 N., R. 13 E.

1. Topeka Limestone member, represented by the Coal Creek Limestone, 1' exposed.
2. Calhoun Shale member, 17' 6":
 - (1). Iowa Point Shale, greenish blue, with thin seams of blue limestone in upper portion, 7'.

- (2). Meadow Limestone, gray, with large pelecypods and many *Fusulina*, 2' 6".
- (3). Jones Point Shale, mostly argillaceous, with calcareous bodies, 8'.
3. Deer Creek Limestone member, 28' 4":
 - (1). Ervine Creek Limestone, 22' 6":
 - a. Limestone, weathered brownish, with chert in middle, 1' 6".
 - b. Shale, dark to light seams, 1' at places.
 - c. Limestone and shale, 20':
 - (a). Hard limestone, 1' 4" +.
 - (b). Yellowish shale, 4" to 6".
 - (c). Limestone, hard, 15'.
 - (d). Limestone, shaly at base, 3' 2".
 - (2). Mission Creek Shale, argillaceous to calcareous, 1' 1"; carbonaceous in upper 3".
 - (3). Haynies Limestone, dark gray, blocky, 1'.
 - (4). Larsh Shale, upper portion yellowish, most of division black, carbonaceous, bedded, and jointed, 2'.
 - (5). Rock Bluff Limestone, locally known as the "rubble" stone, massive, dense, in one, two, or three beds, 1' 9"; the top 7" carries nodules of iron oxide.

The Ervine Creek Limestone is high in the upland north and northeast of Nehawka, but lowers eastward to below the bottom land level $1\frac{3}{8}$ miles west of Union. Along the South Fork, $1\frac{1}{2}$ miles west of Union, the Coal Creek Limestone is a few feet above the flood plain level. It is a little higher at Union in a poor exposure in the slope east of the Missouri Pacific station.

There are a few outcrops of the Coal Creek and Meadow limestones along the creek southwest of Union and in the slope at town, where the top of the Ervine Creek Limestone was formerly exposed just above the railroad level.

The Coal Creek Limestone, Severy Shale, and associated beds outcrop in a few places north and northwest of Union, on Coal Creek and the next creek west, where they rise north-westward on the Nehawka Anticline.

COAL CREEK SECTION NORTH OF UNION

This is based on exposures east of the Missouri Pacific Railroad, in sections 23 and 14

1. Howard Limestone member, in branches of creek east of railroad, blue, dense, weathered brown, 4' or more. Fauna: Crinoid joints, brachiopods, small gastropods, and pelecypods.

2. Severy Shale member, exposed on two branches of creek east of railroad, 10' or more, as follows:
 - (1). Blue, mostly argillaceous and massive, 3'.
 - (2). Dark, carbonaceous, 4" to 6".
 - (3). Blue, argillaceous, 1'.
 - (4). Nodaway Coal, 1' to 1' 2".
 - (5). Bluish, argillaceous, 2'.
 - (6). Slabby, sandy to calcareous and argillaceous, 3'.
3. Topeka Limestone member, about 6' 2":
 - (1). Coal Creek Limestone, well exposed at first trestle north of Union and on creek east of next trestle north, about 4':
 - a. Limestone, dark blue, massive, with some dark chert in lower portion, 2'.
 - b. Shale, blue, argillaceous, 4" to 6".
 - c. Limestone, blue, 8".
 - d. Shale, blue, argillaceous, 2" to 5".
 - e. Limestone, blue, 6" to 7".
 - (2). Holt Shale, 1' 10"; upper 10" to 1' bluish, argillaceous; lower portion black, fissile. Fauna: *Derbya crassa* common.
 - (3). DuBois Limestone (?), blue, 4" to 5".
4. Calhoun Shale member, 14' or more:
 - (1). Iowa Point Shale, indurated above, clayey below, 4' to 5'.
 - (2). Meadow Limestone, one bluish gray massive bed; not very fossiliferous; with some gray chert in middle; 2' 6" to 3' 2". This ledge is at the first trestle and northeastward.
 - (3). Jones Point Shale, bluish gray, argillaceous to calcareous, with two fossiliferous, calcareous seams near middle, 6' 9" to 7'. Fauna: *Productus semireticulatus*, *Marginifera splendens*, and *Rhombopora lepidodendroides* the main species.
5. Deer Creek Limestone member, on creek bed under first trestle, massive, weathered yellowish brown, 5' exposed.

EXPOSURES SOUTHEAST OF UNION

Beds of the Wabaunsee formation, dropping slowly southeastward, form the south side of the Weepingwater Valley southeast of Union, the lowest beds being considerably lower in elevation than the Coal Creek Limestone at Union, the distance between being about 1½ miles without any outcrops on which to determine the attitude of the strata. No doubt, the main part of the Jones Point deformation passes southbeds outcrop in a few places north and northwest of Union, on westward through this part of the Weepingwater Valley. Evidently the Scranton Shale and other strata between the Coal Creek Limestone and the Wabaunsee formation occur in this narrow covered stretch, dipping rapidly southeastward.

THE LITTLE NEMAHA CROSS SECTION

The Pennsylvanian strata are exposed at widely separated places in the little Nemaha drainage, in Lancaster, Johnson, Otoe, and Nemaha counties. Except in a small area in the vicinity of the town of Otoe, where a definite correlation of the beds has not been made, all of the exposures are in the Wabaunsee formation.

The outcrops in the west and central parts of the area are badly obscured and disconnected. Those between the vicinity of Brock and the Missouri are nearly continuous and favorable for study.

Relatively large areas in Nemaha and Johnson counties are occupied by one or more of the basal beds of the Permian System. They have been investigated in detail by Professor Bengtson, whose findings are to be published as a special report.

Plate V shows the attitude of the exposed beds in the Little Nemaha area in east-west cross section. This cross section, for reasons given later, is extended to the Salt Creek valley, to include exposures in the vicinity of Roca. The cross section is not extended through the outcrops in the middle course of the valley, i.e., at Syracuse, Unadilla, and Palmyra, because the beds in this stretch have not been correlated without some doubt.

The occurrence, character, and correlation of beds in the Nemaha cross section are shown by the following descriptions and sections, working eastward:

ROCA SECTION

This is in Salt Creek valley about 10 miles south of Lincoln. The exposures extend from one-half mile south of town northward along the east side of Salt Creek valley for a distance of $2\frac{1}{2}$ miles, and in Warner Creek valley across sections 7, 8, and 9, toward the outcrops in the Little Nemaha valley west of Bennet. The section is run with those in the Little Nemaha area because of its similarity and proximity to the latter, and because there are no other Pennsylvanian ex-

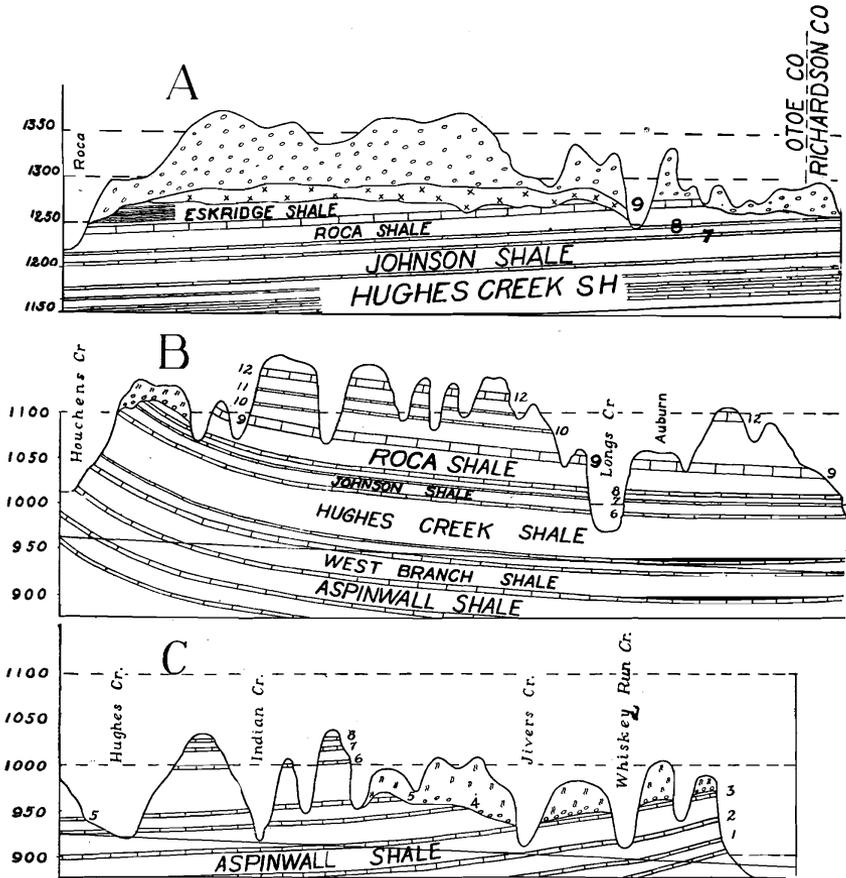


PLATE V.—The Little Nemaha Valley cross section: A, Roca to east of Bennett; B, Southwest of Brock to east of Auburn; C, East of Auburn to the Missouri. Limestones: 1, Dover; 2, Brownville; 3, Falls City; 4, Americus; 5, Houchen Creek; 6, Long Creek; 7, Glen Rock; 8, Howe; 9, Neva, 10--, limestone beds in the Eskridge Shale member; 12, Cottonwood.

posures in the Salt Creek valley except near Ashland where the outcrops are included with those of the Platte cross section.

The Roca section is as follows:

1. Eskridge Shale member. The basal 15' to 20' of this division, part of which may be the Neva Limestone member, is exposed under the drift and the Dakota formation in sections 8, 9, and 17. It is best shown in the abandoned Warner Quarry north of Roca where the section made several years ago when the quarry face was well shown is as follows:
 - (1). Shale, dark gray, argillaceous to very calcareous, with a few poorly defined geodes and thin fossiliferous limestone lenses carrying crinoid stems, *Composita subtilita*, horn corals, and pelecypods; thickness exposed below the drift, about 2'.
 - (2). Limestone, dark gray, jointed, weathers light gray, with many fossils, such as small horn corals and pelecypods, 4" to 6".
 - (3). Shale, bluish, bedded, jointed, argillaceous, with some sand, somewhat indurated, weathers buff to yellowish, no fossils observed, 2' 6".
 - (4). Limestone, bluish, two firm beds, with some carbonaceous material, fossiliferous, 1' 1".
 - (5). Shale, dark, hard, slabby, fossiliferous, somewhat carbonaceous at base, 1' 3". Fauna: *Productus semireticulatus*, *Composita subtilita*, and crinoid joints common.
 - (6). Limestone, bluish gray, fossiliferous, weathers yellowish to brownish, 8" to 9"; upper portion earthy; lower portion massive and quite firm.
 - (7). Shale, 1' to 1' 2"; upper 6" to 8" light gray, bedded, argillaceous, weathers yellowish; lower 5" light gray, calcareous, hard.
 - (8). Limestone, bluish, massive, forms blocks, weathers buff, with some fossils, 6".
 - (9). Shale, 1' 8"; upper 1' dark, argillaceous, bedded, jointed, weathering yellowish; middle 3" dark gray, fossiliferous limestone; lower 4" to 5" dark, slaty, jointed.
 - (10). Limestone, two or three dark blue, massive, fossiliferous beds which weather yellowish with brownish specks, 1' to 1' 4".
 - (11). Shale, bluish, argillaceous, plastic, weathers yellowish, 4' to 5'.
2. Neva Limestone member. The Neva is the main division in this section. It is exposed in the old quarries and slopes at Roca, along Warner Creek north and northeast of Roca, at the edge of the upland east of Salt Creek $1\frac{1}{4}$ to $1\frac{1}{2}$ miles north of town, and in the small bench along the west side of Salt Creek valley in the vicinity of Hanlon where it has been reached in shallow wells.

The Neva, i.e., the main portions of it, is composed of two limestones separated by shale. The upper limestone is a dark

gray, massive bed cut by nearly vertical north-south and east-west even joints with wide spacing. It is somewhat argillaceous and separated into thin layers which weather light gray. The thickness exposed along the roadside south of Warner Creek between sections 8 and 9 is 7 to 8 feet. Although not very fossiliferous, this bed carries *Pinna*, *Aviculopecten*, *Productus semireticulatus*, and other fossils. Pelecypods are common. The shale is not well exposed. It seems to be about 2 feet thick and is composed of argillaceous, slabby, limy layers. The basal limestone is blocky and about 2' 9" thick. It is exposed in a recent road excavation just south of Warner Creek.

3. Elmdale Shale member, about 34':

- (1). Roca Shale, at Roca and along Warner Creek, thickness 16' to 18'. Its upper portion, slumped a few feet, is as follows near the depot at Roca:
 - a. Shale, grayish, slabby, sandy to calcareous, jointed at places, about half limestone and half shale, 4' 6".
 - b. Shale, bluish with brownish hue, bedded, with some sand, but largely clay, 4".
 - c. Shale, bluish, massive, argillaceous, extending below railroad, 4' 6" exposed.

Near the center of section 8, south of Warner Creek, is the following complete exposure of the Roca Shale:

- a. Shale, bluish, argillaceous, with calcareous material, 1' 6".
- b. Siltstone, buff colored, massive, with calcite in joints and cavities, 1' 2".
- c. Shale, bedded, 5' to 6'; lower portion olive green, with a few calcareous concretions and very thin seams of fossiliferous limestone in one zone at places.
- d. Shale, grayish blue, with three thin yellowish bands probably formed from weathered limestone, and a faint band of purple shale, 4'.
of purple shale, 4'.
- e. Shale, massive, maroon, mottled with gypsum, 1' 6".
- f. Shale, grayish blue, argillaceous, calcareous, massive, 1' 6".
- g. Shale, maroon, massive, argillaceous, 1' 2".
- h. Shale, grayish blue, massive, weathers yellowish, 1' 4".
- (2). Howe Limestone, along Warner Creek in sections 7 and 8, thickness 3' to 4'. Stone, dark gray, massive to irregular or slabby, weathers buff to brownish. At most exposures this bed is part weathered and part unweathered. At places it carries calcite and some small geodes. The badly weathered stone is vesicular. There are few fossils. One of the best exposures of the fresh stone, also of the partly weathered material, is

north of Warner Creek along the east side of section 7, about 400' south of the railroad. A very good exposure of the weathered phase is in the south bank of Warner Creek, east of the north-south road crossing the center of section 7.

- (3). Bennett Shale, about 9' 6". The best exposure of this is in a cut-bank of Warner Creek 1¼ miles north of Roca. It shows:
 - a. Shale, bluish, argillaceous, few fossils, 5' 6".
 - b. Limestone, bluish, massive, weathers buff, few fossils, 11".
 - c. Shale, 3' 6"; upper portion bluish, argillaceous with some indurated material; lower portion dark, part fissile, with many specimens of *Orbiculoidea missouriensis*.
- (4). Glen Rock Limestone, in the lower part of the cut-bank on Warner Creek near the railroad, dark bluish gray, massive, not much jointed, weathers buff to gray, 1' 11". Fauna: Small *Fusulina* and brachiopods.
- (5). Johnson Shale, bluish, argillaceous, bedded, about 2' exposed at the cut-bank near the railroad.

Correlation. The beds exposed at Roca have been studied by many geologists and referred to by some as the Pennsylvanian and by others as the Permian. Our investigations show that the section is without doubt in the Wabaunsee formation and nearly identical with portions of the sections at Douglas and Bennett.

DOUGLAS SECTION

This is in the South Fork Little Nemaha between Douglas and Burr.

1. Cottonwood Limestone member, along the South Fork just southeast of Douglas, along the creek east of town, also in the northeast quarter of section 18 three miles east and one mile south of Douglas. It underlies part of the bench-like upland east of Douglas and probably extends a considerable distance under the drift hills west and southwest of town. Its upper and middle portions are well shown under the wagon road bridge just northeast of Douglas. The best exposure, however, in this area is in the creek bank southeast of the Douglas railroad station, with a thickness of 10' 4" as follows:
 - (1). Limestone, light gray to dark gray, shaly or slabby, with few fossils, 2' 6".
 - (2). Limestone, gray, massive, with few fossils, 1'.
 - (3). Limestone, gray, massive, with *Fusulina*, bryozoa, and brachiopods, 3' 4".
 - (4). Limestone, gray, massive, with a good many *Fusulina* and other fossils, 3' 6". The Cottonwood (top) has an altitude of about 1,230' in section 18. It dips about 20' between this point and Douglas. Its massive, fossiliferous zones in the exposures near Douglas weather light gray, and the slabby upper zone weathers

light cream or buff. The stone has been quarried at places in the vicinity of Douglas.

2. Eskridge Shale member, about 38', only the top and base exposed. The thickness as here given is the measured interval between the Cottonwood and Neva limestones. The top of the member in the banks southeast of Douglas is a bluish, argillaceous shale. A maroon, argillaceous band is exposed near the southeast corner of section 11 about one mile southeast of Douglas, and 6' to 8' of the basal portion of the member crops out in the right bank of a ravine in the south part of section 18 three miles southeast of Douglas. Its lower 15" is a bluish, argillaceous shale interstratified with thin limestone seams. This grades upward into 4' or more of massive, maroon, argillaceous shale, exposed under the drift. The covered portions of the Eskridge east of Douglas are thought to be largely bluish and maroon, argillaceous to arenaceous shales with some limestone.
3. Neva Limestone member, in the south half of section 18, the northeast quarter of section 19, the northeast quarter of section 29, and in the bluffs west of the South Fork from the west side of section 19 southeastward to the west side of section 29, thickness 8' to 9'. The best exposures of the Neva are in the ravines and banks of the South Fork in section 20, where it consists of two massive limestone divisions, separated by about 1' of weathered limestone and shaly material. The top of the upper limestone is light gray and somewhat slabby; the remainder of this division is bluish when fresh and light gray to buff when weathered. At its base are mottled-brownish seams, nearly filled with Ostracods. The shale next below carries a carbonaceous streak and is quite fossiliferous. Its principal fossils are *Productus semireticulatus*, bryozoa, pelecypods, and crinoid joints. Much of the lower limestone division is massive, becoming bedded at the base. Its upper zone carries *Pinna* and pelecypods. The Neva has been quarried in section 30 and at other places. at other places.
4. Elmdale Shale member, 32' 6" exposed:
 - (1). Roca Shale, exposed between 3 and 4½ miles southeast of Douglas, in sections 19, 30, and 29. The best outcrop, thickness about 20', is in the cut-banks of section 20, as follows:
 - a. Shale and slabby limestone, bluish gray when fresh, weathering buff, 2' to 5'.
 - b. Shale, olive green, bedded to massive, argillaceous, with some sand and calcareous material, weathering gray to buff, 12' or more. This carries small selenite crystals, a few calcareous bodies, and calcite geodes in the lower portion.
 - c. Shale, maroon, massive, mostly argillaceous, with calcite geodes, some calcareous concretions, and many small crystals of selenite, 1' 6" to 3'.
 - (2). Howe Limestone, in the bed and banks of the South Fork from the north side of section 30 southeastward to section 29, thickness 4' to 5' or more. The stone is grayish to buff, slabby to

massive, badly slumped, and shattered at places or weathered vesicular. Free calcite occurs in the unweathered basal portions of this bed.

- (3). Bennett Shale, in the cut-banks west of the South Fork bridge located on the east side of section 30, about 8' exposed:
- a. Shale, bluish, mostly argillaceous, portions indurated, arenaceous and calcareous, weathering yellowish, 3'; the middle portion is weathered limestone.
 - b. Shale, bluish gray to black, largely argillaceous, 5' exposed:
 - (a). Shale, dark gray, somewhat arenaceous, quite fossiliferous, with *Composita subtilita* and pelecypods the main fossils, 2'
 - (b). Shale, carbonaceous, black, plastic, fossiliferous, 5" to 7".
 - (c). Shale, dark gray, massive, fossiliferous, 1' 6".
 - (d). Shale, carbonaceous, coal-like, 2".
 - (e). Shale, black, massive, plastic, with *Orbiculoidea* and *Lingula*, 5" to 6".
 - (f). Shale, very dark gray, crumbly, fossiliferous, 5".
 - (g). Shale, black, massive, plastic, with *Orbiculoidea*. Only 5" of this is exposed above the creek bed, altitude about 1,120'.

Rock benches formed on the Neva occur in sections 18, 19, 20, and 30. The beds in the vicinity of Douglas dip south-westward.

BENNETT SECTION

This is a combined section of the Pennsylvanian beds along the Little Nemaha and its tributaries in the vicinity of Bennett extending from west and southwest of town eastward more than two miles (Figure 34). Much of the upland is deeply mantled with drift which is underlain at places by the Dakota formation.

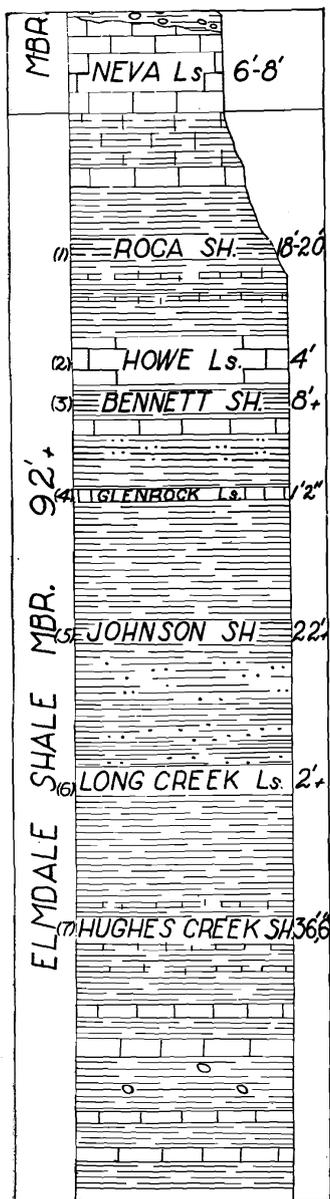
1. Neva Limestone member, exposed west, southwest and south of town, i.e., along the creek in the southeastern part of section 9, the southern part of section 10, the southeastern part of section 10, and the west part of section 11. The outcrops are now badly obscured, but a thickness of about 8' is reported to have been quarried.
2. Elmdale Shale member:
 - (1). Roca Shale, shown northwest of Bennett and along the Little Nemaha across sections 9, 10, and 11; thickness 18' to 20'. Section northwest of town:
 - a. Shale, argillaceous, to calcareous, weathers yellowish, 4' to 5'.
 - b. Limestone, badly weathered, yellowish, fossiliferous, with *Aviculopecten* and other pelecypods, 1' 6".

- c. Shale, light blue to olive green, argillaceous, bedded above, with thin seams of grayish limestone near base, 10' to 11'.
 - d. Shale, argillaceous, part maroon, with bluish band at base, 1' to 2'.
- (2). Howe Limestone, in foot of the slope west of Bennett, in the Little Nemaha Valley across sections 9 and 10, and gradually higher southward and eastward across south side of section 12. Stone buff to dark gray, slabby to massive, not very uniform, weathers granular to vesicular, thickness about 4'. It has a few fossils. The fresh stone, which is the exception in the exposed bed, is dark gray, hard and dense, due to the presence of free calcite. The Howe Limestone has been quarried at a few places in this area.
- (3). Bennett Shale, exposed from west of Bennett and the south side of section 10 eastward; thickness about 8' including:
- a. Shale, bluish, argillaceous, part calcareous, fossiliferous, 2' 6" to 4'. Fauna: *Meekopora prosseri*, sea urchin spines, and a few brachiopods.
 - b. Limestone, just above creek bed southwest of town and gradually higher in the cut-banks down-valley, 1' to 1' 2". This stone is bluish gray, and not very fossiliferous. It weathers buff or yellowish.
 - c. Shale, well shown in creek bank southwest of town, 3' 7":
 - (a). Shale, light blue, arenaceous to argillaceous, weathers dark gray, 10".
 - (b). Shale, nearly black, carbonaceous, resembles coal, 5". This is in the right bank of the creek near water level west of Bennett. It is higher in the slope farther southeast, and near the top of the cut-banks southeast of town.
 - (c). Shale, dark gray, argillaceous to sandy, somewhat calcareous, 8" to 10". Specimens of *Orbiculoidea missouriensis* are common.
 - (d). Shale, 6" to 8".
 - (e). Shale, dark, argillaceous, in four bands at places, somewhat slabby, bedded to massive, 1' 6". The basal 3" is hard and earthy. It carries *Orbiculoidea*, *Composita subtilita*, *Ambocoelia planoconvexa*, and other fossils.
- (4). Glen Rock Limestone, in one or two bluish gray beds which form large blocks, weathering dark gray, buff, or brownish, 1' 2" to 1' 10". Stone, quite hard, with some calcite, carbonaceous matter and pyrites of iron at some places. This limestone is exposed on the creek bed west of Bennett and higher in the banks and upland southeast. It has been quarried at places in sections 11 and 12. Fauna: Small, slender *Fusulina*, crinoid joints, brachiopods, and fragments of bryozoa.
- (5). Johnson Shale, in the cut-banks of the Little Nemaha and its tributaries southeast of Bennett, about 22' 6" as follows:
- a. Shale, bluish, massive to poorly bedded, with two zones of dark grayish, calcareous concretions near the top, 10'.

- b. Shale, bluish gray, maroon at base and top, argillaceous, poorly bedded, 3'.
 - c. Shale, dark gray with buff hue, silty to sandy, massive but bedded, somewhat indurated, forms vertical faces at places, 3'.
 - d. Shale, dark, argillaceous, bedded, with thin arenaceous seams mostly at the base, 3' 6".
 - e. Shale, massive, laminated, sandy to argillaceous, with some calcareous material, 6".
 - f. Shale, dark, bedded, somewhat slaty, 10" to 11".
 - g. Shale, sandy, massive, 5".
 - h. Shale, dark gray, sandy, 8".
- (6). Long Creek Limestone, in the cut-banks south of the Little Nemaha southeast of Bennett and farther east, 2' to 2' 6". Stone, dark gray, with some earthy material; weathers buff to yellowish. It occurs as one massive bed or is broken into three or more layers with shale partings. On its upper surface is a dark gray, slabby, fossiliferous crust underlain by 4" of fossiliferous shale. Fauna: *Allorisma terminale*, *Pinna*, *Composita subtilita*, *Spirifer cameratus*, crinoid joints, etc.
- (7). Hughes Creek Shale. The top of this division is exposed below the Long Creek Limestone near the middle of section 11 southeast of Bennett and what may prove to be its base is shown in a ravine north of the railroad two miles east of town. Section: a. Shale and thin limy layers, 18' 6" with the following sub-zones:
- (a). Shale, bluish to dark argillaceous, massive to bedded, with some thin seams of limestone and a few fossils, about 10'.
 - (b). Seams of limestone and shale, 1' 6" to 2'. This rises from below the river in the southwest quarter of the northeast quarter of section 11, becomes well exposed in the cut-bank near the road east of this section and at places along the creek in the north half of section 12. The limestone seams are dark gray, arenaceous, fossiliferous, weathering buff. The shale partings are dark blue, argillaceous, plastic, and fossiliferous. Fauna: *Productus cora*, *Chonetes granulifer*, bryozoa, and other fossils are plentiful in the stone, *Productus cora* being the leading species.
 - (c). Shale, best exposed southeast of Bennett in a cut-bank near the east side of section 11, about 6' 6", top 1' 6" bluish, argillaceous, bedded, with *Chonetes granulifer*, *Composita subtilita*, *Spirifer cameratus*, and other fossils; middle portion with calcareous seams carrying many *Chonetes granulifer*, *Productus semireticulatus*, *Spirifer cameratus*, *Septopora biserialis*, *Thamniscus*, *Rhombopora lepidodendroides*, *Meekopora prosseri*, and

other species, about 1' 6"; basal portion, bluish, argillaceous, bedded, jointed, massive, with *Ambocoelia planoconvexa*, *Chonetes geinitzianus*, *Spirifer cameratus*, *Rhombopora lepidodendroides*, and other species scattered throughout but fewer than in the calcareous seam zone next above, 3' 6".

- b. Limestone and shale, 19' 6" +:
- (a). Limestone, the topmost layer on creek bed one mile southeast of Bennett, blue to dark gray, hard, massive, with some earthy material, fossiliferous, jointed, forms small rectangular blocks which shell off on weathering, 8" to 9". *Pugnax osagensis* is the leading fossil.
 - (b). Shale, dark bluish or black, argillaceous, with *Derbya crassa*, *Composita subtilita*, *Ambocoelia planoconvexa*, bryozoa, and many *Orbiculoidea*, 1' 8" to 2'.
 - (c). Limestone, dark gray, somewhat earthy, quite fossiliferous, forms large blocks, 1' to 1' 2", with shale near middle. Fauna: Echinoid spines, *Chonetes granulifer*, *Spirifer cameratus*, crinoid joints, *Meekopora prosseri*, *Rhombopora lepidodendroides*, *Composita subtilita*, etc. This and the succeeding layers are exposed north of the creek in the ravine two miles east of Bennett.
 - (d). Shale, bluish, dark at base, weathers buff, argillaceous to earthy, with some sand and lime concretions, 3' 6". Fauna: Brachiopods and *Orbiculoidea*.
 - (e). Limestone, dark gray, earthy, fossiliferous, with crinoid joints, *Ambocoelia*, *Pustula*, *Chonetes*, etc., 10" to 1'.
 - (f). Shale, bluish to dark, mottled, argillaceous to calcareous, 2'. Fauna: Crinoid joints, *Chonetes granulifer*, *Derbya crassa*, *Ambocoelia planoconvexa*, *Spirifer cameratus*, and bryozoa.
 - (g). Limestone, dark gray, quite earthy, with *Derbya* and *Pustula*, 8".
 - (h). Shale, black, very arenaceous, 3".
 - (i). Limestone, dark gray, sandy, with *Pustula*, *Productus semireticulatus*, *Ambocoelia planoconvexa*, etc., 4" to 5".
- c. Shale, thickness (?), probably 8".
3. Americus Limestone member (?), exposed in ravine south of bridge on east-west road 2½ miles east of Bennett as one dark blue, massive bed, 1' 3" to 1' 5". It forms large blocks which weather light gray. Fauna: *Bellerophons*, *Pinna*, crinoid joints, *Productus semireticulatus*, etc.
4. Admire Shale member (?), in ravine and bank of the Little Nemaha 2½ miles east of Bennett, 14' 6":
- (1). Shale, 1' 6"; dark gray, with lignitized wood in upper 1'; lower 5" to 6" bedded, with some sand and pebbles. It may represent a break in depositions with land material at this place.
 - (2). Shale, massive, buff to bluish, cut with thin hard plates, making a rough surface, 4' 6".



- (3). Shale, on bed or ravine and in creek bank northeast, maroon, massive, argillaceous, 2' to 3'.
- (4). Shale, in bank of Little Nemaha, largely bluish gray and argillaceous, 6' or more exposed.

The beds at Bennett seem to dip slightly southwestward. This is best shown at the cut-bank near the east side of section 11. They lower considerably southward to Douglas and 30 feet or more westward to Roca.

Correlation. Division 1 of the Bennett section is without doubt the Neva Limestone. It is the same as the member correlated as the Neva at Douglas where it is the first prominent limestone below the Cottonwood. The succeeding strata down through the Roca Shale, Howe Limestone, and Bennett Shale are nearly identical with those exposed at Douglas and Roca.

The units referred to the Glen Rock Limestone, Johnson Shale, Long Creek Limestone, and Hughes Creek beds are very typical lithologically and faunally, hence their correlation is certain. There is some doubt, however, regarding the stratigraphic position of the strata referred provisionally to the Americus Limestone and Admire Shale.

FIGURE 34.—Columnar section southeast of Bennett.

PALMYRA SECTION

In the south bank of the Little Nemaha, just southeast of town, 32' 6" :

- a. Shale, with violet hue, argillaceous, 5' to 6'.
- b. Shale, maroon, massive, 6'; upper portion brick red and largely argillaceous; basal portion forming sandy-micaceous-calcareous debris and with a few fossils, such as crinoid joints and *Chonetes granulifer*.
- c. Shale, bluish, bedded, argillaceous to arenaceous, with rusty seams, 9'.
- d. Shale, blue, argillaceous, massive, 16' exposed above the bed of the Little Nemaha which is about 12' below the level of the railroad at the Palmyra station.

This section seems to fall in the Admire Shale member, probably in the horizon of the Aspinwall Shale, yet the position has not been decided definitely.

HOOPER CREEK EXPOSURE, BETWEEN EAGLE AND
PALMYRA

Location east of the highway, in sections 9, 10, and 11, T. 9 N., R. 9 E., about 32' exposed:

- a. Limestone, in an abandoned quarry east of the Eagle-Palmyra highway, yellowish, fossiliferous, probably 2'; elevation about 1,215'. Fauna: Brachiopods and large *Fusulina*.
- b. Sandstone, dark gray to bluish, micaceous, thickness (?), 1' or more.
- c. Shale, maroon, probably 1' or more.
- d. Shale, ash colored, 4' or more.
- e. Shale, dark blue, argillaceous, becoming sandy below, with thin rusty colored seams and a few pyrites of iron concretions, about 18'. This division extends southwestward through the hill to the ravine in the east side of section 9.
- f. Shale, bluish, argillaceous, massive, 6' exposed above bed of the ravine.

An exposure, similar to the above and probably in the McKissick Grove Shale member, occurs on the hillside in the northeast quarter of section 10 and the northwest quarter of section 11. It is south of the creek where crossed by the first north-south road east of the highway. The top of this section is about 52 feet above the small bridge on the creek north. The section shows some yellowish, fossiliferous limestone near the top and about 1' 4" of sandy conglomeratic, limy shale a few feet lower. Sandy shales are exposed below the latter down to the covered slope above the bridge.

These exposures are thought to be in the McKissick Grove Shale member.

Farther down Hooper Creek, in sections 18 and 19, T. 9 N., R. 10 E., located about 2 miles north and 2½ miles east of Palmyra, is the following combined section in the banks of a branch of Hooper Creek, thickness about 18 feet:

- a. Shale, poorly exposed in section 18, thickness a few feet.
- b. Limestone, bluish gray to yellowish, weathered and shattered, 1' 4" or more; lower portion somewhat sandy, slabby, and quite fossiliferous. Fauna: Bellerophons and brachiopods.
- c. Shale, greenish blue, massive, mostly argillaceous, blocky at surface, with many small gray calcareous concretions, no fossils observed, 2' 3".
- d. Limestone, dark gray to light gray, with dark gray limestone pebbles and uneven or rough bedding plains, 5" to 6". This forms thin, rough blocks. It has few fossils except small gastropods.
- e. Shale, blue, argillaceous to sandy, massive, with small calcareous concretions, weathers gray, forms small blocks, 1' 3".
- f. Limestone, exposed in section 18 and in a cut-bank in section 19. Stone, dark, gray, massive, with rough surface, weathers yellowish brown, thickness 2' or more. The top portion forms small, yellowish, sub-spherical blocks cut with thin calcite veins.
- g. Shale, gray, argillaceous to sandy, bedded, with some mica, 6' to 7' exposed in section 19 and less in section 18.

Much of the above section is at or near the horizon of the Tarkio Limestone. However, the beds have not been definitely correlated.

HILLSIDE EXPOSURE THREE-FOURTHS MILE SOUTHWEST OF UNADILLA

1. Limestone, dark gray to brownish, fossiliferous, forms flat, rounded blocks, 1' 3" to 1' 6"; top portion dense, apparently oolitic, with granular feel; middle and basal portions somewhat earthy, weathered yellowish brown.
2. Shale, yellowish, fossiliferous, calcareous above and below, 2' 10"; middle portion maroon, argillaceous.
3. Limestone, bluish gray, one or two massive jointed layers, weathers buff, forms large rectangular blocks, 1' 9". Fauna: Crinoid joints, small gastropods, brachiopods, and bryozoa.
4. Shale, blue, argillaceous, weathers yellowish, 1' 10".

5. Limestone, about 3' 3":
 - (1). Limestone, weathered yellowish, fossiliferous, upper surface uneven, 1'.
 - (2). Limestone, dark gray, weathers yellowish, jointed, forms sharp, flat debris, 1' 3". Fauna: Crinoid joints, Rhombopora lepidodendroides, and fragments of brachiopods.
 - (3). Shale, bluish, largely argillaceous, fossiliferous, 4" to 6". Fauna: Chonetes granulifer, crinoid joints, etc.
 - (4). Limestone, irregular, weathered yellowish, quite fossiliferous, 6".
6. Shale, 20' or more:
 - (1). Maroon, massive, argillaceous, crumbly, 12'.
 - (2). Bluish, massive, argillaceous, 8'.
7. Limestone, poorly exposed, forms slight hump in slope, thickness and character (?).
8. Shale, probably 10'.
9. Limestone, at mouth of small ravine, apparently in two layers, thickness (?); upper layer shattered, thickness (?); lower layer dark gray, dense, massive, 7" to 8".
10. Colluvial slope to flood plain of the Little Nemaha, 18' to 20'.

Correlation. Numbers 1 to 5 of this section may represent the Tarkio. The correlation of the lower subdivisions has not been decided, yet number 6 seems to be the Willard Shale or a considerable portion of it.

THE UNADILLA SECTION

1. Tarkio Limestone member, exposed under the upper part of town and on hillside northwest of town. This seems to be in the horizon of divisions 1 to 5 of the section three-fourths mile southwest of Unadilla where the conditions are better for study and sectioning.
2. Willard Shale member, about 26':
 - (1). Shale, maroon, uniform, crumbly, argillaceous, 12' to 14'.
 - (2). Shale, bluish green, argillaceous, bedded at the top, 7' to 9'.
 - (3). Limestone, earthy, shattered, with a few fossils, 1'.
 - (4). Shale, bluish, argillaceous, with some calcareous material, 5'.
3. Emporia Limestone member, 8' or more:
 - (1). Limestone, one massive, bluish gray bed, 1' to 1' 3".
 - (2). Shale, blue, argillaceous, with thin indurated seams, probably 3' to 4'.
 - (3). Limestone, poorly exposed, brownish, thickness about 1' 4" or more. There is some evidence that the thickness of this may be 3' to 4'.
4. Humphrey Shale member, about 20' 6" exposed:
 - (1). Auburn Shale, poorly exposed, largely bluish green and argillaceous, with a thin, hard limestone below the middle, about 10'.

- (2). Wakarusa Limestone (?), weathered yellowish; not very fossiliferous, massive, with some arenaceous material, forms rectangular blocks with pitted edges, 1' 5" to 1' 9". This bed is exposed in an excavation at a small cow barn in the south-east part of town.
- (3). Soldier Creek Shale (?), about 9' exposed in road gutter:
 - a. Bluish, argillaceous, 4' or more.
 - b. Maroon, with fine calcareous concretions, 1' or more.
 - c. Bluish gray, about 3'.
 - d. Maroon, top 6" exposed in lower part of gutter of road at foot of slope in southeast part of town, elevation about 10' above the railroad.

SECTION AT THE SWARTHMAN PLACE SOUTH OF
UNADILLA

This is based on exposures in the cut-banks and ravines along the south side of the Little Nemaha, thickness about 27 feet:

1. Limestone, dark gray to light gray, broken into small pieces, 6" or more exposed.
2. Shale, mostly blue and argillaceous, 2' or more.
3. Limestone, light gray with rough feel, quite fossiliferous, forms sub-spherical blocks, 9" to 11".
4. Shale, bands of blue and maroon, argillaceous, 3' or more.
5. Limestone, bluish gray, weathers light gray, forms large rectangular blocks, 1' 7" to 1' 8". This bed is exposed on both branches of the ravine on the Swarthman place where it forms small falls. Fauna: *Chonetes granulifer*, *Spirifera cameratus*, *Ambocoelia planoconvexa*, small gastropods, and crinoid joints.
6. Shale, blue, argillaceous, massive, apparently without fossils, 1' 8" or more.
7. Limestone, bluish, massive, or broken by shale seams, weathers yellowish-brown, exposed in south cut-bank of the Little Nemaha just west of the old water power site, 4' 4". Altitude of base about 1,078'. Fauna: *Entilettes hemiplicata*, *Chonetes granulifer*, *Marginitifera splendens*, *Composita subtilita*, *Spirifer cameratus*, *Myalina*, *Pinna*, crinoid joints, *Rhombopora lepidodendroides*, and fenestrated bryozoa.
8. Shale, exposed in cut-bank, 13':
 - (1). Dark blue to bluish gray, argillaceous, 1'.
 - (2). Maroon, massive; with calcareous concretions, 4' to 5' below top; about 12' exposed above the river at the Swarthman place and " exposed at the cut-banks farther east where there are thin rusty seams in the lower portion.

Correlation. The correlation of these beds has not been decided beyond question. The section down to the heavy maroon shale is similar to the one on the hill southwest of Unadilla. The maroon shale next below carries considerable calcareous concretionary material in contrast to the uniform shale of the latter section. Also, this section has a much lower elevation, and there seems to be no dip or fault between the locations of the sections. The horizon is the Tarkio or lower.

EXPOSURES IN THE SPUR OF THE UPLAND BETWEEN WOLF RUN CREEK AND THE LITTLE NEMAHA

This is in the southeast quarter of section 7 north of the highway between Syracuse and Unadilla.

1. Shale, thin limestones and some sandstone, about 20'. There is some maroon shale near the top, below which is about 8" of bluish gray limestone. Next below is arenaceous to argillaceous shale, modified by two or three thin sandstones and large sandstone lenses. Bluish to violet argillaceous shale occurs at the base.
2. Limestone, 1' 4"; apparently in two beds, separated by a thin red to bluish shale; upper limestone weathered nodular and not in a condition for measurement; the lower and main limestone is dark gray, massive, with *Ambocoelia planoconvexa*, crinoid joints, *Rhombopora lepidodendroides*, and *Fusulina*.
3. Shale, badly covered, probably 18' to 20'.
4. Limestone, now covered, but formerly exposed in south bank of Wolf Run Creek below the abandoned quarry, thickness (?).
5. Shale, maroon, top 2' to 3' formerly exposed above the bed of Wolf Run Creek.

The beds in the spur southeast of the quarry dip southeastward. The correlation of the strata of this section has not been decided beyond doubt. Division 1 resembles the basal portion of the McKissick Grove Shale, and Number 2 probably is the Tarkio Limestone.

SECTION WEST OF SYRACUSE

Made on exposures in the quarries and slopes between 1½ and 3 miles west of Syracuse.

1. Elmdale Shale member, 10' or more exposed:
 - (1). Limestone, in hillsides and above quarry farthest west, one or two thin layers, about 1' 2"; upper layer, bluish gray, dense,

with few fossils, weathers light gray, buff, or brownish, 6" to 8"; lower layer weathered yellowish, about 7".

- (2). Stine Shale, mostly bluish and argillaceous, with thin limestone seams and some concretionary material in upper portion, also a few geodes at places, 9'. Fauna in middle and upper zones: *Meekopora prosseri*, *Septopora biserialis*, *Rhombopora lepidodendroides*, *Cyclotrypa barberi*, *Chonetes granulifer* (large), *Productus semireticulatus*, *Spirifer cameratus*, *Marginifera splendens*, *Composita subtilita*, *bellerophons*, *pelecypods*, echinoid spines, crinoid joints, etc.
2. Americus Limestone member, 5' to 6':
 - (1). Limestone, one or two massive layers, light gray to dark gray, with limonite concretions at places, weathers buff to brownish, forms large blocks with uneven surface, 1' 6". Fauna: Crinoid joints, Pinna, and many Fusulina. This division has been quarried at several places west and southwest of Syracuse.
 - (2). Shale, bluish, argillaceous, with some calcareous material, 2' or more.
 - (3). Limestone, 1' 9"; upper 6" to 7" dark gray, fine textured, with few fossils, weathers cream colored, forms large flat blocks. It resembles lithographic stone; the lower 1' 2" is lighter colored with some earthy material, and forms rounded blocks which shatter.
 3. Admire Shale member:
 - (1). West Branch Shale, about 26':
 - a. Shale, olive green, argillaceous, crumbly, with some maroon near base, 8' to 10'.
 - b. Limestone, best exposed in ravine in northwest quarter of section 19, bluish gray, irregular, fine textured, dense, somewhat laminated, shows dendrites, about 1' 3".
 - c. Shale, 6' to 8'; upper portion with thin sandy seams and concretionary material, weathered yellowish; middle and base bluish to dark gray, argillaceous, bedded, jointed, with some induration, weathered yellowish.
 - d. Limestone, dark gray, massive, earthy at places, fossiliferous, weathers light gray, forms thin blocks which shatter, about 1'. This is best exposed in the hillside below the quarry farthest west and just south of the concrete bridge 1½ miles west of Syracuse. Fauna: *Meekopora prosseri*, *Rhombopora lepidodendroides*, *Productus cora*, *Allorisma terminale*, crinoid joints, etc.
 - e. Shale, badly covered below quarry farthest west in section 13; probably with some limestone near top and a hard, dark blue, fossiliferous seam a little lower in which are many *Derbya crassa* and echinoid spines. The shale below this seam is largely bluish and argillaceous. Total thickness, 7' to 8'.
 - (2). Falls City Limestone (?), poorly exposed, slabby, thickness (?), with many small pelecypods.

- (3). Aspinwall Shale (?), in slope to ravine, poorly shown, about 20'.
 (4). Brownville Limestone (?), forms hump low in slope.

The exposures at Unadilla and west of Syracuse are not connected by outcrops or by stratigraphic constants. The highest unit exposed on the northwest, i.e., in the vicinity of Unadilla, is what seems to be the Tarkio Limestone, and the lowest to the southeast in the section west of Syracuse, probably is in the horizon of the Brownville Limestone. There should be about 70 or 80 feet of strata in the narrow covered belt between, and this seems to be greater than can be accounted for by the observed dip of the beds at the spur east of Unadilla or at the section west of Syracuse, hence there may be some warping or faulting here, or both. This covered belt is in line with the deformation which extends southwestward from Jones Point to past Otoe.

SECTION SOUTHWEST OF SYRACUSE

Outcrops of shale and thin limestone occur in a hill one mile southwest of town and about one mile farther southwest, in section 29 as follows:

1. Elmdale Shale member, 10' or more:
 - (1). Stine Shale, in badly covered slopes, bluish, about 9', with the following fauna: Crinoid joints, echinoid spines, *Meekopora prosseri*, *Rhombopora lepidodendroides*, *Chonetes granulifer*, *Composita subtilita*, *Spirifer cameratus*, *Productus semireticulatus*, etc.
2. Americus Limestone:
 - (1). Limestone, bluish gray, fairly compact, fossiliferous, forms large thin blocks, weathers light gray to cream colored, 8" to 10".
 - (2). Shale, bluish gray, argillaceous, with sandy seams, weathers yellowish, with a few fossils, 2' to 2' 6".
 - (3). Limestone, thin earthy beds separated by a shale seam, 3' 6"; stone badly shattered and weathered, fossiliferous. Fauna: *Productus semireticulatus*, *Spirifer cameratus*, *Chonetes granulifer*, *Allorisma terminale*, *Fistulipora nodulifera*, *Polypora* sp., *Septopora biserialis*, and *Rhombopora lepidodendroides*.
3. Admire Shale member:
 - (1). West Branch Shale, about 16' exposed:
 - a. Shale, bluish, argillaceous, weathers yellowish, 5'. Top exposed on bed of ravine west of quarry and full thickness shown in ravine one-fourth mile east of quarry.

- b. Shale and limestone layers, in west bank of east ravine, 3' to 4'; upper 6" very dark gray, earthy, fossiliferous limestone; next 3' to 3' 6" bluish bedded shale, underlain by four thin, dark gray, earthy, fossiliferous limestone layers separated by shale seams.
- c. Shale, dark blue, argillaceous, part carbonaceous, finely bedded, forms small plates, weathers yellowish, 5'.
- d. Claystone, dark bluish gray, forms blocks which shatter, 4" to 5". Fauna: Brachiopods and pelecypods.
- e. Shale, badly covered, rusty, argillaceous, weathers yellowish, 1' 2" or more.
- f. Limestone, dark gray, very earthy, 5" to 6". Fauna: Pelecypods and brachiopods.
- g. Shale, weathered yellowish, 1' exposed in ravine east of quarry.

EXPOSURES BETWEEN OTOE AND DUNBAR

There are a few outcrops on the North Fork, near Otoe (formerly Berlin), Dunbar, and Lorton. In the hillsides just northwest of Otoe and about 2 miles north of town is a dark gray limestone, probably the Ervine Creek or higher in the general section. A few exposures on beds dipping southeastward occur between Otoe and Dunbar. The best shown of these are just above and below the Nyman Coal. They are the Pony Creek Shale, Dover Limestone, and Table Creek Shale. They occur in the southeast quarter of section 30, the north half of section 31 and the east half of section 32 passing into section 33, and across section 3.

There is a 16-foot exposure in a cut-bank about one mile west of Dunbar. It seems to be in the Pony Creek Shale and formed of bluish gray fine sand and clay with a few friable sandstone concretions like those at Dunbar.

SECTION AT DUNBAR

This has been worked out on the exposures in the upland under the west part of town and in a cut-bank about three-eighths mile south of town.

1. McKissick Grove Shale member:

(1). Pony Creek Shale, 30' 6":

- a. Shale, in ravine in southwest part of town and along creek and ravines south of town, about 20'; upper portion largely

bluish gray, bedded, sandy to argillaceous, with large gray sandstone concretions above the middle; lower portion exposed, bluish to maroon, with some yellowish brown, sandy flakes; base not shown.

- b. Nebraska City Limestone, exposed at edge of bottom land, south of town, bluish gray to brown, sandy, fossiliferous, with crinoid joints, *Chonetes granulifer*, *Productus semireticulatus*, *Rhombopora lepidodendroides*, and other species, 1' 6" to 2'.
 - c. Shale, bluish, slabby, 4'.
 - d. Shale, maroon, massive to bedded, 5'.
- (2). Dover Limestone, in creek bank, dark gray, fossiliferous, about 1' 6".
- (3). Table Creek Shale, in creek bank, about 14' exposed to creek. This has about 1' of the Nyman Coal near the top.

SECTION ONE MILE SOUTH AND ONE AND ONE-HALF MILES EAST OF DUNBAR

Along Fox Creek in the north half of Section 19, T. 8 N., R. 13 E.

1. Elmdale Shale member:

(1). Stine Shale, about 12' exposed:

- a. Shale, weathered dark brown, probably maroon where fresh, 3'.
- b. Limestone, at top of old quarry and in upland east, blue, dense, weathers gray to buff; fossiliferous, 9".
- c. Shale, bluish at top, grading downward into bands of violet and gray, 8' to 9'. Most of this is argillaceous shale separated by thin, sandy, lime seams. Fauna: Crinoid joints, echinoid spines, *Rhombopora lepidodendroides*, *Meekopora prosseri*, *Septopora biserialis*, *Lophophyllum profundum*, *Composita subtilita*, *Productus semireticulatus*, *Chonetes granulifer*, *Spirifer cameratus*, etc. Many small pelecypods occur in a stony seam near the middle of the division.

2. Americus Limestone member, the quarry bed, light bluish gray to dark gray, fossiliferous, weathers yellowish brown; forms large, thin, rounded blocks and angular debris, thickness (?). Some of the blocks removed from the quarry are 8" to 1' 3" thick. A yellowish limestone which weathers bladed and vesicular in the lower portion is exposed just below the horizon of the quarry ledge. This may represent the bottom limestone of the Americus.

3. Admire Shale member, 46' 4":

(1). West Branch Shale, largely argillaceous, 24":

- a. Bluish gray, argillaceous, massive, no fossils observed, 4'.
- b. Maroon, argillaceous, 2'.
- c. Grayish blue, massive, argillaceous, cut by many small blades, no fossils observed, 6'.
- d. Olive colored, argillaceous, no fossils observed, 4' to 5'.

- e. Dark gray, argillaceous to silty, sandy and calcareous, with an indurated band and a thin fissile seam; total thickness, 6'.
 - (2). Falls City Limestone, bluish gray, jointed, weathers buff, forms slabs, especially in upper portion, about 4'. The basal portion is quite argillaceous.
 - (3). Aspinwall Shale, about 16':
 - a. Shale, dark gray to bluish gray, massive, but slightly bedded at top, crumbly, 2' more or less.
 - b. Claystone, light gray to buff, indurated, limy, 1' 6" to 2'.
 - c. Shale, mostly maroon, argillaceous, massive, with a thin indurated band 2' below top, about 12'.
 - (4). Brownville Limestone, bluish gray, weathers yellowish, 2' 4". This separates into upper and lower portions and forms rough blocks without distinctive form. Fauna: Crinoid joints, *Chonetes granulifer*, *Allorisma*, and a few bryozoa.
4. McKissick Grove Shale member:
- (1). Pony Creek Shale, mostly argillaceous, somewhat arenaceous, 5' 9".
 - a. Bluish, massive, argillaceous, 2' 9".
 - b. Maroon, massive, argillaceous, 3' exposed above creek bed.

The Stine Shale and Americus Limestone are exposed eastward in the south side of Fox Creek valley for about 1½ miles from the quarry. Several outcrops occur to the south in the ravines and slopes east and west of the North Fork between Dunbar and 2 miles south of Lorton.

SECTION TWO MILES NORTH AND THREE-FOURTHS MILE EAST OF LORTON

In ravine near the road crossing at the corners of sections
25, 30, 31, and 36.

- 1. Admire Shale member, probably 4' exposed:
 - (1). Aspinwall Shale, pink, argillaceous, about 2'.
 - (2). Brownville Limestone (?), forms rounded blocks, weathers yellowish; thickness (?).
- 2. McKissick Grove Shale member:
 - (1). Pony Creek Shale, about 21':
 - a. Shale, 4' to 5'.
 - b. Limestone, shattered, shaly, 8" or more.
 - c. Shale, bluish gray, argillaceous, 2' to 3'.
 - d. Shale, largely maroon, massive, 11' to 12'.
 - (2). Dover Limestone, bluish, weathers dark gray to brownish, fossiliferous, 8" to 1' 3" or more.
 - (3). Table Creek Shale, 13' 8" exposed:
 - a. Shale, blue, crumbly, 1' 2".
 - b. Nyman Coal, about 6".

- c. Shale, 12' exposed; top 6' to 7' bluish, argillaceous to arenaceous, bedded to massive, soft to indurated, with a 2" to 3" zone 3' below top carrying many *Chonetes granulifer* and some other fossils; lower portion not well exposed.

The Dover Limestone is well shown in a ravine in the north-east quarter of section 36 where it is overlain with about 8 feet of maroon shale. Limestone associated with vesicular beds and probably in the horizon of the *Americus* is exposed in the upland east of the valley between Dunbar and Lorton, as follows:

1. In the northwest quarter of section 30.
2. In the southwest quarter of section 31.
3. Near the center of section 31.

EXPOSURE ONE-HALF MILE EAST AND THREE-FOURTHS MILE SOUTH OF LORTON

In the creek bank near the center of Section 12, T. N., R. 12 E.

1. Shale, sandy to argillaceous, with heavy grayish sandstone concretions in upper portion, bluish and bedded near base, thickness 15' exposed. Stone is reported to occur a few feet above this, but none is now shown.
2. Nebraska City Limestone (?), dark gray, massive, sandy, with crinoid joints and a few other fossils, about 1' 6". This bed dips eastward about 6' in a distance of 72'.
3. Shale, bluish or dark gray, 4', grading downward into 1½' of yellowish, limy beds.

About 2 miles northeast of Lorton at a point east of the creek and near a house at the center of the section, is an earthy, sandy lime bed near the level of the flood plain. This, which may prove to be the Nebraska City Limestone, is about 1' 10" thick and somewhat micaceous. It is overlain by 6 feet or more of shale exposed, and there is topographic evidence of higher beds.

SPRING CREEK EXPOSURES

There are a few widely scattered outcrops in Spring Creek valley from near its head to its junction with the Little Nemaha east of Tangeman. Most of them, however, are in poor condition for study.

SECTION SIX MILES SOUTH AND TWO MILES EAST OF COOK

In Sections 6 and 7, T. 7 N., R. 12 E.

The McKissick Grove Shale member occurs in the valley sides and hills which are deeply mantled with glacial drift. The key bed in the section is the Tarkio Limestone. Section:

1. McKissick Grove Shale member, at the Schmidt Quarry in section 6, northeast of school house:
 - (1). Table Creek Shale, 5' 2":
 - a. Shale, badly obscured, but probably bluish and argillaceous, 3'.
 - b. Limestone, dark gray, shattered and weathered, quite fossiliferous, 8" or more. Fauna: *Productus semireticulatus*, *Spirifer cameratus*, crinoid joints, *Rhombopora lepidodendroids*, and other bryozoa.
 - c. Shale, dark gray, calcareous, fossiliferous, 1' 6". Divisions (2) and (3) are transitional beds between the Tarkio Limestone and the Table Creek Shale.
2. Tarkio Limestone member, well exposed under the bridge west of the school house, in the creek bank one-fourth mile northeast of the bridge, at the Schmidt Quarry, and at the edge of the valley east of the school house. The elevation of its top is 4' to 5' below the bridge on Spring Creek and 15' or more higher in the quarries east of the school. This shows a dip to the west of about 15' in three-eighths of a mile. The massive limestone of the member is thicker here than at most places, especially so at the Schmidt Quarry, where the section shows:
 - (1). Limestone, bluish gray, weathers brownish, hard, somewhat brittle, 1' 2" to 1' 6".
 - (2). Shale, dark gray to bluish, fossiliferous, arenaceous to argillaceous, 3" to 6".
 - (3). Limestone, bluish gray where fresh, massive, usually in one bed, jointed, forming very large blocks, 6'. This horizon carries many large *Fusulina* and *Osagea*.
 - (4). Limestone, bluish gray, weathers buff, massive, separates as two layers, about 1'.

The Tarkio exposed at the bridge and along the creek to the north is too much weathered and covered for accurate measurement. The quarry face east of the school is nearly covered with overburden and cannot be measured without excavation.
3. Willard Shale member, in banks of Spring Creek from the bridge north, about 12' exposed:
 - (1). Maroon to mottled, greenish-blue, argillaceous but carrying hard calcareous bodies, about 5' at the bridge and 7' farther north.
 - (2). Grayish blue, argillaceous and calcareous, fossiliferous above; plastic and less calcareous in lower portion; thickness exposed, 5'.

SECTION TWO AND ONE-HALF MILES WEST AND THREE-
FOURTHS MILE NORTH OF TALMAGE

In the center of Section 28, T. 7 N., R. 12 E.

1. Shale and thin limestone, about 8':
 - (1). Shale, bluish at base, evidently maroon above, argillaceous, 1' or more exposed below the drift.
 - (2). Limestone, poorly exposed, dark gray, forms sharp blocks, about 7".
 - (3). Shale, grayish, about 1' 2".
 - (4). Limestone, in upper part of abandoned quarry, light gray, dense, forms rounded blocks, about 1'. Fauna: Crinoid joints, brachiopods, and a few other fossils.
 - (5). Shale, bluish gray, bedded, argillaceous, with a few fossils, 4'.
2. Limestone, separated by shale, 3' 10":
 - (1). Limestone, gray, weathers buff to yellowish, jointed, forms large blocks, 1' 6" to 1' 8" exposed. Fauna: Crinoid joints (large and small), Rhombopora, lepidodendroides, Septopora biserialis, Polyopora sp., a few Fusulina, and several brachiopods.
 - (2). Shale, bluish gray, bedded, argillaceous, with some fossils, about 1'. This grades into limestone above and below.
 - (3). Limestone, light gray, weathers brownish, becomes shattered along middle, somewhat sandy and porous at base, 1' 4". Fauna: Chonetes granulifer, Productus cora, Allorisma, Rhombopora lepidodendroides, fenestrated bryozoa, etc.
3. Shale, about 26":
 - (1). Shale, bluish, argillaceous to sandy, cut by hard plates, weathered yellowish, 3' 6".
 - (2). Shale, maroon, mostly massive, with some jointing, largely argillaceous, about 5'. This seems to carry a thin bed of weathered limestone near its base.
 - (3). Shale, in bands of different shades of gray, largely argillaceous, with some calcareous concretions, a portion bedded, fossiliferous in basal 3' to 4'; total thickness, 18' to 19'.
4. Limestone, with a shale separation, 3' 9":
 - (1). Limestone, gray to brownish, massive, fossiliferous, 1' 4". The principal fossils are crinoid joints and Productus semireticulatus.
 - (2). Shale, bluish where fresh, weathers yellowish to brownish, argillaceous, with some calcareous material, fossiliferous, 1' to 1' 3" or more.
 - (3). Limestone, bluish gray, massive, weathers yellowish to brownish, 1' 4" exposed. Fauna: Crinoid stems common.
5. Slope to creek bed, about 15'.

The divisions of this section are correlated provisionally as follows:

- Number 1, the base of the McKissick Grove Shale.
- Number 2, Tarkio Limestone.
- Number 3, Willard Shale.
- Number 4, Emporia Limestone.

EXPOSURES AT TANGEMAN

In Section 21, T. 7 N., R. 12 E.

The outcrops here are in the foot of the upland south of the railroad, rising 25 feet or more above the bottom land to an altitude of about 1,030 feet. Section:

1. Limestone, gray, weathers yellowish, thickness (?).
2. Shale, about 10' to 11':
 - (1). Maroon, largely argillaceous, 6'.
 - (2). Bluish, argillaceous, massive, with some small calcareous bodies, 4' to 5'.

These beds have not been correlated.

EXPOSURES NORTHWEST OF TALMAGE

There is a very good outcrop in the railroad cut near the center of section 26 about 1½ miles northwest of town and a badly covered one in the spur of the upland just south of an abandoned course of the river in the northeast corner of section 27. The beds are nearly identical at these places. They show as follows in the south face of the railroad cut:

1. Shale, poorly exposed.
2. Limestone, dark gray, fossiliferous, thickness (?).
3. Shale, maroon above, bluish below, about 10' or 11'.
4. Limestone, top exposed in north railroad gutter, brownish, weathered chalky.

Division 2 seems to be the same as one of the beds high on the hillsides in the west half of section 27 and near the middle of section 28 where it was quarried several years ago.

There are no exposures of any consequence between Talmage and Brock. It is thought, however, that the strata have a low southeast dip in this covered stretch.

Beginning southwest of Brock and extending southward up Houchen's Creek to near Johnson and eastward past Glenrock and Auburn, there are nearly continuous outcrops of beds dipping southeastward, first quite rapidly, then slowly.

SECTION ON HOUCHEN CREEK BETWEEN JOHNSON
AND BROCK

I. Permian System; Council Grove Formation

1. Cottonwood Limestone member, exposed at places along branch of Houchen's Creek northeast of Johnson, the following in the southwest quarter of section 4:
 - (1). Bluish-gray, weathers slabby, 2' 6".
 - (2). Dark gray, massive, forms large rectangular blocks, with a few *Fusulina*, 2' 7" to 2' 8".
 - (3). Gray, massive, with many *Fusulina*, 2' 6". On weathering this forms a shaly seam 8" below the top.
 - (4). Gray, massive, with small cherty concretions and many *Fusulina*; weathers into layers and rounded blocks, 4' to 5'. At places there is a 2" shale seam 6" to 8" above the base.

II. Pennsylvania System; Wabaunsee Formation

1. Eskridge Shale member, 49' or more:
 - (1). Shale, in section 4 and other places, argillaceous, in bands of blue, red, or chocolate colored, 14' to 16'.
 - (2). Limestone, on bed of creek in section 4, dark gray, dense, forms flat blocks, weathers yellowish or light gray, with crinoid joints and brachiopods throughout and small pelecypods in upper portion, 1' to 1' 2".
 - (3). Shale, covered at most places on Houchen Creek, well shown along the creek to the east. Shale argillaceous, in bands of purple, olive, maroon, chocolate, and light bluish gray, about 12'.
 - (4). Limestone, gray, massive, forms rectangular blocks, 1' +. Fauna: *Fusulina*, a few large pelecypods, and crinoid joints.
 - (5). Shale, exposed on creeks east, blue to olive colored, argillaceous, modified by buff or gray silty bands and very thin sandy flakes which weather yellowish brown, 12' to 16'.
2. Neva Limestone member, forms bench in northwest quarter of section 4, badly covered at most points, probably 8'.
3. Elmdale Shale member, exposed along Houchen Creek between section 4 and the center of section 29:
 - (1). Roca Shale, badly covered in the northwest quarter of section 4, thickness 20' or more.
 - (2). Howe Limestone, on creek bed in northwest quarter of section 4, about 4'.
 - (3). Bennett Shale, covered in northwest quarter of section 4, and southwest quarter of section 33, about 8'.
 - (4). Glen Rock Limestone, in east bank of creek in northwest quarter of section 4, dipping rapidly southeastward; high in section 31 and the southeast quarter of section 29, at top of exposure in the west bank of creek 1½ miles north of Johnson; dark gray, dense, fossiliferous, with *Pinna*, *Fusulina*, etc., about 1' 6".

- (5). Johnson Shale, northwest quarter of section 4, in west creek bank $1\frac{1}{2}$ miles north of Johnson, bluish to yellow, mostly argillaceous, with some calcareous and arenaceous material, 16'.
- (6). Long Creek Limestone, well shown on creek bed $1\frac{1}{2}$ miles north of Johnson, yellowish, bedded to very irregular, with geodes at places, about 6'.
- (7). Hughes Creek Shale, best shown east of creek through section 29, where it has the well-marked faunal horizon near top; thickness 45'.
- (8). Houchen Creek Limestone, east of creek in sections 29 and 32, where it forms a bench; weathered yellowish and irregular, with large masses of algal growth, 3' to 5'.
- (9). Stine Shale, east of creek in section 29, about 17 or 18':
 - a. Shale, in blue and maroon bands, about 8'.
 - b. Limestone, arenaceous, weathers buff and nodular, 6" to 8".
 - c. Shale, badly covered, about 3'.
 - d. Limestone seam, with pelecypods.
 - e. Shale, bands of blue and red, argillaceous to arenaceous, fossiliferous in lower portion, about 6'.
4. Americus Limestone member, part covered, the main portion dark-gray or weathered brownish, forms rectangular blocks, 1' 2" to 1' 4". Fauna: Fusulina, crinoid joints, a few bryozoa, several brachiopods, small gastropods, pinna, Myalina.
5. Admire Shale member:
 - (1). West Branch Shale, about 9" exposed:
 - a. Shale, nearly black, bedded, weathers brownish, 2".
 - b. Shale, bluish, argillaceous below; bladed and calcareous above, 3'.
 - c. Claystone, irregular, calcareous, 1'.
 - d. Shale, bluish gray, argillaceous, crumbly, 3' exposed above creek bed.

Some badly covered beds, probably older than the above, are exposed in the northeast quarter of section 29, southwest of Dunbar.

COMBINED SECTION, GLENROCK TO AUBURN

I. Permian System, Council Grove Formation

1. Cottonwood Limestone member, about 12' thick southwest of Glenrock; apparently thinner in cap of hill south of Auburn. This division forms the highest rim rock, altitude 1,100' near Auburn and 1,120' or more west of Glenrock.

II. Pennsylvanian System; Wabaunsee Formation

1. Eskridge Shale member, forms slope between the Cottonwood and Neva limestones; divisions or beds the same as in the section northeast of Johnson, but their combined thickness is somewhat greater, averaging 50' and reaching 60' at places.

2. Neva Limestone member, about 12', forms a high disconnected rock bench. The best exposure, along the highway crossing Cemetery Hill west of Auburn, shows:

- (1). Limestone, one massive, dark gray bed, weathering light gray, with many ostracods, 4" to 6".
- (2). Shale, dark gray, weathers yellowish to brownish, slabby and vesicular, 1' to 2' 4".
- (3). Shale, 1'; bluish and argillaceous in upper 6"; somewhat arenaceous and calcareous in lower 6".
- (4). Limestone, bluish gray, massive, grading into shale above; with myriads of ostracods, 1' 6".
- (5). Shale, argillaceous, slabby, 4".
- (6). Limestone, bluish to light gray, massive, dense, with some earthy material, free calcite, and pebbles, 1' 2" to 1' 6". This has many ostracods.
- (7). Shale, argillaceous, 6".
- (8). Limestone, dark gray, dense, massive, with some free calcite, pebbles, and many ostracods, 1' 8".

The Neva has slumped badly at this position. Probably (1), (2), and (3) are transitional beds at the base of the Eskridge member, like those at Roca.

3. Elmdale Shale member, about 62' exposed:

- (1). Roca Shale, in slope west of cemetery, 24', including:
 - a. Shale, light gray on surface, light blue where fresh, argillaceous, with faint hue of maroon in middle, also some calcareous material throughout, 7'.
 - b. Shale, olive green, argillaceous, with maroon hue near base, 11'.
 - c. Limestone, brownish, vesicular, 1'.
 - d. Shale, maroon, argillaceous, 1' 6" to 2'.
 - e. Shale, bluish, calcareous, 3' 9".
- (2). Howe Limestone, yellowish, earthy, arenaceous, badly weathered, 4'.
- (3). Bennett Shale, dark to dark blue, 5', with a thin black layer 1' 8" above its base and a platy carbonaceous layer 1' 6" higher. The dark layer carries many lingula and orbiculoidea, as at Bennett and Douglas.
- (4). Glen Rock Limestone, gray to yellowish, badly weathered, slabby, 1' 2".
- (5). Johnson Shale, about 15':
 - a. Claystone and slabby layers, mostly bluish and argillaceous, 10' 6".
 - b. Dark, earthy zone, 1' 5".
 - c. Calcareous seam, 2".
 - d. Shale, bluish, argillaceous, 1'.
 - e. Calcareous seam, 3".
 - f. Shale, bluish, argillaceous, 1' 8".
- (6). Long Creek Limestone, dark gray, weathered yellowish to brownish and vesicular, 1' 8" to 2' 2".

- (7). Hughes Creek Shale, 11' exposed above creek bed west of cemetery:
- a. Calcareous to slabby layers which weather grayish to yellowish, 1' to 2'.
 - b. Shale, dark, bedded, argillaceous, 1' 2".
 - c. Shale, 1' 4" to 2', dark, weathers grayish, largely argillaceous, but somewhat calcareous and indurated, causing it to resemble limestone. This carries *Productus cora* and other brachiopods. It is the same as zone A, sub-zone (B) at Bennett.
 - d. Shale, dark blue, lighter on weathered surface, argillaceous, plastic, bedded to massive and fossiliferous throughout, but thin seams of limestone are very fossiliferous. Thickness exposed above creek bed, 7'. *Chonetes granulifer*, *Spirifer cameratus*, *Rhombopora lepidodendroides*, *Septopora biserialis*, *Meekopora prosseri*, *Productus cora*, *Ambocoelia planoconvexa*, and crinoid joints. This is the same as zone 7a, sub-zone (C) at Bennett.

SECTION AT ROHRS

Modified after N. A. Bengtson

This is on Long's Creek, in the northeast quarter of Section 22, T. 5 N., R. 13 E.

I. Permian System; Council Grove Formation

1. Cottonwood Limestone member:
 - (1). Limestone, one hard, tabular bed, weathered buff or yellowish brown, 10".
 - (2). Limestone, badly weathered, 8'.

II. Pennsylvanian System; Wabaunsee Formation

1. Eskridge Shale member, 7' exposed:
 - (1). Shale, light blue, argillaceous, calcareous, 5'.
 - (2). Shale, maroon, 2' shown above creek.

North of the Little Nemaha between northeast of Glenrock and opposite Auburn there are some good exposures of the Neva and older beds dipping slowly southeastward. Beyond this stretch the Hughes Creek strata outcrop at places to beyond Schwartz Run northwest of Nemaha City. South of the river, between Auburn and Stine, are exposures of beds from the Neva down to the Admire Shale member.

COMBINED SECTION AT HOWE

1. Neva Limestone member, in the upland south and east of town but not in condition for accurate measurement.

2. Elmdale Shale member, 38' 3" or more exposed:
- (1). Roca Shale, poorly shown south and southwest of town, represented by bands of blue, greenish, and maroon shale; basal portion very irregular, with much bladed material and a few geodes; combined thickness 20' or more.
 - (2). Howe Limestone, in ravines southwest of Howe at an elevation of 20' above the depot, and northeast of town where it holds a poorly defined bench along the east side of Hughes Creek. Stone light gray, weathered, with bladed material and rose colored quartz geodes, about 4'.
 - (3). Bennett Shale, 8':
 - a. Greenish, argillaceous, 2'.
 - b. Greenish, with thin, light-colored limestone and concretionary lime, 6'.
 - (4). Glen Rock Limestone, weathered dark gray, vesicular, irregular, 1' 3".
 - (5). Johnson Shale, about 5' exposed:
 - a. Shale, greenish, blocky, 2'.
 - b. Shale, greenish, argillaceous, massive, 3' shown above creek bed. The Johnson Shale, Long Creek Limestone, and Hughes Creek Shale crop out along Hughes Creek north and northeast of Howe.

STINE SECTION

In Section 5, T. 4 N., R. 15 E.

1. Elmdale Shale member, 94' exposed:
 - (1). Howe Limestone, poorly exposed across east-west road and near the southeast corner of the section, altitude about 1,060', thickness probably 4'.
 - (2). Bennett Shale, Glen Rock Limestone, and Johnson Shale, badly covered in slopes, combined thickness about 26'.
 - (3). Long Creek Limestone, forms poorly defined high bench, weathers yellowish, about 4'.
 - (4). Hughes Creek Shale, Houchen Creek Limestone, and Stine Shale, forming a gradual slope with a few outcrops, about 60'. The characteristic faunal zone near the top of the Hughes Creek Shale is exposed west of the pine grove on the hill.
 - (5). Houchen Creek Limestone and Stine Shale, exposed in cut-bank along Indian Creek:
 - a. Shale, bluish, argillaceous, with many pelecypods, and some brachiopods, 3'.
 - b. Limestone, earthy, forms rounded blocks, with pelecypods, 6".
 - c. Shale, argillaceous, 3' 6".
 - d. Limestone, bluish to dark gray, weathers yellowish, fossiliferous, 8".
 - e. Shale, blue to dark, argillaceous, 7' 6".
2. Americus Limestone member, in cut-bank in the northwest quarter of section 5, about 8' 6":

- (1). Limestone, light gray to buff, somewhat earthy, massive, 1' to 1' 4". Fauna: Pinna, large Allorisma, Myalina, and a few brachiopods.
 - (2). Shale, about 6'; bluish, argillaceous, massive above; black and bedded below.
 - (3). Limestone, part weathered yellowish; slabby at top, 1' 4" to 1' 6".
3. Admire Shale member, 19' or more exposed:
- (1). West Branch Shale, in cut-bank on Indian Creek:
 - a. Shale, dark, with some platy material; massive at base, 3'.
 - b. Shale, light blue, argillaceous, massive, crumbly, 12'.
 - c. Limestone, gray, weathering nodular and yellowish, irregular, 1' or more.
 - d. Shale, light blue, argillaceous, massive, with some induration, 3' exposed on creek bed.

The Long Creek Limestone and the Hughes Creek Shale with its distinctive faunal zones are exposed at various places in the Indian Creek valley southwest of Stine. The following section, along the road between the southeast quarter of section 7 and the northeast quarter of section 17, is typical:

- a. Long Creek Limestone, poorly exposed near top of hill, 2' or more.
- b. Slope, about 23'; upper part covered; lower part with shale showing *Chonetes granulifer*, *Chonetes vernuilianus*, *Spirifer cameratus*, *Productus semireticulatus*, *Meekopora prosperi*, *Rhombopora lepidodendroides*, large *Fusulina*, etc.
- c. Limestone (five thin beds) and inter-stratified shale, 14'. This horizon is also quite fossiliferous, with *Meekopora prosperi*, *Productus semireticulatus*, *Spirifer cameratus*, *Margini-fera splendens*, *Composita subtilita*, and other species.
- d. Covered slope to bridge, 11'.
- e. Bridge to creek bed, 19', with massive, greenish shales forming the lower 4'.

SECTION ONE MILE SOUTH AND ONE AND ONE-HALF MILES
EAST OF STINE (Bracken)

In the north half of Section 9, T. 4 N., R. 15 E.

Some of the basal beds of the Elmdale Shale member are poorly shown along the ravine in the northwest quarter of section 9. The following section is based on exposures in the northeast quarter of section 9:

1. Americus Limestone member, 8' or more:
 - (1). Limestone, light bluish gray, one bed, forms irregular blocks, about 1' 4". Fauna: Crinoid joints, Pinna, and brachiopods.
 - (2). Shale, yellowish, 3" to 4".
 - (3). Shale, blue, mostly argillaceous, 5' 6".
 - (4). Limestone, earthy, 9" to 1' 4".
2. Admire Shale member, 22' or more exposed:
 - (1). West Branch Shale, about 20':
 - a. Bluish, argillaceous, massive, part bedded, 11'.
 - b. Slabby, sandy-lime beds, and shale seams, 2' to 3'.
 - c. Bluish, weathering yellowish, mostly argillaceous, 6' to 7' to 7'.
 - (2). Falls City Limestone, bluish gray, part dense, weathering brownish and porous; thickness (?) probably 2' or more; altitude about 912'.

The Falls City Limestone is exposed at various places south of the valley between this section and south of Nemaha City. It forms a poorly defined bench which extends into Jivers and Whiskey Run valleys. The Americus Limestone crops out in a ravine in the southeast quarter of Section 10, T. 4 N., R. 15 E.

In places, the slopes along Jivers Creek and its branches are occupied by beds higher than the Falls City Limestone, up to the Long Creek bed which is quite well shown in the northeast quarter of Section 34, T. 4 N., R. 15 E., where it has been quarried. The main faunal zone of the Hughes Creek Shale is shown there on a hill spur north of the quarry.

There are intermittent exposures on Whiskey Run of beds from the Falls City Limestone up to the Hughes Creek Shale, the latter being quite well shown near the Nemaha-Richardson county line. The strata dip slowly northwestward between these points and Stine.

SECTION IN THE BLUFF SOUTH OF THE MOUTH OF THE LITTLE NEMAHA

1. Admire Shale member, about 29' 6" exposed:
 - (1). Falls City Limestone, high in bluff but slumped at places, bluish gray, massive, weathered brownish, forms large rectangular blocks, 2' 6". Fauna: Pelecypods and ostracods.
 - (2). Aspinwall Shale, about 25':
 - a. Shale, bluish, argillaceous, 7' to 8'. A seam of limestone in the upper part is rich in Myalina.
 - b. Limestone, bluish gray, 6" to 1'.

- c. Shale, blue, massive, argillaceous, 8'.
- f. Shale, maroon, grading into blue, about 9'. This is quite calcareous and includes an earthy limestone.
- (3). Brownville Limestone, dark gray, weathers brownish, broken in upper part, mostly massive, 1' 10" to 2' 8".
- 2. McKissick Grove Shale member, about 36':
 - (1). Pony Creek Shale, about 17' to 18':
 - a. Shale, blue, argillaceous, with some sand, bedded to massive, 6'.
 - b. Limestone, light bluish gray, fossiliferous, 1' to 1' 4".
 - c. Shale, maroon, massive or bedded, 10' to 11'.
 - (2). Dover Limestone, earthy, not well exposed, thickness (?), probably about the same as at the Aspinwall Ferry.
 - (3). Table Creek Shale, with the Nyman Coal at the top, followed by bands of blue, dark, and maroon shale and some sandstone, none well shown in the 15' to 20' slope to the river.

THE BIG NEMAHA CROSS SECTION

There are many exposures of the Pennsylvanian and Permian beds in the various branches of the Big Nemaha Valley of Nebraska, in Johnson, Pawnee, Richardson, and Nemaha counties, on strata from the Deer Creek member to the Wreford Limestone member.

The Table Rock Anticline and the Humboldt Fault are the dominant structural features of this cross section. They bring the older strata to the surface in a comparatively wide north-south belt and separate the area into east and west areas, which, although very unequal in extent, have the same sequence of the beds exposed (Plate VI). This cross section is like the Kansas Valley section between Manhattan and a few miles west of Topeka, the beds having the same character but differing somewhat in elevation and exposure.

The strata of the Big Nemaha cross section dip westward from the Missouri River to southeast of Dawson beyond which they are nearly horizontal with low reversals to the Humboldt Fault. West of the fault they left quite rapidly in the east flank of the Table Rock Anticline and lower gradually in its west flank.

Correlation. The study of the Big Nemaha area began in the vicinity of Tecumseh on exposures of the Tarkio Limestone, Willard Shale, and Emporia Limestone, then thought

to be the Cottonwood, Eskridge, and Neva members. Later the Table Rock Anticline was discovered, and the Cottonwood Limestone proper was found to occur high above the Tarkio with which it had been confused. The Cottonwood was then traced through many exposures and used as a key bed in further study. The Eskridge and Neva members were found to occur in regular order beneath it, as in Kansas, but the boundaries of the Elmdale and Admire members were not determined in Nebraska until after the lower members of the Wabaunsee had been worked out and correlated with exposures in Iowa, Missouri, and Kansas. The Scranton member presented no difficulties. The Howard, Severy, Topeka, Calhoun, and Deer Creek members were not correlated in the exposures of the Table Rock Anticline southeast of Du Bois until 1923, after which the Americus Limestone was traced from its type locality in Kansas to the Big Nemaha sections, thus establishing the boundary between the Elmdale and Admire members in Nebraska.

DESCRIPTION OF EXPOSURES

The Big Nemaha drainage is formed principally by the North Branch Nemaha and the South Branch Nemaha, each with a number of tributaries. The details of the exposures in the area, starting in the northwest and working eastward, are shown by the following descriptions and sections:

Exposures Near Vesta. There are a few badly concealed outcrops in the vicinity of Vesta. Their exact stratigraphic position, which probably is near the base of the Permian, has not been determined.

Vicinity of Tecumseh. From west of Tecumseh to below Elk Creek are nearly continuous exposures of some of the lower beds of the Wabaunsee formation, dipping westward. At the foot of the slope west of Tecumseh, in the southwest quarter of section 29 and the northwest quarter of section 32, is the following exposure:

1. McKissick Grove Shale member:

(1). Pony Creek Shale:

a. Shale, gray, badly covered, thickness (?).

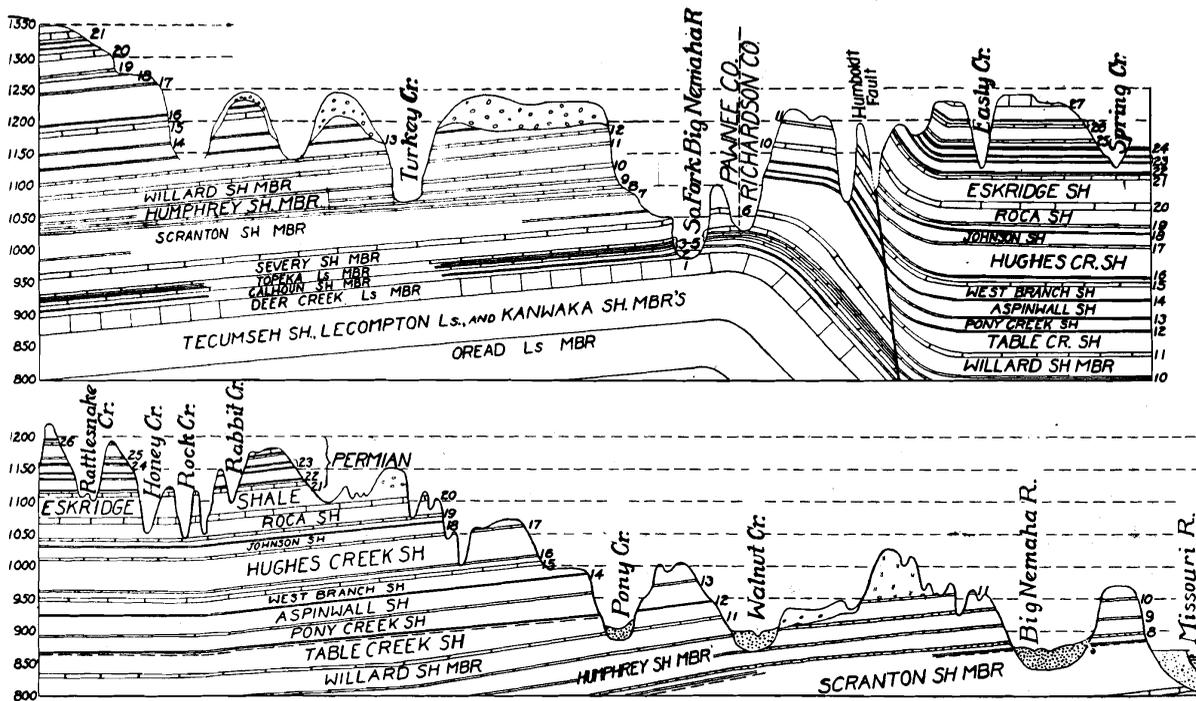


PLATE VI.—The Big Nemaha Valley cross section. Limestones: 1, Deer Creek beds 2, Meadow; 3-5, Topeka; 6, Howard; 7, Rulo; 8, Burlingame; 9, Wakarusa; 10, Emporia; 11, Tarkio; 12, Dover; 13, Brownville; 14, Falls City; 15, Americus; 16, Houchen Creek; 17, Long Creek; 18, Glen Rock; 19, Howe; 20, Neva; 21, Cottonwood; 22, Morrill; 23, Eiss; 24, bed in the Easley Creek Shale; 25, Sabetha; 26, beds in the Speiser Shale; 27, Wreford.

- b. Nebraska City Limestone (?), dark gray, with *Rhombopora lepidodendroides*, *Chonetes granulifer*, 1' +.
 - c. Shale, bluish above, part reddish at base, about 5'.
- (2). Dover Limestone, about 10' above the bottom land, 2'.

In a ravine north of the golf course, seven-eighths mile south of Tecumseh, is the following section:

1. McKissick Grove Shale member:

- (1). Pony Creek Shale, about 16' 6" exposed:
 - a. Shale, gray, argillaceous to sandy, bedded, with rusty seams, 10' to 12'.
 - b. Shale, bluish-gray above, maroon below, 2' 6".
 - c. Nebraska City Limestone (?), dark gray, earthy, forms large slabs or blocks, 1'.
 - d. Shale, maroon, massive, 2' shown above bed of the ravine.

South of the Tecumseh Cemetery, in the northwest quarter of Section 24, T. 5 N., R. 11 E., is the following exposure:

1. McKissick Grove Shale member, 10' or more exposed:
- (1). Shale, thickness (?), a few feet.
 - (2). Nyman Coal, about 1'.
 - (3). Shale, gray, silty to sandy, with yellowish, sandy seams, 3'.
 - (4). Sandstone, with fine flakes of mica, 2'; upper portion bluish gray; lower portion soft.
 - (5). Shale, sandy, bedded, 3'.
 - (6). Slope to flood plain, 10' to 12'.

In the new channel of the Big Nemaha River southeast of Tecumseh, near the center of section 34, is the following:

1. Emporia Limestone member (lower bed), bluish-gray, massive, weathers yellowish, separates into layers, 5' 9" to 6'. Fauna: *Fusulina*, crinoid joints, and brachiopods.
2. Humphrey Shale member:
- (1). Auburn Shale, 10' 6":
 - a. Shale, dark gray, sandy, 1'.
 - b. Shale, blue, argillaceous, with some calcareous bodies, 1'.
 - c. Shale, maroon with gray mottling, sandy to argillaceous, massive, bedding shown where weathered, with some induration, 5'.
 - d. Shale, bluish gray with some maroon, argillaceous to sandy, 1' 8".
 - e. Shale, blue, bedded, argillaceous, 1' 10" exposed above the river bed.

RAILROAD CUT SECTION TWO MILES SOUTHEAST
OF TECUMSEH

Southwest quarter of Section 35, T. 5 N., R. 11 E.

1. Tarkio Limestone member, holds poorly-defined rock terrace, massive, weathered brownish, with myriads of robust *Fusulina* and *Osagea*, 5'.
2. Willard Shale member, badly covered in slope, base exposed in railroad cut, 28' to 30'.
3. Emporia Limestone member, 9' 2" shown in cut:
 - (1). Limestone, one bed, fossiliferous, with rough surface, forms rectangular blocks, 1' 2".
 - (2). Shale, dark blue, argillaceous, with some sand, 2'.
 - (3). Limestone, separated by shale seams, 6'; fossiliferous, jointed, and quite firm except where badly weathered.
4. Humphrey Shale member:
 - (1). Auburn Shale, 4' exposed in cut:
 - a. Shale, grayish, argillaceous, with sandy-lime seams, 2' 6".
 - b. Shale, maroon, 1' 6" exposed.

SECTION TWO AND ONE-HALF MILES SOUTHEAST OF
TECUMSEH

In ravine in southwest quarter of Section 3, T. 4 N., R. 11 E.

1. Tarkio Limestone member, 8' 4" or more:
 - (1). Limestone, dark gray, hard, conglomeratic, 2'.
 - (2). Limestone, disintegrated, with some shale, bluish gray, pebbly, with many *Fusulina*, 1' +.
 - (3). Limestone, light gray or weathered yellowish, blocky near base, with many *Fusulina*, 5' 6".
2. Willard Shale member, about 28':
 - (1). Shale, sandstone and disintegrated limestone, irregular, 3' to 6'. This has about 1' of broken down limestone at the base.
 - (2). Shale, reddish, not very regular, 1' to 2'.
 - (3). Shale, ashy-gray, argillaceous to sandy, massive or bedded, with thin, sandy layers, about 18'.
 - (4). Shale, dark, argillaceous, 8".
 - (5). Shale, blue above, maroon below, massive, argillaceous to sandy, 2' 6".
3. Emporia Limestone (upper bed), forms rock bench at edge of the Big Nemaha flood plain, about 2' shown.

The Tarkio Limestone is exposed in sections 34, 35, 2, 3, and the northwest quarter of section 11, forming an eroded bench.

CARSON CREEK SECTION TWO AND ONE-HALF MILES
SOUTH OF TECUMSEH

South half of Section 4, T. 4 N., R. 11 E.

1. McKissick Grove Shale member, 27' 3" exposed:
 - (1). Pony Creek Shale, 11' 6":
 - a. Shale, exposed in creek bank west of school house, grayish, 3'.
 - b. Nebraska City Limestone, dark gray, earthy, sandy, 6" to 8".
 - c. Shale, bluish-gray, irregular, part massive and dark gray, 2'.
 - d. Shale, grayish to yellowish and red, irregular, massive, part bedded, sandy, micaceous, 6'.
 - (2). Dover Limestone, in creek bank north and west of school, about 3' 6".
 - a. Limestone, bluish, hard, fossiliferous, 1' 3".
 - b. Limestone, dark gray, shelly, quite fossiliferous, 2' 4".
 - (3). Table Creek Shale, about 12' 3" exposed:
 - a. Nyman Coal, 4" to 8".
 - b. Shale, bluish gray, argillaceous, irregular but bedded, 4' 6".
 - c. Sandstone, one or two layers, soft, massive, 1' 3".
 - d. Shale, bluish gray, sandy, massive, no fossils observed, 6' exposed in creek bank northeast of school.

SECTION THREE MILES SOUTH OF THE EAST SIDE
OF TECUMSEH

In ravine south of creek between the southeast quarter of Section 9 and the southwest quarter of section 10.

1. McKissick Grove Shale member, 17' 8":
 - (1). Dover Limestone, 3' 4":
 - a. Limestone, about 2' exposed; upper portion forms rounded blocks; lower portion yellowish, jointed, forming rectangular blocks.
 - b. Shale seam, 3" to 4".
 - c. Limestone, dark gray, shelly, earthy, somewhat arenaceous, 1'.
 - (2). Table Creek Shale, 5' 6" exposed:
 - a. Shale, blue, argillaceous, 1'.
 - b. Nyman Coal, 1'.
 - c. Shale, blue, argillaceous, with rusty flakes, 1'.
 - d. Sandstone, concretionary, probably 2'.
 - e. Shale, blue, bedded, argillaceous, with some rusty flakes, 6" exposed at top of covered shale slope to creek.

SECTION TWO MILES NORTH AND THREE-FOURTHS MILE
WEST OF ELK CREEK

Along the north-south road, between the northeast quarter of section 14 and the northwest quarter of Section 13.

1. Emporia Limestone member, 11' 6":
 - (1). Limestone, bluish, massive, weathers yellowish, with many crinoid joints and brachiopods, 1' 6".
 - (2). Shale, blue, argillaceous, 3' to 4'.
 - (3). Limestone, bluish gray, weathered brownish and as three beds, 1' 8".
 - (4). Shale, blue, argillaceous, fossiliferous, 4".
 - (5). Limestone, weathered brownish and slabby, 8".
 - (6). Limestone, a hard seam, 2".
 - (7). Shale, argillaceous, 4".
 - (8). Limestone, gray, fossiliferous, 8" to 10".
 - (9). Shale, calcareous or weathered limestone, fossiliferous, 6" to 8".
 - (10). Limestone, gray, 2'.
2. Humphrey Shale member, 30' 6" or more exposed:
 - (1). Auburn Shale, 20' +:
 - a. Shale, blue, calcareous, 1' 3".
 - b. Shale, maroon, bedded, argillaceous, with some fine mica, 5'.
 - c. Shale, blue, weathered gray, about 14' exposed.
 - (2). Wakarusa Limestone, 4' 6":
 - a. Limestone, blue, weathered brownish, with crinoids, *Productus semireticulatus*, etc., 1' 4".
 - b. Shale, argillaceous to calcareous, fossiliferous, 1' to 2'.
 - c. Limestone, two beds, weathered gray to brownish, fossiliferous, 1' 8".
 - (3). Soldier Creek Shale, blue, argillaceous, with some calcareous seams and plates, 6' exposed.
3. Burlingame Limestone member, poorly shown along the creek southwest.

The Emporia Limestone caps a high rock bench in section 11 northwest of Elk Creek in which the Wakarusa, Burlingame, and Rulo limestones form small terraces, and the top of the Scranton member is covered in the lower valley sides.

SECTION ONE AND THREE-FOURTHS MILES WEST OF ELK CREEK

In ravine in southeast quarter of section 22 and southwest quarter of section 23.

1. Willard Shale member, west of bridge, bluish gray, massive or bedded, argillaceous to sandy, 10' shown.
2. Emporia Limestone member, 4' 9":
 - (1). Limestone, light gray, one bed, weathered buff, jointed, forms rectangular blocks, 1' 3". Fauna: Crinoid joints and fragments of other fossils.

- (2). Shale, blue, massive; jointed, argillaceous or silty, weathers yellowish, 1' 8".
 - (3). Limestone, blue, massive, with few joints, weathers yellowish, not many fossils, 1' 10".
3. Humphrey Shale member:
- (1). Auburn Shale, bluish gray, massive, argillaceous, 2' exposed above bed of ravine. The basal 6" is loosely indurated.

In most of the distance between Elk Creek and Table Rock the valley sides are formed on drift, and there are few exposures of the Pennsylvanian beds.

SECTION THREE AND ONE-HALF MILES NORTH OF
TABLE ROCK

In the southeast quarter of section 7 and southwest quarter of section 8.

1. Scranton Shale (White Cloud), bluish, argillaceous, basal portion in cut-bank west of road, 15'.
2. Limestone and shale, 5' or more:
 - (1). Limestone, on creek bed east and west of road, dark blue, dense, fossiliferous, with crinoid joints and several species of brachiopods and bryozoa, 8".
 - (2). Shale seam, 3".
 - (3). Limestone, exposed west of road, and in creek bank east of road. This is quite fossiliferous. Fauna: *Septopora biserialis*, *Derbya crassa*, *Derbya bennetti*, *Productus cora*, *Spirifer cameratus*, *Marginifera splendens*, *Pustula nebraskensis*, *Myalina swallowi*, crinoid joints, etc. It is crowded with *Pustula nebraskensis*, *Derbyas*, and *Myalinas*.
 - (4). Shale, formerly exposed in creek bank east of road, bluish, argillaceous, weathered yellowish, with a few fossils, 2' 6".
 - (5). Limestone, formerly shown on creek bed east of road, 1' 2"; top weathered yellowish; the base contains several brachiopods.

There is some doubt regarding the correlation of the limestones of this section. They seem to be in the Scranton Shale member, but are thicker than any known limestones of that member except the Howard, Cass, and South Bend beds of the Platte Valley. They may prove to be the Howard as indicated by the fauna. If so, the Scranton Shale member is thinner here than was expected.

TABLE ROCK SECTION

At the brick plant, south of Taylor Branch, in Section 5, T. 1 N., R. 12 E. (Figure 35).

1. Emporia Limestone member, caps most of the upland, represented by limestone beds and thin shales, but too much concealed for accurate measurements, 8' or more.
2. Humphrey Shale member, 28' to 29':
 - (1). Auburn Shale, blue and maroon, mostly argillaceous, 14'.
 - (2). Wakarusa Limestone, two or three brownish limestones separated by thin shales, 4' or more.
 - (3). Soldier Creek Shale, with bands of blue and maroon, fossiliferous at base, 10' to 11'.
3. Burlingame Limestone member, dark blue, massive, forms large blocks, weathers brownish, 2' 4" to 3'. Fauna: Brachiopods, gastropods, and crinoid joints.
4. Scranton Shale member, about 41' 6" exposed:
 - (1). Silver Lake Shale, 10' 6":
 - a. Argillaceous to sandy, weathered buff, 3'.
 - b. Clayey, with badly weathered, fossiliferous limy material, 2'.
 - c. Dark blue, bedded, argillaceous, quite fossiliferous, 5' 6".
Fauna: Crinoid joints, *Rhombopora lepidodendroides*, a few pelecypods, and several species of brachiopods; *Chonetes granulifer* and *Ambocoelia planoconvexa* very common.

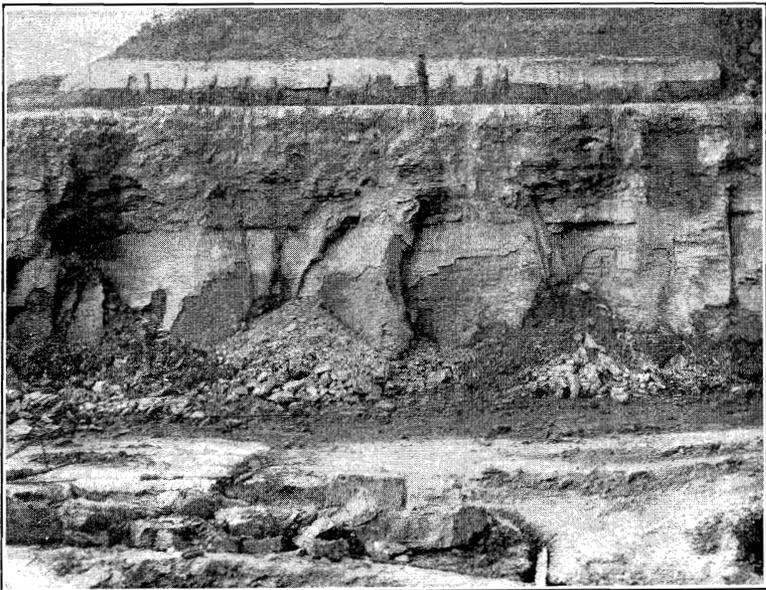


FIGURE 35.—Scranton Shale and base of the Wabaunsee at the Table Rock clay pit.

- (2). Rulo Limestone, dark blue, massive, fossiliferous, weathers brownish, forms large blocks, 1' 10" or less. The upper surface is covered with 1" to 2" of coal-like material.
- (3). White Cloud Shale, 28' 6":
 - a. Shale, largely argillaceous and massive, with some sand, part laminated, 8' 6". There are many plant remains near the top of this. A thin seam of coal, probably the Elmo bed, occurs 1' 8" below the top.
 - b. Shale, dark blue, mostly argillaceous, largely massive, grading laterally into sand and sandstone, 20'. Few fossils are found in this division.
 - c. Limestone, exposed on floor of pit, bluish, fossiliferous, with a thin carbonaceous crust on the upper surface, 7" to 8". This, probably, is the same as bed 2(1) exposed in the section 3½ miles north of Table Rock. It may prove to be older than the Scranton.

The Scranton Shale, grading into sandstone at places, occupies the lower slopes of the Big Nemaha Valley in the vicinity of Table Rock, extending southeastward to beyond Munson Siding and up the valleys of Clear Creek and Taylor Branch. The beds above the Burlingame, up to and including the Tarkio Limestone, are in the upland south and southeast of Table Rock, dipping westward towards Taylor Branch, where they are overlain by the McKissick Grove Shale. There is a very good exposure of Tarkio Limestone 2 miles north-east of Pawnee, where a quarry operated several years ago.

MUNSON SIDING SECTION FOUR MILES EAST AND TWO
MILES SOUTH OF TABLE ROCK

South half of Section 12, T. 2 N., R. 12 E.

The beds of this section dip eastward. The Tarkio Limestone is about 15 to 20 feet above the valley floor just west of Humboldt. It rises to the top place in this section, beyond which, on the crest of the Table Rock Anticline, it has been removed by erosion. Section:

1. Tarkio Limestone member, at the county line and northwestward in section 12, with 5' or more shown.
2. Willard Shale member, poorly shown in ravine near the east side of section 12, about 25'.
3. Emporia Limestone member, caps the hills crossed by the north-south road west of Munson Siding, about 9':

- (1). Limestone, light blue, weathers light gray, forms smooth thin blocks, 6".
 - (2). Shale seam, blue, argillaceous, calcareous.
 - (3). Limestone, blue, dense, one or two jointed beds; forms angular debris; coalesces with (1) at places, 1' 6" to 2'.
 - (4). Shale, bluish, argillaceous, 1' 6" to 2'.
 - (5). Limestone, massive, weathered brownish, fossiliferous, forms large blocks and slabs, 2' to 2' 4".
 - (6). Shale, blue, argillaceous, 1' 8" to 2'.
 - (7). Limestone, gray or brownish, fossiliferous, 1' 6" or less.
4. Humphrey Shale member, 43':
- (1). Auburn Shale, bluish and maroon, largely argillaceous, with a thin fossiliferous limestone 5' above the base, 18'. The basal shale is fossiliferous.
 - (2). Wakarusa Limestone, about 5':
 - a. Limestone, gray, dense, brittle, fossiliferous, weathers brownish, forms slabby blocks, 1' 1".
 - b. Shale seam, blue, about 2'.
 - c. Limestone, 1'.
 - d. Shale seam.
 - e. Limestone, weathered yellowish brown, 8".
 - (3). Soldier Creek Shale, blue and maroon bands, argillaceous to sandy, with fossiliferous limy seams, about 20'. One limy seam is 1' 6" from the top and another 3' 6" above the base of the division. The latter carries a good many gastropods, weathers light gray, and forms rounded blocks.
5. Burlingame Limestone, in two massive, brownish, fossiliferous beds separated by a shale parting, forms a rock bench, about 3'.
6. Scranton Shale member, 19' to 20' exposed:
- (1). Silver Lake Shale, badly concealed, part maroon, 7' to 8'.
 - (2). Rulo Limestone, gray to brown, 1'.
 - (3). White Cloud Shale, mostly covered in slope to railroad on bottom land, 10' to 12' exposed. Altitude of railroad here, about 1,000'.

Between Munson Siding and Humboldt are a number of outcrops along the Big Nemaha and its tributaries, the strata dipping northeastward. The Tarkio Limestone, which is the main key bed, is quite high in the upland east of Dry Branch from which it lowers to near the bottom land level just southwest of Humboldt. This bed is also shown on Kirkham Creek and at points between $\frac{1}{2}$ and $2\frac{1}{2}$ miles west of Humboldt, dropping northeastward.

KIRKHAM CREEK SECTION NORTHWEST OF HUMBOLDT

In sections 31 and 32

1. McKissick Grove Shale member, 12' 6" or more exposed:
 - (1). Maple Hill Limestone, slabby, quite earthy, and fossiliferous, 1' +.
 - (2). Pierson Point Shale, about 11' 6":
 - a. Shale, blue, bedded to massive, with sandy flakes and small concretions, 8'.
 - b. Sandy limestone, 1' exposed.
 - c. Shale, blue to maroon, massive, 2' to 3'.
2. Tarkio Limestone member, poorly shown in creek banks, thickness (?).

EXPOSURE TWO MILES WEST OF HUMBOLDT

West half of section 5

1. McKissick Grove Shale member, 31' exposed:
 - (1). Shale, gray, ashy, 8'.
 - (2). Limestone, bluish, sandy, 8".
 - (3). Shale, argillaceous, 10' to 11'.
 - (4). Maple Hill Limestone, not very fossiliferous, 1' +.
 - (5). Pierson Point Shale, about 11'.
2. Tarkio Limestone member, forms rock terrace which is a few feet lower than the one in sections 31 and 32.

BRICK PLANT SECTION WEST OF HUMBOLDT

1. McKissick Grove Shale member, about 68' exposed:
 - (1). Pony Creek Shale, about 24':
 - a. Shale, maroon, somewhat indurated and irregular above; bluish, argillaceous, and more uniform below; upper surface eroded unevenly, 7' to 12'.
 - b. Nebraska City Limestone (?), bluish, earthy, weathers yellowish, quite fossiliferous, 6" to 8".
 - c. Shale, mostly maroon, part bluish gray, all argillaceous to sandy, 14'.
 - (2). Dover Limestone, bluish, massive, fossiliferous, weathers yellowish, 1' to 2'. This forms the floor of the clay pit.
 - (3). Table Creek Shale:
 - a. Nyman Coal and carbonaceous shale, 5" or more.
 - b. Shale, bluish, arenaceous, fossiliferous, carries hard sandstone concretions and lenses in upper portion. A thickness of 10' or more is exposed at the clay pit and about 14' of the lower portion, most of which is reddish and somewhat sandy, is shown at the spur south of the cemetery. Combined thickness, 20' or more.
 - (4). Maple Hill Limestone, exposed south of the cemetery, about 1'.
 - (5). Pierson Point Shale, south of cemetery, sandy to argillaceous, 11'.

3. Tarkio Limestone member, southeast of cemetery, about 15' above flood plain, 4' exposed.
4. Willard Shale member, concealed in a slope of 15' or more.

There is an interesting outcrop in the vicinity of the road-crossing one mile northwest of Humboldt. At the top is the Dover Limestone underlain by shale in which are many specimens of *Chonetes granulifer*. Below this, along the ravine north, is about 10 feet of bedded carbonaceous shale underlain by a concretionary bed and that by a mottled zone. Here the beds dip northeastward about 8 feet within a distance of 70 feet.

TURKEY CREEK EXPOSURES

Turkey Creek, one of the largest tributaries of the South Fork, extends southeastward through Pawnee County to Kansas where it joins the South Fork Nemaha which extends northward to Nebraska, joining the Big Nemaha east of Salem.

The Turkey Creek exposures are on the west flank of the Table Rock Anticline. Those in Nebraska are formed on strata from above the Cottonwood Limestone down to near the base of the Humphrey Shale member, whereas, southeast in Kansas, the Turkey Creek section extends down to the Howard Limestone, and that on the North Fork Nemaha extends to below the Topeka Limestone member.

SECTION ON WEST BRANCH TURKEY CREEK EIGHT MILES WEST AND ONE AND ONE-HALF MILES SOUTH OF PAWNEE CITY

In the northwest quarter of Section 4, T. 1 N., R. 10 E., and southeast along the West Branch Turkey Creek. Section:

I. Permian System; Council Grove Formation

1. Cottonwood Limestone member, in section 4 and other places on West Branch Turkey Creek, about 5'.

II. Pennsylvanian System; Wabaunsee Formation

1. Eskridge Shale member, 33' to 34':
 - (1). Shale, about 8':
 - a. Blue, argillaceous, 4' to 5'.
 - b. Red, mostly argillaceous, 3' to 4'.

- (2). Limestone, gray, slabby, 1' 6" to 2'.
- (3). Shale, 10' 6":
 - a. Olive colored, argillaceous, thickness variable, about 2'.
 - b. Gray, with maroon stain, massive, irregular, sandy, 8' 6".
- (4). Limestone, gray, irregular, weathers buff, 1' 3".
- (5). Shale, about 12':
 - a. Bluish gray, sandy to argillaceous, 1' 6".
 - b. Maroon, massive, sandy-clayey, 2' 3".
 - c. Gray, irregular, massive, with calcareous induration, 3' 6".
 - d. Maroon and gray, sandy-clayey, with gray calcareous seam, 3' 6".
 - e. Olive colored, argillaceous to sandy, 6".
 - f. Buff colored, sandy, 1'.
- 2. Neva Limestone member, in two or more beds; top 1' or more weathered pitted along the edges of blocks, 6' to 7'.
- 3. Elmdale Shale member, in east one-half of section 4 and across sections 3, 10, and 11, about 52' 6" exposed:
 - (1). Roca Shale, about 21'.
 - (2). Howe Limestone, not well shown, 3' or more.
 - (3). Bennett Shale, south side section 3 and sections 10 and 11, about 7'.
 - (4). Glenrock Limestone, south side of section 3, 1'.
 - (5). Johnson Shale, in section 10, about 17'.
 - (6). Long Creek Limestone, badly covered near creek level in the northwest quarter of section 10, about 3' to 4'.

SECTION SIX MILES WEST OF PAWNEE CITY

In sections 23, 25, and 26, T. 2 N., R. 10 E.

- 1. Elmdale Shale member, about 55' exposed:
 - (1). Bennett Shale, a few feet in covered slope.
 - (2). Glenrock Limestone, forms rock rim, 1' or more.
 - (3). Johnson Shale, bluish, argillaceous, about 18'.
 - (4). Long Creek Limestone, weathered yellowish, with some geodes; forms large slabs, 2' or more.
 - (5). Hughes Creek Shale, about 29' exposed:
 - a. Shale, bluish, largely argillaceous, 18'. There is a well marked fossil zone, 5' above the base in which occur *Meekopora prosseri*, *Rhombopora lepidodendroides*, *Chonetes granulifer*, and other species.
 - b. Limestone, 8".
 - c. Shale, black, fissile, 1' 5".
 - d. Limestone, massive, 1' 4".
 - e. Shale, dark, 2'.
 - f. Shale, with many fossils in calcareous seams, about 3'.
 - g. Fossiliferous, calcareous zone, 6".
 - h. Shale, fossiliferous, 10".
 - i. Limestone, earthy, probably 1'. This rises eastward in the south valley-side, where the beds below it are covered.

JOHNSON CREEK SECTION

South of creek, in sections 28 and 29, T. 1 N., R. 11 E.

(Figure 36)

1. Elmdale Shale member:
 - (1). Stine Shale, 6' 6" exposed:
 - a. Limestone, hard, weathered brownish, forms rounded boulders, 1'.
 - b. Shale, badly covered in slope, about 5' to 6'.
2. Americus Limestone member, in section 28, formerly quarried, now badly covered, forms rounded, blocks, thickness (?), one bed exposed more than 2'.
3. Admire Shale member, 50' 6" or more:
 - (1). West Branch Shale, badly covered, with some calcareous bladed material, and one limestone seam carrying many pelecypods, about 24".
 - (2). Falls City Limestone, top slabby; middle portion weathered yellowish; base arenaceous, 3'.
 - (3). Aspinwall Shale, 21' +:
 - a. Shale, dark, crumbly, 4' 6".
 - b. Limestone, dark gray, earthy, quite fossiliferous, 7".
 - c. Shale, badly slumped, about 9' to 10'.
 - d. Limestone, hard, one bed, 6".
 - e. Shale, mostly maroon, argillaceous to arenaceous, crumbly, 6' 6".
 - (4). Brownville Limestone, typical, 2' 6" to 3'.
4. McKissick Grove Shale member, 30' exposed:
 - (1). Pony Creek Shale, poorly shown, 18' 6".
 - (2). Dover Limestone, 1' 6" or more.
 - (3). Table Creek Shale, in slope to bridge, 10'; to creek bed just north, about 20'. The Nyman Coal and shale are exposed at the top of this slope.

TURKEY CREEK SECTION NEAR THE KANSAS LINE

On exposures in sections 25, 26, 35, and 36

1. Admire Shale member:
 - (1). Aspinwall Shale, reddish and bluish, argillaceous to sandy, a few feet exposed in high slopes of sections 27, 26, and 35.
 - (2). Brownville Limestone (?), high in slopes of sections 26 and 27, about 2'.
2. McKissick Grove Shale member, about 45':
 - (1). Pony Creek Shale, 27' to 28':
 - a. Shales, mostly maroon, sandy-argillaceous, 14'.
 - b. Nebraska City Limestone (?), in sections 34 and 35, rich blue, 8" to 1'.
 - c. Shale, argillaceous to sandy, with sandy lenses, 12' 6".
 - (2). Dover Limestone, dark blue, weathers tan, with white crinoid joints, 1' 6".

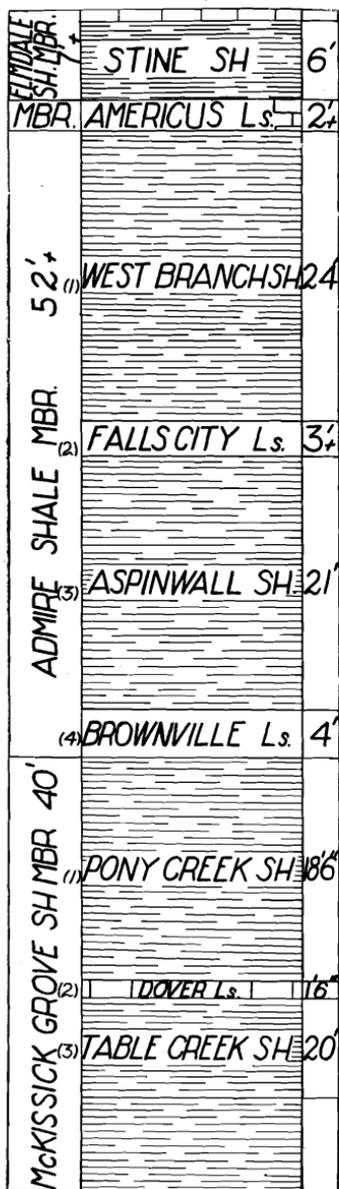


FIGURE 36. — Columnar section on Johnston Creek, Pawnee County.

- (3). Table Creek Shale, 16' or more:
- Nyman Coal, 2" to 6", in southwest and southeast quarter of section 36 and across the line in Kansas.
 - Shale, bluish gray, sandy in upper portion, 6'.
 - Shale, dark, somewhat carbonaceous, largely argillaceous, with many *Orbiculoidea* and some plant remains, 5' 6".
 - Shale, dark, grayish, brown, argillaceous, conglomeratic, loosely indurated, with crinoid joints in upper portion, 1'.
 - Shale, light olive green, 6".
 - Shale, maroon, argillaceous, 2'.
 - Shale, bluish, argillaceous, 6" to 10".

- Tarkio Limestone member, forms rock bench in both sides of the valley, in sections 25, 26, 35, and 36, thickness 5' +. Exposed northward to about 2 miles south of Pawnee City; altitude 1 mile north of state line, 1,120' on east side of valley and 1,100' on west side.
- Willard Shale member, in covered slope, about 30'.
- Emporia Limestone member, forms a rock terrace on each side of the valley in section 36, about 6':
 - Limestone, 1' 3"; upper 3" to 4" slabby, brittle; basal 1' blue, dense, hard, tough.
 - Limestone, two beds, 2' 6". The lower bed is semi-crystalline, massive, weathers brownish, and forms large blocks with banded edges. Fauna: Many pelecypods, large *allorisma* being very noticeable.
 - Shale, olive green, argillaceous, 8".
 - Shale, or disintegrated limestone, calcareous, very fossiliferous, 1' +. Fauna: *Bryozoa*, crinoid joints, and several species of brachiopods.

- (5). Limestone, light brownish, blocky, with fossil fragments, 6".
6. Humphrey Shale member, about 19' exposed:
- (1). Auburn Shale, calcareous, weathered brown, about 7' in section 36.
 - (2). Wakarusa Limestone, about 4' 2" shown in banks of Turkey Creek, section 36:
 - a. Limestone, 1' 6".
 - b. Shale, 1' 4" to 1' 8".
 - c. Limestone, 1' 2".
 - (3). Soldier Creek Shale, in east bank of Turkey Creek, near the south side of section 36, about 7' or 8' exposed.

Along Turkey Creek in Kansas are exposures of the Tarkio, Willard, Emporia, Humphrey, Burlingame, Scranton, and Howard members. Across the divide, east and north of Turkey Creek, i.e., on Nigger Branch and Lore's Branch in Nebraska, beds from the Tarkio Limestone down to the Severy Shale come to the surface in their natural order. Farther southeast in Nebraska at the high point on the Table Rock Anticline, the Topeka, Calhoun, and Deer Creek members are exposed.

SECTION IN THE VICINITY OF DU BOIS

This is made on exposures in the Table Rock Anticline (Figure 37).

1. Tarkio Limestone, high in the upland east and west of the South Fork Nemaha, dipping westward in the west flank and northeastward in the east flank; stone buff to brownish, massive, forming rounded blocks, 5' or more. *Osagea* are common. Fauna: large *Fusulina*, some crinoid joints, and brachiopods.
2. Willard Shale member, high in slopes east and west of the river, 28' to 30'.
3. Emporia Limestone member, three or more light colored or yellowish flagstone limestones and interbedded shales, in both sides of the valley, about 7', with a 2" layer of conglomeratic or brecciated stone at the top at places. Fauna: *Ambocoelia planoconvexa*, *Productus semireticulatus*, *Entiletes hemiplicata*, *Pinna* sp., *Allorisma terminale*, crinoid joints, bryozoa, and some pelecypods.
4. Humphrey Shale member, 38':
 - (1). Auburn Shale, exposed generally below division 3, about 22'. An arenaceous, rusty, calcareous horizon at the top is quite fossiliferous in which *Derbya crassa* and *Productus cora* are the main species. The middle and lower portions are largely bluish and argillaceous.
 - (2). Wakarusa Limestone, a comparatively heavy, yellowish bed or beds; with many crinoid joints and some brachiopods; largely exposed at many places, about 4'.
 - (3). Soldier Creek Shale, argillaceous to arenaceous, about 12'.

5. Burlingame Limestone, poorly shown east and west of South Fork Nemaha, massive, brownish, fossiliferous, thinner than at places near the Missouri, 2' or more.
6. Scranton Shale member, 79' 6" :
 - (1). Silver Lake Shale, sandy to clayey, about 8'.
 - (2). Rulo Limestone, poorly exposed on hillsides, 1' to 2'.
 - (3). White Cloud Shale, best shown in Nemick Hill southwest of DuBois, 70':
 - a. Bluish, argillaceous to sandy, with some carbonaceous material, 4' to 5'.
 - b. Sandy, micaceous shale and sandstone, weathered brownish, 21'.
 - c. Argillaceous, with flakes and seams of sandstone, about 42'.
 - d. Micaceous sandstone, 2'.
 - e. Sandy shale, 8".

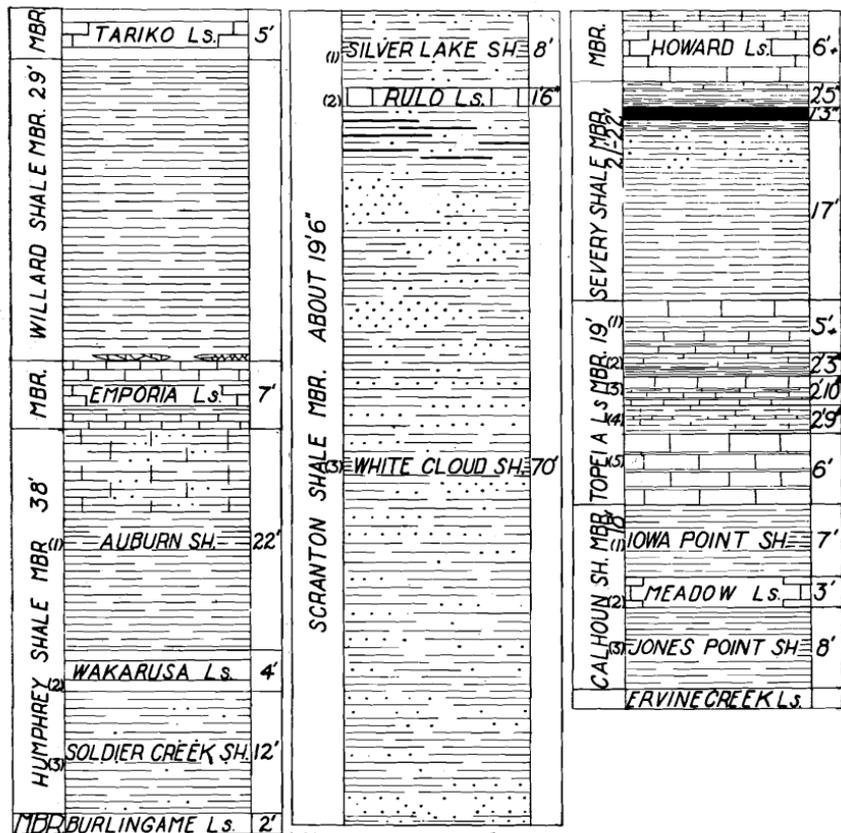


FIGURE 37.—Columnar section in the vicinity of Du Bois.

7. Howard Limestone member, at the waterfall south of town, in bank of South Fork Nemaha west of old mill site southeast of town, in low bench along both sides of the main valley in the vicinity of DuBois, along Turner Creek, two miles southeast of DuBois, and southward in Kansas, 6' to 8'. The upper 2' is shaly and disintegrated. Most of the main bed is massive, bluish gray, weathering brownish. Fauna: Several species of brachiopods, bryozoa, gastropods, and pelecypods; some cephalopods, and other fossils.
8. Severy Shale member, 21' to 22':
- (1). Shale, exposed below waterfall south of DuBois, 2' or more:
 - a. Calcareous, fossiliferous, 4" to 6".
 - b. Black, massive to bedded, with many *Lingula*, 4" to 7".
 - c. Grayish, fossiliferous, 5" to 6".
 - d. Black, silty above, massive below, 6".
 - e. Rotted, fossiliferous, 2" to 4".
 - (2). Nodaway Coal, shown below waterfall on Lore's Branch south of Du Bois, at the old mill site on Turkey Creek, on Turner Creek, and southward in Kansas, 1' 2" to 1' 4".
 - (3). Shale, at old mill dam and on Turkey Creek, 17' to 18'.
 - a. Gray, argillaceous, 6".
 - b. Black, slaty, 7".
 - c. Bedded, sandy, micaceous, with ripple marks at base, 3' 6".
 - d. Bluish, bedded to massive, unfossiliferous, argillaceous, 13' to 14'.

The Severy Shale is well shown in Kansas southeast of DuBois where its middle and lower zones are bluish and argillaceous with some sand, and there is a thin limestone seam near the base.

9. Topeka Limestone member, on Turner Creek near the center of section 25, i.e., 1½ miles east and 1 mile south of Du Bois; also along a creek south in Kansas, about 19':
- (1). Coal Creek Limestone, 5' or more:
 - a. Limestone, dark gray, somewhat siliceous, forms large flat blocks, with many *Fusulina* and bryozoa, 1' 6".
 - b. Shale, bluish, argillaceous to calcareous, weathers buff, 1' 6".
 - c. Limestone, blue, dense, massive, fossiliferous, weathers brownish, 1' +.
 - d. Shale seam, dark, 4" to 6".
 - e. Limestone, dark blue, massive, forms rectangular blocks, with specimens of *Myalina*, crinoid joints, and bryozoa, 7" to 8".
 - (2). Holt Shale, 2' 3"; upper portion bluish gray, argillaceous, with some calcareous material; lower portion black, fissile.
 - (3). DuBois Limestone, about 2' 10":
 - a. Limestone, dark blue, massive, 1' 2"; upper surface roughened with large *Myalinas*.
 - b. Shale seam, calcareous, 5".
 - c. Limestone, separated by shale seam, dark blue, dense, quite fossiliferous, with small *Myalinas*, 1' 3".
 - (4). Turner Creek Shale, bluish gray, calcareous, with lime seams near top, 2' 9".
 - (5). Curzen Limestone, gray or dark gray, 4 or 5 uneven beds separated by shale seams, about 6'. Fauna: Fenestrated bryozoa and brachiopods.

10. Calhoun Shale member, 18' or more:
 - (1). Iowa Point Shale, on Turner Creek west of the center of section 25, thickness 7' or more.
 - (2). Meadow Limestone, in a cut-bank near mouth of Turner Creek, about 3'.
 - (3). Jones Point Shale, formerly exposed at the mouth of Turner Creek in an interval of about 8'.
11. Deer Creek Limestone member. The top of the Ervine Creek Limestone is exposed on the bed of the South Fork Nemaha at the mouth of Turner Creek.

The strata dip eastward from the axis of the Table Rock Anticline to the Humboldt Fault. The topmost bed in most of this stretch is the Tarkio Limestone. It lowers to the northeast quarter of Section 33, T. 1 N., R. 13 E., the northwest quarter of Section 16, T. 1 N., R. 13 E., the northeast quarter of Section 9, T. 1 N., R. 13 E., the east half of Section 28, T. 2 N., R. 13 E., and the northeast quarter of Section 16, T. 2 N., R. 13 E., which positions are at the fault zone, beyond which the Neva, Cottonwood, Garrison, and Wreford beds cap a poorly defined fault scarp which faces westward.

SECTION, FIVE AND ONE-HALF MILES SOUTH OF HUMBOLDT

Made on beds dipping eastward in sections 3 and 9 of T. 1 N., R. 13 E.

Starting with the Permian beds at the top of the escarpment in the east side of section 3, at an elevation of 190 to 200 feet above the valley floor of the South Fork Nemaha, the section is as follows:

I. Permian System; Council Grove Formation

1. Garrison Shale member, about 34' exposed in the Eiss Hill in the northwest quarter of Section 3, T. 1 N., R. 13 E.:
 - (1). Easly Creek Shale, weathered buff to brownish, about 5' of the lower portion shown in which is a cavernous, gypsiferous zone.
 - (2). Eiss Limestone, 9' 10":
 - a. Limestone, one layer, dark gray, siliceous, hard, massive, forms large rectangular blocks, 1' 3" to 2'. This holds the rim of the escarpment.
 - b. Shale, bluish, argillaceous, with fine calcareous material, quite fossiliferous, about 7'. Fauna: *Chonetes granulifer*, *Rhombopora lepidodendroides*, etc.
 - c. Limestone, dark gray, earthy, becomes hard on exposure and shatters, 1' 4". Fauna: *Chonetes granulifer*, pelecypods and many specimens of *Thamniscus*, *Fenestella*, and *Rhombopora* at the top.

- (3). Stearns Shale, 18' 3":
 - a. Dark gray, with a calcareous crust at the base, 6'.
 - b. Dark maroon, argillaceous, 6'.
 - c. Gray, slabby, calcareous, 6' 3".
 - (4). Morrill Limestone, gray, hard, massive, 1' to 1' 3".
 - (5). Florena Shale, light gray, very calcareous, 2' to 3' 6".
2. Cottonwood Limestone member, light gray, with many *Fusulina*, forms large, rectangular blocks, 6' to 7'.

II. Pennsylvanian System; Wabaunsee Formation

1. Eskridge Shale member, in the Eiss Hill, 37' to 38':
- (1). Shale, blue, surface grayish, due to limestone debris lowering from the Cottonwood above, about 10'.
 - (2). Limestone, light gray, forms blocks which shatter, 8" to 10".
Fauna: A good many pelecypods at places.
 - (3). Shale, mostly argillaceous, 10' 4":
 - a. With calcareous material, 5'.
 - b. Chocolate colored, 4'.
 - c. Gray, 1' 4".
 - (4). Limestone, dark gray, shattered, 1' to 1' 3".
 - (5). Shale, mostly argillaceous, 16' to 17':
 - a. Gray, 2'.
 - b. Maroon, becoming dark gray at base, 1' 10".
 - c. Irregular, part with calcareous induration, 1' 8" to 2'.
 - d. Chocolate colored, 2'.
 - e. Gray, 4' 6".
 - f. Reddish, weathering yellowish, 5'.
2. Neva Limestone member, limestones and interbedded shales, forming a poorly defined rock bench, about 14'.
3. Elmdale Shale member, about 80' exposed where most of the section is made, as below:
- (1). Roca Shale, covered in slope, 20' or more.
 - (2). Howe Limestone, forms bench-like hump, about 4'.
 - (3). Bennett Shale, about 8'.
 - (4). Glenrock Limestone, with many *Fusulina*, 1'.
 - (5). Johnson Shale, 14' or more.
 - (6). Long Creek Limestone, weathered yellowish, holds a poorly defined bench, 3' to 4'. Fauna: A few pelecypods and brachiopods.
 - (7). Hughes Creek Shale, about 27' exposed:
 - a. Shale, bluish, bedded, argillaceous, 14'. Fauna: *Chonetes granulifer*, *Productus cora*, and *Meekopora prosseri* are the main species.
 - b. Limestone and shale, about 13':
 - (a). Limestone, dark gray, earthy, shattered, 4" to 6".
 - (b). Shale, 2' to 2' 6"; upper 2' black, massive to platy, with *Orbiculoidea missourienis*; lower 6" bluish gray with large specimens of *Ambocoelia planoconxeva*.
 - (c). Limestone, blue, breaks into irregular blocks which shatter, weathers light buff, 6". Fauna: Crinoid joints common; *Ambocoelia*, *planoconvexa* on upper surface.

- (d). Shale, blue to black, bedded, with calcareous seams, very fossiliferous in middle below a black horizon, 6' 6". Fauna: *Chonetes granulifer*, *Productus semireticulatus*, *Meekopora prosseri*, crinoid joints, etc.
- (e). Limestones and interstratified shale seams, fossiliferous, 1' 6" to 2'.
- (f). Shale, bluish gray, largely argillaceous, fossiliferous, 1' 1".
- (g). Limestone, badly weathered, brownish, with many pelecypods and gastropods. 2" to 3".
- c. Shale and covered slope, in which division "c" of the Hughes Creek beds probably occurs, only a few feet of the top portion being exposed. A thin blocky shale at the top of this division dips eastward 3' in 12'.

The lower portions of this section are based on exposures about one-half mile southwest beginning in section 9 and extending westward across Eiss Hill into section 10. The strata here dip eastward, the highest bed exposed passing under zone "b" of the Hughes Creek Shale, the top portion of which is exposed at the foot of the escarpment to the north-east. The section continued on the south Eiss Hill, east of where crossed by the north-south road, follows:

- (1). Houchen Creek Limestone (?) and Stine Shale (?) and the Americus Limestone badly covered in the hill side east of the highway. Conditions are not favorable for measurement.
- (2). West Branch Shale, badly covered, thickness (?).
- (3). Falls City Limestone, caps the high point on Eiss Hill, elevation 1,180'; stone typical but only 1' 8" thick.
- (4). Aspinwall Shale, in hill side along road between sections 9 and 10, about 40':
 - a. Shale, blue, with some sand, calcareous nodules and a good many joint blades in upper portion, 12'.
 - b. Shale, argillaceous, maroon, 10'.
 - c. Limestone, bluish gray, with earthy variegation, forms large, thin blocks, weathers yellowish, 8". Fauna: Crinoid joints, *Marginifera splendens*, and *Derbya crassa*.
 - d. Shale, greenish blue, argillaceous to calcareous, bedded, 2'.
 - e. Shale, maroon, bedded, with sandy flakes and calcareous concretions, 1' 6".
 - f. Limestone, two thin beds, mottled gray-yellow-brown, dense, fossiliferous, 8" to 1'.
 - g. Shale, greenish gray and maroon, micaceous, about 4' to 6'.
 - h. Limestone, dark gray, weathers lighter colored, 7" to 10".
 - i. Shale, 8'; bluish gray above; with a 2" carbonaceous streak 1' below top; lower portion maroon.
- (5). Brownville Limestone, poorly exposed on hill side in section 9, about 2' or more.

2. McKissick Grove Shale member:
 - (1). Pony Creek Shale, in slopes of sections 4 and 9, thickenses (?).
 - (2). Dover Limestone, in hill side in section 9, thickness (?).
 - (3). Table Creek Shale, not observed. It should occur in the zone where there seems to be faulting.
3. Tarkio Limestone member, caps benches in sections 4 and 9, 5' or more.
4. Willard Shale member, in bench and slope, about 30'.
5. Emporia Limestone member, two well defined beds separated by shale, 4' to 5'.
6. Humphrey Shale member: The Auburn Shale unit is in the foot of the slope in the northwest corner of section 9.

The strata dip eastward for a short distance east of the Humboldt Fault, then become nearly flat or undulating to a north-south line between Dawson and Salem.

COMBINED SECTION BETWEEN EASLY CREEK AND SABETHA, KANSAS

Between Sections 35 and 36, T. 1 N., R. 13 E., about 8 miles south and 2½ miles west of Dawson and northeast of Sabetha. This section, run primarily to show the thickness and character of the Permian beds, is as follows:

I. Permian System: Chase and Council Grove Formations, about 118' exposed

1. Wreford Limestone member, in high upland, altitude of base 1,280' on the east, dropping to 1,255' or 1,260' in the exposures farthest west and north. The stone has much bluish gray flint, which, being released through the disintegration of the limestone, litters the slopes below. Only the lower portion of the member is shown. Fauna: Several species of bryozoa, brachiopods, Pinna, etc.
2. Garrison Shale member, 112':
 - (1). Speiser Shale, about 47':
 - a. Shale, 19':
 - (a). Greenish blue, with small calcareous bodies, about 9'.
 - (b). Bluish and reddish bands, argillaceous, 10'.
 - b. Limestone and shale, 7' to 8':
 - (a). Limestone, light gray, dense, forms conspicuous, small boulders which weather pitted, 1' or more. Fauna: Pseudomorphs of gastropods in places.
 - (b). Shale, light gray, calcareous, 4' to 5'.
 - (c). Limestone, gray, weathers yellowish brown and cavernous, 1' 6" to 2'.
 - c. Shale, bluish or bluish gray, with a thin band of maroon near the base, small calcareous concretions in the grayish zones, 18' to 23'.
 - (2). Sabetha Limestone, about 12':

- a. Limestone, gray, weathering gray or yellowish brown, 3' to 4'; upper and lower portions tabular; middle portion massive, granular, with oolitic appearance, forms large rounded boulders. This holds a well defined rock terrace. Fauna: Gastropods, a few brachiopods, and fragments of bellerophons and pelecypods.
 - b. Shale, bluish gray, calcareous, with limy nodules, 6' to 7'.
 - c. Limestone, gray, 2' to 3'; upper portion shaly and very fossiliferous; lower portion dense, massive. In places there are shale and limestone seams at the base. Fauna: *Thamniscus*, common; *Aviculopecten*, *Echinoid* spines, brachiopods, etc.
- (3). Easley Creek Shale, about 26':
- a. Shale, in blue, gray, greenish-gray, and reddish bands, part quite calcareous, 12'.
 - b. Limestone, gray, 2' to 4'; massive and hard above; somewhat earthy and shattered below, with myriads of small gastropods in the basal portion at places.
 - c. Shale, 10' to 12':
 - (a). Shale, buff gray, massive, 1' +.
 - (b). Limestone, blocky, 2" to 3".
 - (c). Shale, weathered buff, massive, 1' 10" +.
 - (d). Shale, limy, irregular, like box-work in places, 10".
 - (e). Shale, grayish, with small calcite concretions, about 7' to 8'. This has a reddish band at places.
- (4). Eiss Limestone, about 9':
- a. Limestone, dark gray, massive, siliceous at places, forms irregular blocks; no fossils observed, 1' 3" to 2'.
 - b. Shale, bluish, argillaceous, with some small calcareous concretions; fossiliferous, about 5' 6".
 - c. Limestone, dark gray, earthy, forms fine debris; with many bryozoa, brachiopods, etc., in a crust on the upper surface, 1' 6" to 2'. *Thamniscus* common; some small gastropods.
- (5). Stearns Shale, 14' to 18':
- a. Grayish, calcareous, 1' 6" to 2'.
 - b. Bluish gray, argillaceous, crumbly, 4' to 6'.
 - c. Chocolate or reddish, crumbly, argillaceous, 5' to 8'.
 - d. Light gray, limy, loosely indurated, 2' +.
- (6). Morrill Limestone, grayish, quite hard, 1' 6" to 3'; irregular above, weathering grayish; basal portion weathering brownish and cavernous.
- (7). Florena Shale, light gray, calcareous, with many *Chonetes* granular and a few other species, 3' to 5'. At some points this unit is quite firmly indurated becoming limestone which grades into the Cottonwood, forming with the latter a nearly solid ledge.
2. Cottonwood Limestone member, holds rock bench, and forms large light gray blocks, 6' to 7'. This unit is in much of the upland south of the South Fork Nemaha.

II. Pennsylvanian System; Wabunsee Formation

The Eskridge, Neva, and Elmdale members of this formation are exposed generally in the middle and lower slopes of the South Fork Nemaha from southwest of Dawson to Salem. The oldest bed exposed here is the Houchen Creek Limestone. It crops out at the level of the flood plain just southwest of Salem.

Names of Garrison Units. The subdivisions of the Garrison member are named as follows: Speiser Shale from Speiser Township, Richardson County, Nebraska; Sabetha Limestone, from exposures on the Omaha-Tulsa Highway one mile north of Sabetha, Kansas; Easley Creek Shale from outcrops on Easley Creek, Richardson County, Nebraska; Eiss Limestone, from the Eiss farm south of Humboldt where part of the preceding section was made; Stearns Shale, from south of the Stearns School northeast of Humboldt, Nebraska; Morrill Limestone from exposures 2 miles northwest of Morrill, Kansas.

SECTION NORTHEAST OF HUMBOLDT

Based on exposures along Spring Creek, in sections 1, 2, and 36
of T. 2 N., R. 13 E.

I. Permian System, Council Grove Formation

1. Garrison member, about 40' exposed:
 - (1). Easley Creek Shale, 11' 6":
 - a. Limestone, along the Spring Creek road, in sections 1 and 30, gray, blocky, shattered, weathered buff, 2'.
 - b. Shale, grayish green, massive, weathers sponge-like near top; bedded at the base, 9' 6".
 - c. Shale, maroon, with grayish limy seams, 2'.
 - (2). Eiss Limestone, 9' 6":
 - a. Limestone, forms small waterfall in gutter along Spring Creek road, light gray, with small black specks, weathers rusty in some exposures, 1' or more.
 - b. Gray, bedded, weathers light colored, 6' 6".
 - c. Limestone, shaly, quite fossiliferous, 2'. Fauna: Pectenoid.
 - (3). Stearns Shale, 14':
 - a. Greenish gray, bedded, calcareous, 4' 6".
 - b. Maroon with purplish tint, massive, jointed, 1'.
 - c. Variegated greenish brown, massive, nodular, leaches gray, 2'.
 - d. Gray, earthy, silty, massive, resists weathering, resembles limestone, 1'.
 - (g). Maroon, with greenish gray lenses, massive, 4'.
 - (h). Gray, bedded, quite calcareous, leaches white, 1' 6".
 - (3). Morrill Limestone, 2' 6".
 - a. Limestone, dense, hard, brittle, 5".
 - b. Shale, light gray, calcareous, massive, 8".
 - c. Limestone, 1' 4"; upper 4" weathers rusty and silty; basal 1' breaks into two or three hard, yellowish beds.
 - (4). Florena Shale, poorly shown, grayish, fossiliferous, 6" or more exposed, thickness probably 3'.
2. Cottonwood Limestone member, in section 36 and south in the escarpment in sections 1 and 2. The stone is typical, thickness 5' to 6'. It holds a bench.

II. Pennsylvanian System, Wabaunsee Formation

1. Eskridge Shale member, 39' or more:
 - (1). Shale, blue, argillaceous, weathers light gray, 14'; with band of maroon 3' above base. The surface of this shale is strewn with debris released from the Cottonwood Limestone.
 - (2). Limestone, light gray, resembles lithographic stone, breaks into small blocks which shatter forming fine debris, 1' to 1' 5". Fauna: A few pelecypods.
 - (3). Shale, bands of gray, greenish blue, chocolate, maroon, about 12'. The surface is covered with rock debris.
 - (4). Limestone, slabby, irregular, with a few fossils, 1'.
 - (5). Shale, bluish, argillaceous, with a lime seam near middle, 11'.
2. Neva Limestone member, poorly exposed across the road near the southeast corner of section 2, thickness, probably 7'. Fauna: Crinoid joints, brachiopods, bryozoa, etc.
3. Elmdale Shale member:
 - (1). Roca Shale, in covered slope, the top being about 21' above the bottom land level.

SECTION ON LITTLE MUDDY CREEK

In the northwest quarter of Section 7, T. 3 N., R. 14 E., or about 5 miles north and 3 miles east of Humboldt

I. Permian System, Council Grove Formation

1. Garrison Shale member:
 - (1). Easley Creek Shale, about 12' 6" exposed:
 - a. Limestone, forms bench, brownish, dense, blocky, 2'; altitude 1,090' to 1,095'.
 - b. Shale, gray or maroon, about 10' to 11'.
 - (2). Eiss Limestone and Stearns Shale, about 21':
 - a. Limestone, brownish, hard, calcitic, with lime-like cavities paralleling bedding planes, 2' 6" to 3'. Springs issue from this limestone.
 - b. Stearns Shale, blue, very dark blue when wet, argillaceous, thickness, probably 18'. There is a fossiliferous limy layer near the top from which Derbyas, Meekellas, and a trilobite were collected. This seems to be the basal portion of the Eiss Limestone.
 - (3). Morrill Limestone, exposed in gully, brownish, thickness not well shown.
 - (4). Florena Shale, exposed in north creek bank, 2' to 3'.
2. Cottonwood Limestone member, top exposed in north creek bank, altitude, 1,058'.

The details of this and the other section of the Garrison member were worked out by Professor N. A. Bengtson in connection with his study of the Permian System in Nebraska.

Between Humboldt and Salem are well defined exposures on each side of the North Fork Nemaha on beds from the

base of the Garrison member down to the Hughes Creek Shale. The upland is capped in succession eastward by the Garrison beds, the Cottonwood Limestone, and the Neva Limestone.

SECTION IN THE VICINITY OF SALEM

I. Permian System, Council Grove Formation

1. Cottonwood Limestone member, in a conical hill about one mile southwest of town and at many places west and southwest, 5' or more.

II. Pennsylvanian System, Wabaunsee Formation

1. Eskridge Shale member, basal layers in upland at various places south of the South Fork Nemaha, about 36'.
2. Neva Limestone member, caps most of the upland west of Salem. It has wide range south of the South Fork Nemaha, thickness 7' or more.
3. Elmdale Shale member, about 75' exposed:
 - (1). Roca Shale, under part of Salem and in the upland west, about 20'.
 - (2). Howe Limestone, poorly exposed in valley sides southwest of Salem, 3' or 4'.
 - (3). Bennett Shale, in slope one mile southwest of town; shown in gutter of east-west road, about 9'.
 - (4). Glenrock Limestone, in slopes southwest of Salem, about 1'.
 - (5). Long Creek Limestone, well shown back of house north of bluff-line road southwest of Salem, about 4'. This stone weathers yellowish.
 - (6). Hughes Creek Shale, in the lower slopes at Salem, well shown in foot of bluff just southwest of town, about 35' exposed.
 - (7). Houchen Creek Limestone, in the base of the slopes at Salem.

The strata rise eastward from west of Salem to the Missouri but are flattened somewhat at the Kansas line south of Falls City. The high upland southeast of Salem includes all beds of the Wabaunsee formation from the Neva Limestone down to near the base of the West Branch Shale.

SECTION ALONG CREEK THREE MILES SOUTH AND TWO AND ONE-HALF MILES EAST OF SALEM

In Section 24, T. 1 N., R. 15 E.

1. Admire Shale member, about 50' exposed:
 - (1). West Branch Shale, poorly exposed in gutter of east-west road on hill side between the southwest quarter of section 24 and the northwest quarter of section 25.
 - (2). Falls City Limestone, along creek near south side of section 24 and northward to beyond the center of section, 1' 10".
 - (3). Aspinwall Shale, about 30':

- a. Shale, along creek in section 24, bluish gray, argillaceous, 4' to 5'.
- b. Limestone, bluish gray, fossiliferous, 1'. Fauna: *Marginitifera splendens* is the main fossil.
- c. Shale, blue, with calcareous joint fillings near middle, weathers light gray, 20'.
- d. Shale, maroon, 4' exposed above creek bed.

SECTION THREE AND ONE-HALF MILES SOUTHWEST OF FALLS CITY

In the south half of section 19 and the north half of section 30.

- 1. Admire Shale member:
 - (1). Falls City Limestone, caps upland, dipping westward, 3' or more.
 - (2). Aspinwall Shale, about 32':
 - a. Shale, bluish, argillaceous, with many sandy joint fillings, 15'.
 - b. Limestone, 6".
 - c. Shale, bluish, 4'.
 - d. Shale, maroon, 6'.
 - e. Limestone, not well exposed, 8" or more.
 - f. Shale, covered, thickness (?).
 - g. Shale, bluish, 5'.
 - (3). Brownville Limestone, gray, poorly exposed, thickness formerly shown 3'.
- 2. McKissick Grove Shale member:
 - (1). Pony Creek Shale, a few feet of the upper portion exposed 40' above bed of ravine.

SECTION TWO MILES WEST AND ONE-HALF MILE NORTH OF MORRILL, KANSAS

I. Permian System, Council Grove Formation

- 1. Garrison Shale member:
 - (1). Eiss Limestone, 9' or more:
 - a. Limestone, weathered slabby, 2' exposed.
 - b. Shale, gray, calcareous, 6' 6".
 - c. Limestone, with many specimens of bryozoa largely of the genus *Thamniscus*, 1' 6" to 1' 10".
 - (2). Stearns Shale, blue, about 16'; upper 6' blue; middle 4' chocolate; basal 6' or more, bluish and poorly exposed.
 - (3). Morrill Limestone, yellowish, poorly exposed, 1' to 2'.
 - (4). Florena Shale, in slope, probably 5'.
- 2. Cottonwood Limestone member, poorly shown above covered slope, 5' or more.

SECTION TWO AND ONE-HALF MILES SOUTH AND ONE MILE WEST OF FALLS CITY

This is east of Pony Creek in the northeast quarter of section 33.

- 1. Admire Shale member, 37' exposed:
 - (1). Falls City Limestone, caps hill, 3' or more. It is eroded through on the southeast. The lower portion weathers knotty and yellowish.

- (2). Aspinwall Shale, 31' to 32':
 - a. Shale 14' to 15'; upper portion bluish and argillaceous; next 4' grayish, calcareous, and bladed; lower portion somewhat banded, bluish, and more argillaceous.
 - b. Limestone, light gray or bluish gray, somewhat shattered, 8" to 10".
 - c. Shale, in covered slope, about 16'.
 - (3). Brownville Limestone, gray, weathers brownish, forms a bench, 2' 6" or more.
2. McKissick Grove Shale member:
- (1). Pony Creek Shale, thickness (?), difficult to determine accurately.
 - (2). Dover Limestone, poorly exposed, quite hard at places, with a few fossils, 1' or more.
 - (3). Table Creek Shale:
 - a. Shale, 8' to 10'.
 - b. Sandstone, in small gulleys and ravines, dark blue, hard, weathers brownish, 8" or more.
 - c. Slope to flood plain, with evidence of sandy material, also sandy concretions, about 40', much or all of which is developed into the Table Creek Shale.

At the state line south of Falls City and extending southward, west of Reserve, Kansas, is an eroded high bench held by the Falls City Limestone. West of this is a succession of terrace-like uplands developed on the Falls City, Long Creek, Howe, and Neva limestones, the last named making the most striking feature. At a lower level in the Pony Creek valley is a bench on the Brownville Limestone.

SECTION UNDER PONY CREEK BRIDGE ONE AND ONE-HALF MILES SOUTH OF FALLS CITY

- 1. McKissick Grove Shale, 13' 6" exposed:
 - (1). Table Creek Shale, 2' of the base shown, the top being 5' to 8' below the lowest part of the slope formed on the McKissick Grove Shale in the preceding section.
 - (2). Maple Hill Limestone, two earthy layers separated by a shale seam, about 1' 6"; bluish, weathers slabby and light gray to buff; upper limestone 8" to 1'; lower layer 4" to 5". Fauna: Crinoid joints, *Chonetes granulifer*, *Spirifer cameratus*, *Productus semireticulatus*, and long *Fusulina*.
 - (3). Pierson Point Shale, about 10'; upper 5' dark, argillaceous, bedded, with some selenite crystals; middle 1' black, slaty, somewhat carbonaceous; lower 4' dark, bedded, argillaceous, tough, with a few *Lingula* sp.
- 2. Tarkio Limestone member, top 2' exposed on creek bed, altitude about 880'. This is about 120' lower than the Falls City Limestone in the upland at the state line 2 miles south.

PIERSON POINT SECTION, TWO MILES SOUTHEAST OF
FALLS CITY

1. McKissick Grove Shale member, about 42':
 - (1). Table Creek Shale, 31' 6":
 - a. Stone, limy-sandy, hard, weathers thin bedded, 2' to 4'.
 - b. Sandstone, 20' to 28'; upper portion micaceous, with friable concretions; lower portion friable and cross bedded.
 - c. Limestone, blue, with conchoidal fracture, few fossils, 10" to 1'.
 - d. Shale, blue, part carbonaceous, 3' 6".
 - (2). Maple Hill Limestone, bluish, dense, fossiliferous, forms large blocks, 9" or more.
 - (3). Pierson Point Shale, 10':
 - a. Shale, blue, bedded, plastic, 4'.
 - b. Shale, thin bedded, calcareous, 6'.
2. Tarkio Limestone, exposed just above the railroad, grayish to yellowish brown, fossiliferous, massive, 5' or more. Altitude of top about 895'.
3. Willard Shale member, about 4' exposed:
 - (1). Shale, blue, argillaceous, thin bedded, 1' 6".
 - (2). Shale, 2' 6"; dark at base, upper portion sandy.
 - (3). Slope to bottom land, a few feet.

The Tarkio Limestone is exposed east of the mouth of Walnut Creek and at Preston. The Emporia Limestone outcrops low in the slopes near the mouth of Muddy Creek and west of Preston. This and the other beds down to near the Burlingame Limestone are above the river level in the spur across the valley east of Preston, and some additional lower divisions are shown south of Rulo.

SECTION AT THE SPUR OF THE UPLAND ONE AND ONE-
HALF MILES SOUTH OF RULO

In the north half of Section 30, T. 1 N., R. 18 E.

1. Emporia Limestone member, caps spur, top eroded, thickness remaining, 5' to 6'.
2. Humphrey Shale member, 51':
 - (1). Auburn Shale, blue and maroon bands, mostly argillaceous, with thin seams of limestone, about 26'.
 - (2). Wakarusa Limestone, in two or more beds, bluish, dense, weathering brownish, 3' or more.
 - (3). Soldier Creek Shale, about 22'; top 2' chocolate colored, the rest bluish, with two thin limestone seams.
3. Burlingame Limestone member, badly concealed, bluish, massive, forms large blocks, weathers rusty brown, 5'+; altitude of the base about 876'. The main fossils are crinoid joints and brachiopods.

4. Scranton Shale member:

- (1). Silver Lake Shale, badly covered, blue, argillaceous, 8'.
- (2). Rulo Limestone, formerly exposed at foot of slope, blue, massive, fossiliferous, weathers rusty brown, 1' 4" to 1' 10". Fauna: Brachiopods, gastropods and *Lophophyllum profundum*.
- (3). White Cloud Shale, upper portion formerly exposed. The Elmo Coal near the top of this division has been mined here.

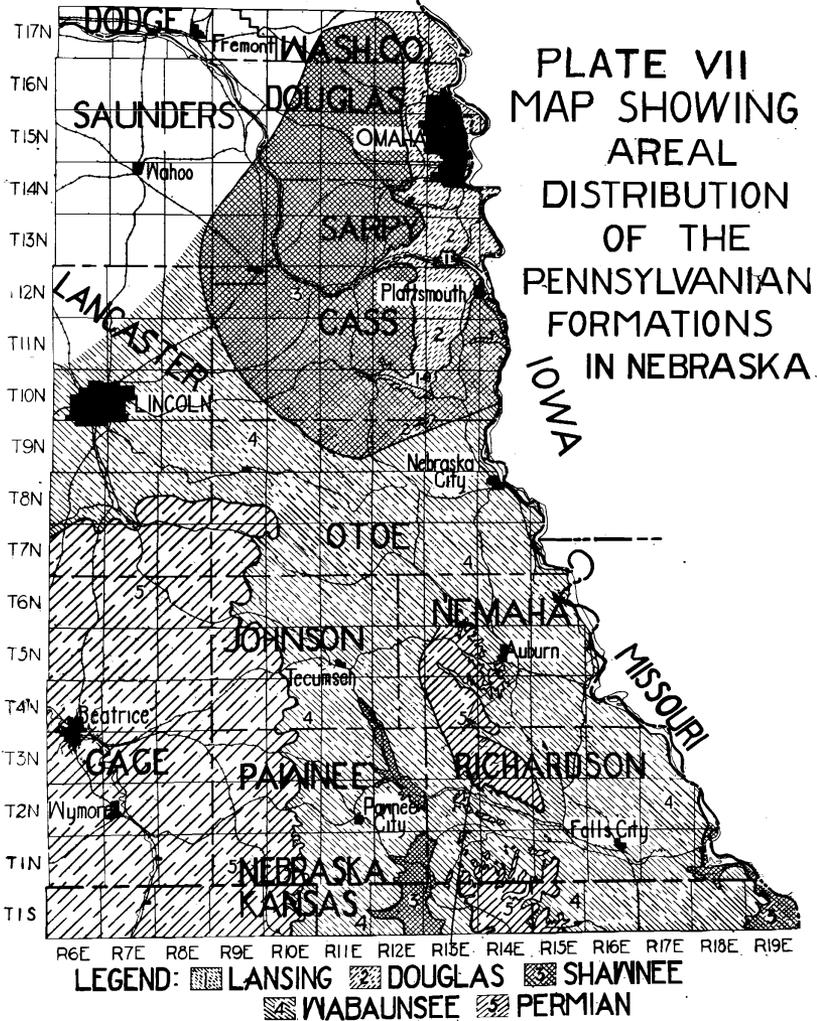
AREAL DISTRIBUTION OF FORMATIONS

Plate VII shows the outcrop areas of the Pennsylvanian formations in Nebraska, extending into northern Kansas. Although seven or eight formations of the system probably occur in southeastern Nebraska, only the upper four of them are exposed. The map or plate shows where each formation is at the surface or overlain by one or more of the following mantling deposits: Alluvium, loess, drift, and the Dakota formation.

Lansing Formation. What is thought to be the Stanton Limestone, which is the youngest member of this formation, is exposed in two small areas, i.e., west of LaPlatte and Oregopolis and on the North Fork Weepingwater northwest of Nehawka.

Douglas Formation. This is at the surface in a comparatively large area on the Nehawka Anticline from near Nehawka northward to beyond Omaha. It forms a small area on the South Fork Weepingwater; extends westward in the Weepingwater Valley to just beyond Weepingwater, in the Platte Valley to near Cedar Creek, and down the Missouri below Plattsmouth to Rock Bluff and Rock Creek Valley. Data are not available for determining the exact boundary of the formation northwest of Omaha.

Shawnee Formation. This is exposed along the Missouri in the southeastern part of Richardson County, on the crest of the Table Rock Anticline in the vicinity of Du Bois, and along the Big Nemaha between Elk Creek and a few miles southeast of Table Rock, and is more widely shown in the flanks of the Nehawka Anticline. The south boundary of the last named area is quite well marked by the Jones Point deformation, but the boundaries on the west and northwest are



only provisional. The formation is exposed at Ashland and at various points along the Platte eastward to beyond Louisville and south of Richfield. The west boundary is somewhere be-

tween west of Ashland and east of Lincoln, probably near Greenwood, extending northward to between Valley and Omaha or farther beneath the Dakota formation.

Wabaunsee Formation. This outcrops quite widely. It passes beneath the Permian beds on the west and at places east of the Table Rock Anticline as shown by Plate VII. The formation is covered by the Dakota Sandstone (Cretaceous age) in the vicinity of Lincoln and in places farther east. Just how far it extends northward in Saunders and other counties is not known.

Permian Formations. The Council Grove formation and the basal member of the Chase formation are exposed in the Pennsylvanian area of southeastern Nebraska. They are shown together on the areal map.

ECONOMIC RELATIONS

Although this volume is restricted to the stratigraphy of the Pennsylvanian beds, and although the economic relations are to be covered in separate reports, it seems advisable to make a brief review of the coal, stone, clay, and water resources, and of the oil and gas possibilities of the Pennsylvanian System as indicated by this stratigraphic study. This review, together with the preceding cross sections and descriptions, may be of assistance to those wanting economic data awaiting the final reports on these subjects.

Coal Resources. There are several thin coal beds in the Pennsylvanian System in Nebraska. Those of the Des Moines Series are restricted to the extreme southeast corner of the state, at depths somewhat greater than shown in the Davis well at Forest City, Missouri. They seem to be too thin and too deep for economic production.

The Nodaway, Elmo, and Nyman beds, exposed in several places, and lying under much of the southeastern part of the state at comparatively shallow depths, have been the sources of small production, mainly by drifting. They could be mined for local use, if necessary, but probably not for commercial production.

Stone Resources. Twenty-six of the Pennsylvanian limestones have been quarried in Nebraska, some of them quite extensively, especially the Ervine Creek and Platts-mouth beds. In many places the stone has been worked out in the valley sides to the point where the over burden became too thick for profitable quarrying. In a few places the stone is mined (Figure 38) without the drawback of removing the over burden. This is true with the Ervine Creek Limestone, which has a thick massive zone at the top which holds the roof between the pillars. Such mining has been done in the vicinity of Louisville. It would seem, also, that some of the limestone in the uplands farther back from the valleys might be removed through shafts as is done in coal mining.

There are a number of places aside from those now worked, where stone could be quarried and mined for rip-rap, road building, and cement manufacture.

Clay Resources. Some of the shale units, such as the Scranton, McKissick Grove, and Admire members, carry argillaceous clay suitable for brick and tile manufacture, as at Table Rock, Humboldt, Dunbar, Nebraska City, Unadilla, Auburn, and other places. At most points there are thin limestones, and in some places lensing sandstones, which must be removed with the clay. These by-products are used for rip-rap and other purposes. Brick and tile plants operate on the Pennsylvanian beds at Table Rock, Humboldt, and Nebraska City.

Water Resources. In most of the Pennsylvanian outcrop area of Nebraska, there are shallow well water supplies in the alluvial and drift deposits, and it is not necessary to seek deeper supplies. In some places, however, wells have been extended to the shallower limestones and sandstones of the system. The salt water which has been encountered at various depths, is used in a small way for sanitarium purposes.

Oil and Gas Possibilities. The stratigraphy of the Pennsylvanian beds, as described in the preceding pages of this report, should serve in the interpretation of the oil and gas possibilities. It indicates both favorable and unfavorable

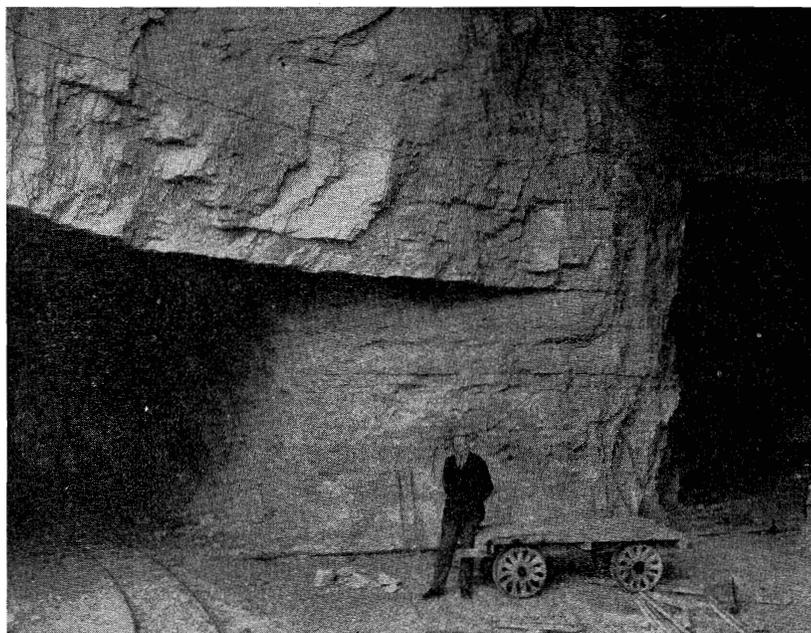
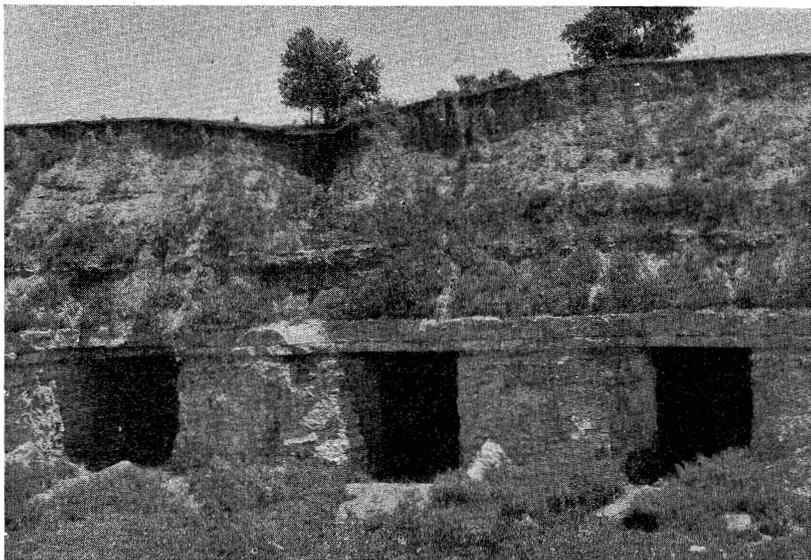


FIGURE 38.—Mining the Ervine Creek Limestone near Louisville.

conditions for evaluation by oil geologists. The logs of the wells show that there are likely oil and gas horizons in the rock system below the Pennsylvanian. The granite wells at DuBois and Table Rock condemn the axial part of the Table Rock Anticline, and the well northwest of Nehawka condemns part of the Nehawka structure. It is evident, however, that there is some chance for oil and gas in the flanks of the Table Rock and Nehawka anticlines, and probably in the Richfield and Redfield anticlines. It would seem, also, that there are possibilities in the broad terrace just east of the Humboldt Fault. The depth required for oil and gas prospecting in the structures cited above is much less than is generally supposed.

LOGS OF DEEP WELLS

THE AMERADA PETROLEUM COMPANY WELL

Four miles north and two miles west of Nehawka
(NE. of Sec. 11, T. 11 N., R. 12 E.)
Altitude about 1,145'

STRATUM	Thickness		Depth	
	Feet	Inches	Feet	Inches
Colluvial wash and drift.....	27		27	

PENNSYLVANIAN SYSTEM

MISSOURI SERIES, 309' 10"

I. Douglas Formation, 109' 2":

1. Oread Limestone member:

(1). Base of Plattsmouth Limestone:

a. Grayish, massive, part weathered buff	2	7	29	7
b. Dark gray, dense, with free calcite; large Fusulina at base.....	4	10	34	5
c. Dark gray, soft.....	2		36	5
(2). Heebner Shale, nearly black.....	3	7	40	
(3). Leavenworth Limestone, bluish gray, dense, brittle, fossiliferous.....	2		42	
(4). Snyderville Shale, 14':				
a. Bluish gray, calcareous, indurated, massive	8	6	50	6
b. Brownish above, maroon below, mottled with blue, massive.....	5	6	56	
(5). Weeping Water Limestone, gray, massive, not very compact, fossiliferous, shaly near top and base.....	8		64	

2. Lawrence Shale member, 55' 6":

(1). Shale, 44':

a. Gray, very fossiliferous, indurated	2		66	
b. Red and yellowish with blue mottlings, argillaceous	7		73	
c. Weathered yellowish, with reddish seams, probably at an unconformity, argillaceous to arenaceous, bedded, with some fine mica	4	6	77	6
d. Bluish, argillaceous to calcareous, with carbonaceous band (core destroyed)	30	6	108	
(2). Shoemaker Limestone, dark gray, massive, earthy, compact, fossiliferous	5		113	
(3). Shale, 6' 6":				
a. Dark gray to black.....		6	113	6
b. Nearly black, finely bedded, fossiliferous	1	2	114	8
c. Dark gray, calcareous.....		6	116	2

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d. Limestone, gray, dense.....	4		115	6
e. Dark gray	6		116	
f. Bluish gray, calcareous.....	3	6	119	6
g. Limy shale, bluish gray.....	2		121	6
3. Iatan Limestone member, 9' 8":				
(1). Limestone, dark gray, irregular, "pellet" structure.....	4	10	126	4
(2). Shale, gray, calcareous, with many Fusulina	1	2	127	6
(3). Limestone, dark gray, massive, fos- siliferous, shaly at base.....	1	10	129	4
(4). Shale, bluish gray, argillaceous to calcareous	1	10	131	2
(5). Limestone, gray dense, massive.....	1+		132	2
4. Weston Shale member, calcareous	4		136	2

II. Lansing Formation, 60' 10":

1. Stanton Limestone member, 26' 6":				
(1). Limestone, medium dark gray, mas- sive, dense, brittle, fossiliferous; with calcareous shale between 149' 6" and 152' 10". Fauna: Crinoid fragments, Chonetes granu- lifer; Fusulina near middle; Squamularia perplexa near base....	18	10	156	
(2). Shale, with limestone bodies, dark gray, calcareous, massive. Fauna: Fenestella, Squamularia perplexa, crinoid fragments, fenestrated bryozoa, Pugnax osagensis, and Productus cora	4	11	159	11
(3). Shale, dark, laminated.....		5	160	4
(4). Limestone, gray, massive.....		6	160	10
(5). Limy shale, gray.....		6	161	4
(6). Shale, dark, carbonaceous, very fos- siliferous. Fauna: Rhombopora lepidodendroides, Ambocoelia plano- convexa, Pugnax osagensis, Orbi- culoidea missouriensis, Astartella concentricus, Aviculopecten occi- dentalis, Myalina swallowi, Pleurio- phorus sp., Edmondia sp., and Euphemus carbonarius		6	161	10
(7). Limestone, very dark gray, indurated, Rhombopora lepidodendroides.....		10	162	8
2. Vilas Shale member, 8' 4":				
(1). Limy shale, very dark gray, indurated, crinoid fragments, and Marginifera splendens		10	163	6
(2). Shale, dark gray, bedded.....	1	9	165	3
(3). Shale, bluish gray, massive, with cal- careous concretions near top, pyriti- ferous	5	9	171	

3. Plattsburg Limestone member, dark gray to light gray, massive, fossiliferous, part oolitic, part clastic; reticulate in top of lower portion, with some silt and scattered small flakes of mica at base, and some limy pebbles; a few <i>Fusulina</i> , crinoid fragments. <i>Spirifer cameratus</i> near top; shale between 174' 8" and 175' 6" with <i>Orbiculoidea missouriensis</i>	8		179	
4. Lane Shale member, 18':				
(1). Dark gray, fine textured, brittle.....	3	4	182	4
(2). Dark gray, argillaceous, fossiliferous		8	183	
(3). Gray, argillaceous, crumbly, pyritiferous. Fauna: <i>Septopora biserialis</i> , <i>Fenestella</i> sp., <i>Rhombopora lepidodendroides</i> , <i>Derbya crassa</i> , <i>Pustula nebrascensis</i> , <i>Myalina swallowi</i> , <i>Aviculopecten occidentalis</i> , <i>Limopteria marion</i> (?), <i>Griffithides</i> sp.	4	10	187	10
(4). Limestone, light gray, massive, crinoid fragments	6	8	194	6
(5). Shale, bluish gray, limy, massive, fossiliferous	1	6	196	
(6). Shale, dark bluish gray, limy, massive, pyritiferous, fossiliferous.....	1		197	

III. Kansas City Formation, 139' 10":

1. Iola Limestone member, grayish, massive, with dark gray shale bands, fossiliferous. Fauna: <i>Fusulina</i> (few), <i>Fenestella</i> sp., <i>Rhombopora lepidodendroides</i> , crinoid joints, <i>Chonetes</i> sp., <i>Productus magnicostatus</i> , <i>C. subtilita</i> , <i>Spirifer cameratus</i> , <i>Marginifera splendens</i> , and <i>Derbya crassa</i>	15	10	212	10
2. Chanute Shale member, 24' 2":				
(1). Limestone and shale, in layers, dark gray. Fauna: <i>Fusulina</i> , crinoid fragments, <i>Ambocoelia planoconvexa</i> , and <i>Composita subtilita</i> identified	5		217	10
(2). Limy shale, dark gray, fossiliferous. Fauna: Crinoid fragments, <i>Spiriferina kentuckyensis</i> , <i>Marginifera</i> , sp.	1		218	10
(3). Limestone, very dark gray, fossiliferous, but specimens not in good condition. Crinoid fragments, <i>Ambocoelia planoconvexa</i> , and <i>Pugnax osagensis</i> identified.....		8	219	6
(4). Shale, dark gray, limy-sandy, fossiliferous	1		220	6

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(5). Shale, black, with gray specks.....	9	221	3
(6). Limestone, dark gray, <i>Septopora biserialis</i> , <i>Rhombopora lepidodendroides</i> , and crinoid joints.....	11	222	2
(7). Shale, bluish gray, indurated, fine textured, brittle, pyritiferous, with fossil fragments not in condition for identification.....	10	4	232
(8). Limestone, gray.....	2	232	8
(9). Shale, dark gray, carbonaceous-argillaceous	4	233	
(10). Limestone, gray.....	2	233	2
(11). Shale, dark gray, very fossiliferous, <i>Productus cora</i> abundant, many <i>Fusulina</i> in limy seams.....	5	233	7
(12). Shale, bluish gray.....	3	5	237
3. DeKalb Limestone member, dark gray to light gray, massive, fragments of crinoids and brachiopods.....	8	245	
4. Cherryvale Shale member, 8' 6":			
(1). Limestone or massive limy shale, <i>Rhombopora lepidodendroides</i> , and crinoid fragments.....	1	6	246
(2). Shale, gray, argillaceous, crumbly.....	1	9	248
(3). Shale, black or dark gray, with some carbonaceous material.....	9	249	
(4). Shale, bluish gray, argillaceous, calcareous in lower portion.....	4	6	253
5. Winterset Limestone member, 29':			
(1). Limestone, part oolitic, reticulate, part dense with shale fillings, and fossils poorly preserved. Fauna at 255' 2": <i>Endothyra</i> , Crinoid joints plentiful, Crinoid radial plates, very small gastropods, <i>Rhombopora lepidodendroides</i> , <i>Productus cora</i> , <i>Derbya crassa</i> , <i>Meekella striatacostata</i> , <i>Composita subtilita</i> , <i>Orbiculoidea missouriensis</i> <i>Chonetes laevis</i> (?), <i>Chonetes verneuillianus</i> (early variety).....	8	6	262
(2). Limestone, gray, earthy.....	2	5	264
(3). Limestone, gray, massive.....	1	7	266
(4). Shale, bluish gray, argillaceous, quite fossiliferous	1	9	267
(5). Limestone, light gray, silty, with very small limy lumps and some pyrites; lithographic below; quite fossiliferous, <i>P. cora</i> (abundant), <i>Cliothyridina orbicularis</i>	1	3	269

(6). Shale, dark gray, argillaceous, calcareous, with very small limy lumps; <i>Productus cora</i> , <i>Bucanopsis meekana</i> , <i>Myalina swallowi</i> , <i>Pleurophorus</i> sp.....	2	8	271	8
(7). Limestone, light gray, massive, part oolitic, with incipient dolomitization; scattered minute <i>Fusulina</i>	10	10	282	6
6. Galesburg Shale member, top gray, fossiliferous; next 6" coal-like; middle and base, bluish gray, argillaceous, part nodular, with some very fine mica. Fauna at 283' 6" to 284' 6": <i>Fusulina</i> , <i>Endothyra</i> , <i>Trochammina</i> , and other foraminifera; crinoid joints, <i>Polypora</i> sp., <i>Rhombopora lepidodendroides</i> , <i>Orbiculoidea missouriensis</i> , <i>Ambocoelia planoconvexa</i> , <i>Composita subtilita</i> , <i>Productus magnicostatus</i> , <i>Spirifer cameratus</i> (?), <i>Pustula nebrascensis</i> , <i>Derbya crassa</i> , <i>Chonetes granulifer</i> (stunted), <i>Chonetes verneuillianus</i> (variety), <i>Astartella concentrica</i> , <i>Pelecypod</i> (?), <i>Patellastium concentrica</i> , <i>Schizostoma catilloides</i>	8	2	290	8
7. Bethany Falls Limestone member, 24':				
(1). Limestone, dark gray, massive, oolitic, with shale layers near the middle and base; <i>Osagea</i> , a few foraminifera, and a fragment of <i>Stenopora</i> sp.	10		300	8
(2). Shale, upper portion gray, massive; lower portion dark and bedded, combined thickness.....	1	10	301	6
(3). Limestone, very dark gray, dense; upper portion filled with fossils not in condition for identification; one <i>Meekella striatocostata</i> . The following occur near the middle: <i>Osagea</i> (few); <i>Endothyra</i> , <i>Valvulina</i> , <i>Climacammina</i> , and other foraminifera; sponge spicules; <i>Ambocoelia planoconvexa</i> , <i>Productus cora</i> , <i>Pustula nebrascensis</i> , <i>Chonetes subtilita</i> , <i>Productus magnicostatus</i> , <i>Derbya singula</i> , <i>Productus pertenuis</i>	3		305	6
(4). Limestone and shale, dark gray; upper 3' 6" nearly pure limestone; remainder with limestone pebbles or bodies; shale calcareous; <i>Climacammina</i> , <i>Fusulina</i> (small), and other foraminifera; sponge spicules, crinoid fragments.....	9	2	314	8

8. Ladore Shale member, 7' 4":
- | | | | | |
|--|---|---|-----|---|
| (1). Shale, gray, limy, massive; <i>Margini-
fera splendens</i> (common), <i>Ambo-
coelia planoconvexa</i> , <i>Orbiculoidea
missouriensis</i> , <i>Chonetes verneuili-
anus</i> | 1 | 8 | 316 | 4 |
| (2). Shale, black, bedded; <i>Lingula car-
bonaria</i> , <i>Pugnax osagensis</i> , <i>Nucu-
loopsis ventricosa</i> , <i>Acanthopecten</i> sp. | 2 | 2 | 318 | 6 |
| (3). Limestone, dark gray, dense, massive;
<i>Valvulina</i> , <i>Sponge spicules</i> | | 6 | 319 | |
| (4). Shale, bluish gray, argillaceous, mas-
sive | 3 | | 322 | |
9. Hertha Limestone member, 14' 10":
- | | | | | |
|---|---|----|-----|----|
| (1). Limestone, dark gray; dense, nodular,
earthy, with some pyrites; stylo-
litic, with poorly preserved fossils;
algal growth a feature; <i>Osageia</i> ,
<i>Valvulina</i> , <i>Trochommina</i> , <i>Endo-
thyra</i> ; fragment of bryozoa..... | 6 | | 328 | |
| (2). Limestone, light gray to dark gray,
i.e., clouded, fine textured, brittle,
dense; fractures with sharp edges,
with some shale in upper portion
which is not fossiliferous. Fauna of
lower portion: <i>Endothyra</i> , <i>Valvu-
lina</i> , and other foraminifera, <i>Valvu-
lina</i> , and other foraminifera,
<i>Sponge spicules</i> , <i>Squamularia per-
plexa</i> | 8 | 10 | 336 | 10 |

DES MOINES SERIES, 125' 8"

1. Limestone and shale, 16' 2":
- | | | | | |
|---|---|---|-----|---|
| (1). Shale, 4' 7": | | | | |
| a. Shale, dark gray, calcareous, with
some limestone bodies; <i>Lingula
carbonaria</i> , <i>Pugnax osagensis</i> ,
<i>Orbiculoidea missouriensis</i> | 1 | 2 | 338 | |
| b. Limestone, dark gray, dense..... | | 2 | 338 | 2 |
| c. Shale, gray, argillaceous, massive,
lumpy, with slickensides..... | 3 | 3 | 341 | 5 |
| (2). Limestone, upper portion dark gray,
fine textured; lower portion medium
dark gray, semi-crystalline, with
some lime pebbles, pyrites, stylo-
lites and fossil fragments; algal
growth; <i>Valvulina</i> , <i>Trochommina</i> ,
crinoid fragments, <i>Composita sub-
tilita</i> , small gastropods..... | 1 | 7 | 343 | |
| (3). Shale, bluish, calcareous, pyritiferous
at top, with fine light colored mica
and small dark or brownish limy
concretions, some being filled with
calcite | 5 | | 348 | |

(4). Limestone, dark gray, massive, cavernous, reticulate, with silt-clay filling, stylonitic; upper portion with brownish tinge; good sized pelecypod at 349'. Fauna: Small gastropods, crinoid plates and joints, echinoid spines, Squamularia perplexa, Rhipodomella carbonaria, and Composita subtilita.....	3		351	
(5). Shale, bluish; Orbiculoidea, and Composita subtilita		8	351	8
(6). Limestone, dark gray to brownish gray, semi-crystalline, with some pyrites, scattered fine mica, brachiopod fragments, and stylonites; lower portion with a few Ambo-coelia planoconvexa, a good many crinoid joints, and many Fusulinella sp.	1	4	353	
2. Shale and limestone, 21' 6" :				
(1). Shale, bluish, argillaceous, massive, with many small calcareous concretions	3	6	356	6
(2). Shale, bluish to reddish, silty or sandy, lumpy, with some slickensides	9	6	366	
(3). Shale, dark gray, argillaceous-arenaceous	1		367	
(4). Shale, mostly red, arenaceous-argillaceous, with small flakes of mica....	3	8	370	8
(5). Limestone, dark gray, cavernous, filled-in with bluish gray shale; quite fossiliferous; upper 6" massive; middle and lower portions shaly; Fusulinella, crinoid joints (common), Chonetes granulifer, Chonetes mesolobus, Composita subtilita, Pugnax osagensis (?), Ambo-coelia planoconvexa	2	6	373	2
(6). Shale, bluish gray, argillaceous; Fusulinella sp., Orbiculoidea missouriensis, Composita subtilita, Chonetes mesolobus, fish scales, and a shark's tooth.....		8	373	10
(7). Limestone, gray, base with many Fusulinella sp.....		8	374	6
3. Shale and sandstone, 88' :				
(1). Shale, reddish, mottled with bluish gray, calcareous lumps, some fine mica, and slickensides.....	6		380	6
(2). Shale, reddish or solid red, silt and fine sand, slickensides.....	5	6	386	

(3). Sandstone, gray, reddish at top, with lime cement and very fine mica.....	1		387	
(4). Shale, reddish to grayish, even grained, mostly silt, very fine sand, and some clay	3	5	390	5
(5). Limestone, dark gray, cavernous, filled-in with blue and red shale.....		7	391	
(6). Shale, bluish gray, silt and clay, fine grained, breaks along bedding planes	1		392	
(7). Limestone, dark gray, fragmentary, brecciated		2	392	2
(8). Shale, bluish gray, argillaceous-sandy, with some irregular induration; small brownish concretions; massive, except top which is poorly bedded; some fossil fragments.....	3	4	395	6
(9). Shale, red, silty to sandy, massive, with bluish splotches near top.....	4	6	400	
(10). Shale, yellowish brown to reddish, irregular, lumpy; crinoid joints, <i>Composita subtilita</i> , <i>Chonetes mesolobus</i> , <i>Chonetes granulifer</i> , <i>Ambocoelia planoconvexa</i> , <i>Derbya crassa</i> , <i>Pustula nebrascensis</i>	2	8	402	8
(11). Shale, bluish gray with reddish zones, essentially a micaceous sandstone, separates along bedding planes.....	11	10	414	6
(12). Limestone, dark gray, semi-crystalline, dense.....		4	414	10
(13). Shale, dark gray with reddish tinge, slabby, argillaceous		1	414	11
(14). Shale, bluish gray, sandy.....		3	415	2
(15). Shale, gray, mottled with some red, massive, slickensides	3		418	2
(16). Shale, grayish, limy and lithographic at base, becoming quite argillaceous at top with large yellowish and reddish splotches; fossiliferous in lower portion; crinoid fragments, ramose form of bryozoa, <i>Composita subtilita</i> , <i>Spiriferina kentuckyensis</i> , <i>Pustula nebrascensis</i> , <i>Lingula</i> sp., <i>Marginifera splendens</i> (?).....	1	10	420	
(17). Limestone, bluish gray, part weathered yellowish, soft, earthy; crinoid joints, brachiopod fragments.....	1	6	421	6
(18). Shale, bluish gray, argillaceous, crossed by very thin sandy seams....	1	2	422	8
(19). Limestone, dark gray to brownish gray, fragmental, brecciated.....		10	423	6
(20). Shale, bluish, gray with some red; lumpy; slickensides.....	1	6	425	

(21). Shale, reddish to bluish gray, massive, argillaceous-arenaceous, very small concretions in lower portion.....	3		428	
(22). Shale, dark gray, argillaceous, indurated, calcareous.....	1	2	429	2
(23). Limestone, dark gray, dense, semi-crystalline, filled-in with bluish gray shale.....	1		430	2
(24). Shale, blue, massive, fossiliferous at top; <i>Productus cora</i> , <i>Pustula nebrascensis</i> , and fragments of other species		6	430	8
(25). Limestone, dark gray, dense, massive; semi-crystalline below, fossil fragments		6	431	2
(26). Shale, bluish gray, fine grained, argillaceous, darker gray and somewhat earthy at top, <i>Lingula</i> sp.....		8	431	10
(27). Shale, bluish gray, argillaceous, slickensides	2		433	10
(28). Shale, bluish, argillaceous, massive, slickensides, reddish-mottled at top		6	434	4
(29). Limestone, dark gray, semi-crystalline, rather dense, arenaceous, part weathered brownish, small flakes of mica in upper portion, becoming sandy, with 6" of white arenaceous to shaly material at top; pelecypod fragments	1	8	436	
(30). Shale, reddish, mottled yellowish green, argillaceous, indurated, lumpy; slickensides in upper portion; fossiliferous; some <i>Productus cora</i> , <i>Productus cora</i> variety, <i>Pustula nebrascensis</i>	5		441	
(31). Shale, argillaceous, buff in upper half; lower 4" red, with thin carbonaceous seam at 442' 6" and nodular limy fossiliferous or concretionary bodies at 443'; very fine mica, slickensides, and fossils in upper portion; <i>Lingula</i> sp., small pelecypods	3		444	
(32). Limestone, dark gray, semi-crystalline, somewhat cavernous, weathered brownish, with brachiopod fragments		8	444	8
(33). Shale, dark gray at base, somewhat reddish in middle in upper portions; weathered buff at top, arenaceous, fine texture, micaceous; separates along bedding.....	10	4	455	
(34). Shale, dark bluish gray, and silty throughout, massive.....	2	8	457	8

(35). Limestone, bluish gray to dark gray, quite firm	6	458	2
(36). Shale, massive, bluish gray, filled with hard nodular calcareous material, slickensides	1	4	459
(37). Re-worked material, most of it dark gray and limy; cut across by bluish gray shale seams, basal 8" firmly indurated, conglomeratic.....	2		461
(38). Shale, gray, argillaceous, a few pebbles, slickensides.....	1	462	6

MISSISSIPPIAN SYSTEM, 261' 6"

I. Limestone and dolomite, light gray to dark gray, fine to coarse grained, cherty, with a few poorly preserved fossils; weathered brownish, with cavities filled with bluish gray to reddish clay shale, and some pebbles, 111' 6":			
1. Limestone, brownish, fine grained, cherty	1		463
2. Limestone, cavernous, filled-in with shale	6		464
3. Limestone, brownish, fine grained, cherty	2		466
4. Cavernous limestone, gray to brownish, fine grained, filled-in with bluish to reddish shales, more shale than limestone	6		472
5. Limestone, dark gray, massive	1	8	473
6. Limestone, cavernous, filled-in with bluish clay shale.....	2	4	476
7. Dolomite, buff, fine textured.....		6	476
8. Shale in cavities, mostly massive, bluish, with a few small pebbles.....	1	8	478
9. Limestone, brownish, cherty, arenaceous, magnesian	8	10	487
10. Clay-shale filling.....		6	487
11. Limestone, brownish, dolomitic and cherty above, weathered buff below..	2	8	490
12. Shale in cavities, reddish or bluish, argillaceous, pebbly	2	4	492
13. Limestone, bluish gray, cherty.....	1		493
14. Clay shale.....	1		484
15. Limestone, bluish gray, cherty.....	2	1	496
16. Limestone, with clay filling cavities.....	1	11	498
17. Dolomite, silicious, crystalline, dark gray, part vitreous.....	8	6	507
18. Shale in fissures.....	2		509
19. Limestone, gray to brownish, nearly solid, pyritiferous; clay shale at 517' 5" to 518' 4"; thickness.....	22	6	531

20. Limestone, light gray, fine grained, pyritiferous	2	6	534	
21. Limestone, brownish, cherty, pyritiferous, small crystals of galenite.....	6		540	
22. Limestone, medium dark gray, with some calcite in veins.....	2		542	
23. Limestone, brownish, cherty, pyritiferous, with a few crystals of galenite	8		550	
24. Dolomite, brownish, fine grained, with some shale	19	6	569	6
25. Limestone, dark gray, shaly.....	1	3	570	9
26. Limestone, magnesian, pyritiferous; cherty at top	3	3	574	
II. Dolomite and Shale, 59' 6":				
1. Dolomite, light gray, fine grained.....	3	3	577	3
2. Shale, dark gray.....		6	577	9
3. Dolomite, buff, base disintegrated.....	2	5	580	2
4. Shale, gray, indurated.....	1	10	582	
5. Dolomite, vitreous, crystalline.....		8	582	8
6. Dolomite, light gray, fine grained.....		4	583	
7. Shale, gray, with layers of dolomite....	7	8	590	8
8. Dolomite, brownish, arenaceous, crystalline	11	10	602	6
9. Shale, gray, and dolomite, weathered buff or dark gray and pyritiferous....	4	6	607	
10. Dolomite, brownish, siliceous.....	1	6	608	6
11. Shale, gray, indurated, sandy, mottled gray above; argillaceous below.....	2	9	611	3
12. Limestone, medium dark gray, very fine grained to nearly amorphous, magnesian, rather impure.....	1	3	612	6
13. Dolomite, brownish, granular, siliceous	1	2	613	8
14. Shale, greenish blue, argillaceous, crumbly		7	614	3
15. Dolomite, dark gray to medium dark gray, fine grained, with some clay....	3	3	617	6
16. Dolomite, brownish in top, light gray, vitreous, pitted from 621' to 627' except in lower 1' which is fine grained; pyrites at 618' to 621'.....	9	6	627	
17. Shale, bluish gray, crumbly, argillaceous, pyrites at base.....	1		628	
18. Shale, dark gray, massive.....	2	4	630	4
19. Dolomite, fine grained.....		2	630	6
20. Shale, dark gray to nearly black.....	3		633	6
III. Dolomite, 90' 6":				
1. Dolomite, upper 1' brownish; next 2' crystalline, vitreous, with clay in thin seams	8		641	6
2. Dolomite, light gray, fine grained.....	22	2	663	8
3. Shale, gray, indurated.....		5	664	1

4. Dolomite, light gray, fine grained, with darker zones; 4" shale in an oblique seam at 672'.....	21	11	686	
5. Dolomite, light gray, part brownish-mottled, dense to pitted, filled in with bluish shale.....	29	4	715	
6. Dolomite, light gray, fine grained, with shale seams between 718' and 718' 8"	8	8	724	

MISSISSIPPIAN (?) DEVONIAN (?), 45' 5"

1. Dolomite, light gray to dark gray, irregular with shale seams, part weathered buff, pyritiferous.....	9	6	733	6
2. Shaly, dark gray, or weathered, with some dolomite	1	4	734	10
3. Dolomite, massive, granular, part vitreous, pyritiferous	5	2	740	
4. Shale, dark gray, indurated.....	1	4	741	4
5. Dolomite, light gray, fine to coarse, part vitreous	8	10	750	2
6. Shale, dark gray to black.....		4	750	6
7. Dolomite, light gray to dark gray, part earthy, with seams of shale.....	3	6	754	
8. Dolomite, brownish, with some quartz bodies, and dark gray shale layers, part light gray, pyritiferous.....	8	6	762	6
9. Shale, gray, massive, argillaceous.....	3	4	765	10
10. Dolomite, light gray, part fine grained.....	2	5	768	3
11. Shale, bluish gray, argillaceous.....	1	2	769	5

SILURIAN SYSTEM, 643' 1"

1. Dolomite, light gray, part crystallized.....	6	7	776	
2. Dolomite, brownish, dark gray, vitreous, fine grained, dense, pyritiferous, portions with broken down silica.....	25	6	801	6
3. Dolomite, grayish, part brownish mottled, crystalline, mostly vitreous, pyritiferous; pitted, cavities filled with bluish shale. Fauna: Favosites favosus (?) Favosites niagarensis, Halysites catenulatus. These fossils show that this is Silurian. Divisions 1 and 2 above are lithologically a continuation upward of division 3.....	187	6	989	
4. Dolomite, light gray, fine grained to amorphous, with small scattered bodies of broken down silica, and some pyrites; clay fillings in a few fissures.....	28	6	1017	6

5. Dolomite, light gray and light bluish gray, amorphous to fine grained, with some broken down silica, pyritiferous.....	38		1055	6
6. Broken down silica, nearly white, soft.....	1	1	1056	7
7. Flint, bluish to brownish.....		5	1057	
8. Broken down silica, nearly white, soft.....	7	6	1064	6
9. Shale, indurated, light bluish gray, grading into dolomite at top.....	21	6	1086	
10. Core missing	4		1090	
11. Dolomite, light gray to brownish, fine grained, coarser at places.....	26	6	1116	6
12. Dolomite, gray and brown-mottled, crystalline, part pitted, <i>Conchidium occidentalis</i> (?).....	51	6	1168	
13. Core missing	11	5	1179	5
14. Dolomite, medium dark gray, part coquina-like and mottled brownish, crystalline, fine to coarse grained, pyritiferous, with clay in cavities, some broken down silica at places.....	95	7	1275	
15. Dolomite, grayish, crystalline, part pitted	16		1291	
16. Dolomite, lighter gray, fine grained, with some showings of light colored siliceous material	51		1342	
17. Dolomite, gray to brownish, vitreous, pitted at places, pyritiferous.....	70	6	1412	6

ORDOVICIAN SYSTEM, 72'

1. Maquoketa Shale (?), dark gray, sandy; argillaceous in middle and top, with dolomitic layers between 1426' 6" and 1427', and 1420' to 1423' 4". <i>Isotelus</i> sp., <i>Plectambonites sericeus</i> , <i>Dalmanella</i> sp.	23	10	1436	4
2. Galena Dolomite, brownish limestone or dolomite, grading into dark gray shale above and below, with some pyrites.....	14	8	1451	
3. Decorah Shale and Plattville Limestone, 33' 6":				
(1). Shale, dark, sandy, with small bodies of lime. Fauna: <i>Ramosa</i> forms of bryozoa as fragments, <i>Rhinidictya</i> sp., <i>Homotrypa</i> sp., <i>Monticulipora</i> sp., <i>Rafinesquina</i> sp., <i>Rhynchotrema</i> sp., <i>Plectambonites</i> sp., <i>Zygospira recurvirostris</i> (?)	3	4	1454	4
(2). Limestone, dark gray to brownish, shaly at base	5	1	1459	5

PENNSYLVANIAN SYSTEM

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(3). Shale, dark gray, argillaceous, with thin bands of dark gray limestone at top and base.....	8	7	1468	
(4). Limestone (probably the Plattville), brownish, fine grained, dense, conchoidal fracture, fossiliferous, Rafinesquina (common), Trematis ottawaensis	7	2	1475	2
(5). Shale, dark gray to bluish green, argillaceous, brittle, with small light gray, bodies of limestone, showings of pyrites; fossiliferous in upper 1'6". Fauna: Fragments of flattish ramose forms of bryozoa, Rafinesquina sp., Dalmanella sp., Pidnodema subaequata....	9	4	1484	6

ORDIVICIAN (?) CAMBRIAN (?), 76' 2"

1. Shale, dark gray, sandy, with small bodies of light gray limestone in lower two-fifths where they occupy one-third to one-half of the volume. No fossils were found in this division which lithologically is more like the Ordovician than the Cambrian. It may prove to be the former	33	6	1518	
2. Sandstone, dark gray to light mottled, pyritiferous.....	18		1536	
3. Sandstone, gray, weathered buff, fine grained, friable; showings of pyrite. This and the next above may be the St. Peter Sandstone in the Ordovician.....	22	10	1558	10
4. Shale, dark gray, sandy	1	4	1560	2
5. Shale, dark gray, argillaceous.....		6	1560	8

CAMBRIAN SYSTEM, 6' 4"

1. Conglomerate, dark pebbles in gray sand	2		1562	8
2. Conglomerate, like above, with petroleum residue, fragments of Orboloid brachiopods		6	1563	2
3. Sandstone, or sandy shale, dark gray mottled, with poorly preserved fossil fragments	1	3	1564	5
4. Shale, dark, argillaceous, indurated.....		10	1565	3
5. Conglomerate, with dark pebbles and fragments of Orboloid brachiopods.....	1	3	1566	6
6. Sandstone or sandy shale, dark gray.....		2½	1566	8½
7. Conglomerate, with dark pebbles and fragments of Orboloid brachiopods.....		3½	1567	

PRE-CAMBRIAN ROCKS

Mostly reddish to grayish brown, fresh arkose quartzite, with some altered chlorite and diabase, cemented more or less with calcium carbonate.....	261	1828
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This well was completed in October, 1924, as a test for oil and gas. It started with a 6" core; contracted to 3½" at a depth of 515' and to 2½" at 805'. The core was boxed and hauled by truck to the office of the Geological Survey of the University for preservation and study. Mr. Sidney Powers, Chief Geologist of the Amerada Petroleum Company, cooperated fully with the Survey in securing the core and has shown an interest in its study and interpretation. Although neither oil nor gas was found, the core and log of this well have importance in subsurface geology and have great value to Nebraska. It is our best record of the state's formations below those exposed in the natural sections. Fortunately it starts only a few feet above the horizon of the oldest outcrop core and to the correlation of the strata.

The core has been studied quite closely by Dr. Eula D. McEwan of the Department of Geology, Professor C. J. Frankforter of the Department of Chemistry, E. A. Nieschmidt and the writer of the Survey, and Dr. Carl O. Dunbar of Yale University. This investigation has related to the lithology, chemical composition, and fauna of the beds represented in the core and the correlation of the strata.

The Survey disclaims any connection with those reports on this well, which state that the Ordovician rocks were encountered immediately below the Mississippian, or that granite was reached. The state report is as given above.

CAPITOL BEACH WELL WEST OF LINCOLN

Altitude well curb about 1,148'

This well was put down on state land with core drill in the hope of discovering rich salt brine, coal, or other material of economic importance. It was completed in 1887. Mr. B. P. Russell was the geologist in charge of the core and report.

Unfortunately, the core of this well has not been preserved

in a suitable condition for study. Some doubt has been expressed from time to time regarding the depth reached in the well and the accuracy of Mr. Russell's report. It seems now, however, that the well record is quite reliable, and that there was no misrepresentation.

The original report, abridged and modified as to terminology and form, is as follows.

ALLUVIUM AND DAKOTA FORMATION

STRATUM	Thickness		Depth	
	Feet	Inches	Feet	Inches
Soil and subsoil	4		4	
Sand, with greenish tinge	16		20	
Sand, light colored, coarse.....	4	8	24	8
Gravel, coarse.....	23	7	48	3
Sand, light colored, even grained.....	3	9	52	
Gravel, coarse.....	5		57	
Sand, light yellow, even grained.....	17		74	
Sand, light colored, fine, even grained.....	26		100	
Sand, dark yellow, coarse, with some pebbles	12	6	112	6
Sand, light colored, with some angular gravel	21	3	133	9
Sand, yellowish, uniform, angular.....	1	3	135	
Sand, light yellow, with some pebbles.....	12	8	147	8
Sand, light colored, with gravel and chalky pebbles	16	8	164	4
Sand, light colored, no gravel.....	15	4	179	8
Sand and gravel, light colored.....	15	4	195	
Sand and gravel, coarse (very strong brine with artesian flow)	10		205	
Conglomerate, very firm, with pebbles in reddish sand.....	1	4	206	4

(The core was started here)

PENNSYLVANIAN SYSTEM (?), 62' 9"

Sandstone, gray, friable.....	1	9	208	1
Shale, reddish, tough	1	3	209	4
Clay, light drab.....	4	10	214	2
Sandstone, grayish, fine grained, very friable	30	3	244	5
Clay, greenish drab, bedded, with some carbonaceous material	2	10	247	3
Sandstone, reddish, very friable, fine grained	19	10	267	1
Clay, arenaceous, bedded	2		269	1

PENNSYLVANIAN SYSTEM

MISSOURI SERIES, 737' 3"

Chert, dark, impure, hard, grading into shale below		8	269	9
Shale, light blue, argillaceous.....	3	5	273	2

Limestone, shaly; pyritiferous; crinoid joints	4	7	277	9
Shale, argillaceous, finely bedded.....		10	278	7
Sandstone, steel gray, fine, even textured, compact		9	279	4
Sandstone, dark gray, coarse grained, soft.....	21	9	301	1
Shale, brownish, part carbonaceous, bedded, fossiliferous	11	2	312	3
Limestone, compact, crinoid stems.....	11		323	3
Shale, indurated, bedded	4	6	327	9
Limestone, light gray, compact.....	7		334	9
Shale, upper portion carbonaceous, lower por- tion greenish.....	1		335	9
Sandstone, steel gray, hard, fine grained.....	8	10	344	7
Shale, dark brown, variegated	7	8	352	3
Limestone, shaly, crinoid stems and shell frag- ments	7	6	359	9
Shale, red, massive, argillaceous.....	2	5	362	2
Limestone, light gray, hard, with crystals of calcite	2	10	365	
Shale, dark gray, calcareous, fossiliferous.....	9	6	374	6
Limestone, light gray, compact	6		380	6
Shale, greenish, pyritiferous.....	3	4	383	10
Shale, black, carbonaceous, fissile	2		385	10
Shale, greenish, massive, somewhat indurated	6	2	392	
Shale, red, with some induration.....	10		402	
Shale, dark gray to nearly black, bedded, with light colored layers.....	47	8	449	8
Limestone, light gray, dense, pyritiferous.....	5	2	454	10
Shale, brownish, bedded.....	8		462	10
Limestone, dense, arenaceous in places; crin- oid joints.....	4		466	10
Shale, black, carbonaceous.....	1	9	468	7
Limestone, compact, fossiliferous.....	1	2	469	9
Sandstone, steel gray, not very hard, fine grained	1	6	471	3
Shale, reddish, slightly arenaceous.....	8	8	479	11
Limestone, light gray, dense, Fusulina com- mon	25		504	11
Sandstone, reddish, fine grained, friable.....	39	9	544	8
Limestone, light gray, dense, Fusulina and Crinoid joints abundant.....	10		554	8
Shale, red, compact, massive.....	10	4	565	
Limestone, light gray, compact, crinoid joints	8	6	573	6
Shale, dark brown, greenish brown in places, finely bedded.....	5		578	6
Limestone, light gray, rather soft, with 1' 8" of reddish sandstone, artesian water at 600' 6"	50	2	628	8
Shale, black, carbonaceous.....	4		632	8
Limestone, pyritiferous	1	8	634	4
Shale, fossiliferous	8		642	4
Shale, red, compact.....	9		651	4
Limestone, shaly, with crinoid joints.....	9	6	660	10
Shale, red, finely bedded, arenaceous.....	13		673	10

PENNSYLVANIAN SYSTEM

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Limestone, compact, somewhat arenaceous.....	5	4	679	2
Shale, calcareous, with bands of shaly limestone	2	3	681	5
Limestone, light gray, firm.....	14		695	5
Shale, black.....	1	6	696	11
Limestone, fossiliferous	1		697	11
Shale, argillaceous.....	3	4	701	3
Shale, red, with calcareous nodules.....	8	10	710	1
Limestone, light gray, dense to shaly.....	12	2	722	3
Shale, red	3	10	726	1
Limestone, light gray to mottled.....	32	8	758	9
Shale, dark gray, calcareous with limestone seams	1	4	760	1
Limestone, light gray, not very firm.....	3	7	763	8
Flint, probably a nodule.....	4	4	764	
Limestone, light drab colored, with dark spots	11	10	775	10
Shale, slaty, slightly calcareous.....	10	4	786	2
Limestone, shaly in some places, fossiliferous	17	6	803	8
Shale, calcareous	1		804	8
Shale, black.....	1		805	8
Shale, calcareous, with thin limestone seams....	13		818	8
Shale, red	1	6	820	2
Limestone, light gray, compact, seams of reddish sandstone, artesian water at 828'.....	12	6	832	8
Shale, slaty, calcareous	3		835	8
Shale, black, carbonaceous.....	4		839	8
Shale, slaty, calcareous	2	2	841	10
Limestone, gray, shaly in places.....	9	6	851	4
Shale, dark gray, calcareous, bedded, with bands of shaly limestone.....	10	2	861	6
Shale, red, with spots of green.....	5		866	6
Limestone, fossiliferous, part shaly, pyritiferous	13	4	879	10
Shale, dark gray, calcareous.....	7		886	10
Shale, slaty, with calcareous nodules.....	7	9	894	7
Limestone, light gray, hard, some silica.....	6		900	7
Limestone, dark gray, fine textured, like lithographic stone, not very hard, pyritiferous....	10		910	7
Shale, greenish, with calcareous nodules.....	5	6	916	1
Shale, carbonaceous.....	2	6	918	7
Shale, slaty, with some calcareous material, fossiliferous	4		922	7
Limestone, light gray, shaly in places.....	4		926	7
Shale, green, calcareous.....	3		929	7
Limestone, light gray, shaly, not very hard, fossiliferous	10	10	940	5
Shale, dark, slightly calcareous, quite carbonaceous below.....	1	8	942	1
Coal, bituminous		4	942	5
Shale, carbonaceous, containing pieces of coal	3	6	945	11
Limestone, light gray, compact.....	6	3	952	2
Shale, slaty	1	10	954	
Shale, reddish with greenish spots, quite arenaceous	7	2	961	2

Limestone, shaly	1		962	2
Shale, dark, slightly calcareous.....	5		967	2
Shale, argillaceous to calcareous.....	9	9	976	11
Limestone, shaly	15	9	992	8
Shale, bedded, indurated	2		994	8
Limestone, with shale in middle and base.....	11	8	1006	4

DES MOINES SERIES, 70' 1"

Sandstone, red, slightly argillaceous, too crumbly to make core.....	11		1017	4
Shale, dark	2	4	1019	8
Limestone and shale.....		11	1020	7
Shale, greenish.....	2	3	1022	10
Limestone, shaly	1	3	1024	1
Shale, red	2	4	1026	5
Shale, limy, nodular, quite soft.....	10		1036	5
Shale, dark gray.....	7	3	1043	8
Shaly limestone, or limy shale.....	3	11	1047	7
Shale, reddish.....	4	9	1052	4
Sandstone or arenaceous limestone.....	3		1055	4
Sandstone, gray, fine-grained.....	3	6	1058	10
Sandstone, red, coarse-grained, friable.....	10		1068	10
Limestone, grayish, magnesian.....	2		1070	10
Sandstone, reddish, argillaceous	5	7	1076	5

MISSISSIPIAN AND OLDER BEDS, 1386' 7"

Limestone, massive, magnesian	19	8	1096	1
Shale, red	1		1097	1
Limestone, magnesian.....	1	8	1098	9
Quartz, white		4	1099	1
Limestone, gray, magnesian, dense, brittle.....	119	5	1218	6
Sandstone, grayish	14	7	1233	1
Limestone, magnesian.....	194	8	1427	9
Shale, red, indurated.....	12	9	1440	6
Limestone, magnesian, with calcite.....	372	8	1813	2
Limestone, bluish, fine texture.....	34	4	1847	6
Limestone, dark gray, massive, magnesian.....	20		1867	6
Limestone, bluish gray, with fine texture.....	80		1947	6
St. Peter Sandstone (?), dark gray, siliceous, friable	60	6	2008	
Limestone, dark gray, magnesian.....	113	2	2121	2
Sandstone, red, friable, coarse, argillaceous in places	71	7	2192	9
Pre-Cambrian quartzite, red, massive, non- fossiliferous	270	3	2463	

CORRELATION OF PENNSYLVANIAN STRATA IN
THE LOG OF THE CAPITOL BEACH WELL

A close correlation of the strata penetrated in the Capitol Beach well has not been attempted heretofore because of a lack of supplemental data. Now, however, since the log of the Nehawka well throws some light on the subject, and the Pennsylvanian section of southeastern Nebraska is better known, a correlation can be made with some assurance.

That the base of the Pennsylvanian System is at a depth of about 1,068' 10" in the Capitol Beach Bell is generally agreed. It is also obvious that the 62' 6" of shale between 1,006' 4" and 1,068' 10" belongs to the Des Moines Series. This places the base of the Missouri Series at a depth of 1,006' 4", or about 151' 8" above sea level.

The position at which certain strata are exposed in the general section at places northeast, east, southwest, and south of Lincoln has some bearing in this correlation. For example, the Scranton beds outcrop at Ashland, dipping slowly westward. The McKissick Grove Shales are at the surface southeast of Eagle, dipping southward. The Neva is well shown at Bennett slanting southwestward. It is exposed at Roca, a few miles south of Lincoln at an elevation of about 1,225 feet, dipping southwestward. A study of the logs of deep wells in the vicinity of Lincoln shows that the strata here probably dip westward.

If the beds in the horizons and exposures just cited were restored in a section extending across the Lincoln Basin, the Neva Limestone would occupy a position above the bottom-land at an elevation of about 1,200 feet. This would indicate that the upper portion of the Wabaunsee formation, down to the depth encountered in the well, was eroded from this area prior to the deposition of the Dakota formation (Cretaceous). This erosion probably extended 280 feet or more below the Neva Limestone horizon.

In the section of the Wabaunsee formation, based on many exposures, including those at Roca and Bennett, the top of the McKissick Grove Shale is about 240 feet below the Neva,

and the Tarkio Limestone is 278 to 300 feet below the Neva. According to this, the Capitol Beach well should have entered the Missourian Series at or near the top of the Tarkio Limestone.

The distance in the general section, from the base of the Missouri group up to the Tarkio Limestone, is about 680 feet. This interval, or what seems to be the same in the log of the well, is 737 feet or more. The difference, which is about 57 feet, may represent the amount that some of the members have thickened in their extension northwest from the places where the measurements were made in the general section.

The well log shows 69' 2" of shale between 380' 6" and 449' 8". This is where the main body of the Scranton shales should be in the section and is fairly typical of the Scranton. That part of the log between 209' 1" and 380' 6" seems to be the Nemaha beds of the Wabaunsee formation. Its thickness is 121' 5" which is a little more than normal.

Conclusion. On a basis of comparison with the general section as shown by the distance above and below known horizons and from the lithology of the beds described in the log, it is concluded that the first of the Missouri group reached in this well is in the Wabaunsee formation, at or above the Tarkio Limestone.

McKissick Grove Shale (?). The Missouri Series of rocks was reached in the Capitol Beach well at about 208 feet, 247 feet, or 269 feet. The description of the strata between 208 feet and 247 feet is too loose for definite correlation. The beds here are probably Cretaceous, but may prove to be of Missourian age.

According to the log, the strata penetrated between about 247' and 269' 1", are fairly typical of the McKissick Grove Shale. They seem to be in the Missourian Series rather than in the Cretaceous, but the correlation cannot be decided without faunal evidence.

The provisional correlation of the Pennsylvanian System of rocks in the Capitol Beach well below 269' 1" is as follows:

I. MISSOURI SERIES

Bed or Division	Thickness		Depth	
	Feet	Inches	Feet	Inches
1. Tarkio Limestone member, 8' 10":				
(1). Chert, impure, probably dense limestone		8	269	9
(2). Shale, light blue, argillaceous.....	3	5	273	2
(3). Limestone, shaly, pyritiferous, with crinoid joints.....	4	7	277	9
2. Willard Shale member, 34' 6":				
(1). Shale, argillaceous, finely bedded		10	278	7
(2). Sandstone, gray, fine, even textured, compact		9	279	4
(3). Sandstone, dark gray, coarse grained	21	9	301	1
(4). Shale, brownish, part carbonaceous, fossiliferous	11	2	312	3
3. Emporia Limestone member, 22' 6":				
(1). Limestone, compact, crinoid stems....	11		323	3
(2). Shale, slaty.....	4	6	327	9
(3). Limestone, light gray, compact.....	7		334	9
4. Humphrey Shale member, 45' 9":				
(1). Auburn Shale, 17' 6":				
a. Shale, lower portion greenish; upper portion carbonaceous.....	1		335	9
b. Sandstone, gray, hard, fine grained	8	10	344	7
c. Shale, dark brown, irregular.....	7	8	352	3
(2). Wakarusa Limestone, 12' 9":				
a. Limestone, shaly	7	6	359	9
b. Shale, red, massive, argillaceous..	2	5	362	2
c. Limestone, light gray, hard with calcite concretions	2	10	365	
(3). Soldier Creek Shale, dark gray, calcareous	9	6	374	6
5. Burlingame Limestone member, light gray, compact	6		380	6
6. Scranton Shale member, 184' 6":				
(1). Shale, 69' 2":				
a. Greenish, pyritiferous	3	4	383	10
b. Black, carbonaceous, fissile.....	2		385	10
c. Greenish, massive, somewhat indurated	6	2	392	
d. Red, with some induration.....	10		402	
e. Dark gray to nearly black, with light colored layers.....	47	8	449	8
(2). Limestone, light gray.....	5	2	454	10
(3). Shale, brownish.....	8		462	10
(4). Limestone, dense, arenaceous in places, crinoid joints.....	4		466	10
(5). Shale, black, carbonaceous.....	1	9	468	7
(6). Limestone, compact, fossiliferous.....	1	2	469	9

(7). Sandstone, gray, not very hard.....	1	6	471	3
(8). Shale, reddish, slightly arenaceous....	8	8	479	11
(9). Cass Limestone, light gray, dense, Fusulina common	25		504	11
(10). Plattford Shale, reported as sand- stone, reddish, fine friable.....	39	9	544	8
(11). South Bend Limestone, light gray, dense, many Fusulina	10		554	8
(12). Rock Lake Shale, red, compact, mas- sive	10	4	565	
7. Howard Limestone member, light gray, compact, crinoid joints	8	6	573	6
8. Severy Shale member, dark brown, greenish brown in places, finely bedded	5		578	6
9. Topeka, Calhoun, and Deer Creek mem- bers, 55' 10":				
(1). Limestone, light gray, rather soft, with 1' 8" of sandstone.....	50	2	628	8
(2). Shale, black, carbonaceous	4		632	8
(3). Limestone, with some pyrites.....	1	8	634	4
10. Tecumseh and Lecompton members, 61' 1":				
(1). Shale, 17':				
a. Shale, with some fossils.....	8		642	4
b. Red, compact.....	9		651	4
(2). Cedar Creek Limestone, shaly, with crinoid joints.....	9	6	660	10
(3). Shale, red, finely bedded, arenaceous	13		673	10
(4). Lecompton beds, 21' 7":				
a. Avoca Limestone, compact, some- what arenaceous	5	4	679	2
b. Shale, calcareous, with limestone seams	2	3	681	5
c. Cullom Limestone, light gray, firm	14		695	5
11. Kanwaka Shale member, 14' 8":				
(1). Shale, black	1	6	696	11
(2). Limestone, fossiliferous.....	1		697	11
(3). Shale, 12' 2":				
a. Slaty	3	4	701	3
b. Red, with calcareous nodules.....	8	10	710	1
12. Oread Limestone member, 48' 8":				
(1). Limestone, light gray, dense, shaly in some places.....	12	2	722	3
(2). Shale, red	3	10	726	1
(3). Limestone, light gray or mottled.....	32	8	758	9
13. Lawrence Shale member, dark gray, cal- careous with limestone seams.....	1	4	760	1
14. Jatan Limestone member, 15' 9":				
(1). Limestone, light gray, not very firm	3	7	763	8
(2). Flint, very firm, probably a nodule....		4	764	

(3). Limestone, light drab colored, with dark spots.....	11	10	775	10
15. Weston Shale member, slaty, slightly calcareous	10	4	786	2
16. Stanton Limestone member, shaly in some places, fossiliferous	17	6	803	8
17. Vilas Shale member, 16' 6":				
(1). Calcareous	1		804	8
(2). Black	1		805	8
(3). Calcareous, with thin limestone seams	13		818	8
(4). Red	1	6	820	2
18. Plattsburg Limestone member, light gray, compact, seam of reddish sandstone, artesian water at 828'.....	12	6	832	8
19. Lane Shale member, 9' 2":				
(1). Slaty, calcareous.....	3		835	8
(2). Black, carbonaceous	4		839	8
(3). Slaty, calcareous.....	2	2	841	10
20. Iola Limestone member, gray, shaly in places	9	6	851	4
21. Chanute Shale member, 15' 2":				
(1). Dark gray, calcareous, bedded, with bands of shaly limestone.....	10	2	861	6
(2). Red, with spots of green.....	5		866	6
22. De Kalb Limestone member, fossiliferous, part shaly, pyritiferous	13	4	879	10
23. Cherryvale Shale member, 14' 9":				
(1). Dark gray, calcareous	7		886	10
(2). Slaty, with calcareous nodules.....	7	9	894	7
24. Winterset Limestone member, 16':				
(1). Limestone, light gray, hard, some silica	6		900	7
(2). Limestone, dark gray, fine textured, like lithographic stone, not very hard, pyritiferous.....	10		910	7
25. Galesburg Shale member, 12':				
(1). Greenish, with calcareous nodules....	5	6	916	1
(2). Carbonaceous	2	6	918	7
(3). Slaty, with some calcareous material, fossiliferous.....	4		922	7
26. Bethany Falls Limestone member, 17' 10":				
(1). Limestone, light gray, shaly in places	4		926	7
(2). Shale, green, calcareous.....	3		929	7
(3). Limestone, light gray, shaly, not very hard, fossiliferous.....	10	10	940	5

27. Ladore Shale member, 36' 6" :				
(1). Shale, dark, slightly calcareous, quite carbonaceous below.....	1	8	942	1
(2). Coal, bituminous		4	942	5
(3). Shale, carbonaceous, containing pieces of coal.....	3	6	945	11
(4). Limestone, light gray, compact.....	6	3	952	2
(5). Slaty shale	1	10	954	
(6). Reddish shale with greenish spots, quite arenaceous	7	2	961	2
(7). Limestone, shaly	1		962	2
(8). Dark to slightly calcareous shale.....	5		967	2
(9). Argillaceous to calcareous shale.....	9	9	976	11
28. Hertha Limestone member, 29' 5" :				
(1). Limestone, shaly	15	9	992	8
(2). Shale, bedded, indurated.....	2		994	8
(3). Limestone, with shale in middle and at base.....	11	8	1006	4

II. DES MOINES SERIES

(See detailed log of Capitol Beach well, 1006' 4" to 1076' 5")

THE DU BOIS WELL

(Modified after Moore)

This well is on the Church place southeast of DuBois, Nebraska. It started just below the top of the Topeka beds and ended in granite.

Bed or Division	Thickness		Depth	
	Feet	Inches	Feet	Inches
1. Soil and subsoil.....	8		8	
2. Topeka and Calhoun members, 22' :				
(1). Limestone	2		10	
(2). Shale, black	4		14	
(3). Limestone and shale.....	13		27	
(4). Shale	3		30	
3. Deer Creek member, limestone and shale..	20		50	
4. Tecumseh and Lecompton (?) members, 71' 4" :				
(1). Shale, black	1		51	
(2). Shale	21		63	
(3). Shale	54	4	117	4
(4). Shale, black	4		121	4
5. Oread Limestone member and part of the Lecompton member (?), 71' 8" :				
(1). Limestone	21	8	143	
(2). Limestone	27	9	170	9
(3). Shale, black.....	4		174	9
(4). Limestone (Leavenworth).....	1	6	176	3

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(5). Shale, soft.....	11	3	187	6
(6). Limestone (Weepingwater)	5	6	193	
6. Lawrence Shale member, 96' 4":				
(1). Shale, red	24	4	217	4
(2). Shale	5	8	223	
(3). Shale, soft.....	1		224	
(4). Limestone	8		232	
(5). Shale, black.....	32	6	264	6
(6). Shale	12	6	277	
(7). Limestone	4		281	
(8). Shale	8	4	289	4
8. Beds not correlated, 168' 4":				
(1). Limestone	20		309	4
(2). Limestone and shale.....	8	4	317	8
(3). Shale	7	4	325	
(4). Limestone	35		360	
(5). Limestone and shale seams.....	5	8	365	8
(6). Shale, black		6	366	2
(7). Limestone	1	6	367	8
(8). Shale, black	26		393	8
(9). Limestone and layers of shale.....	64		457	8
9. Des Moines Series, 100' 4":				
(1). Shale, black	13	4	471	
(2). Shale, soft, with thin limestone in middle	11	6	482	6
(3). Sandstone, micaceous, some granular limestone	10	6	493	
(4). Sandstone, micaceous, coarse.....	23		516	
(5). Sandstone, micaceous.....	16		532	
(6). Sandstone, very fine.....	18		550	
(7). Sandstone, fine.....	8		558	
10. Granite, reddish	7		565	

DAVIS WELL EAST OF FOREST CITY, MISSOURI

Core-drilled in 1901

Modified and condensed after Hinds and Greene¹

Stratum	Thickness		Depth	
	Feet	Inches	Feet	Inches
Mantle rock.....	75		75	

PENNSYLVANIAN SYSTEM
MISSOURI SERIES

I. Shawnee Formation, 86' 7":

1. Tecumseh Shale member.....	15		90	
2. Lecompton Limestone member, 35' 5":				
(1). Cullom Limestone:				
a. Limestone, very fossiliferous.....	2	4	92	4
b. Shale, greenish	4	4	96	8
c. Limestone, many Fusulina.....	4	7	101	3
(2). Queen Hill Shale.....	3	5	104	8
(3). Big Springs Limestone:				
a. Limestone, dark gray, many Fusu- lina		9	105	5
b. Limestone, gray, shaly below.....	10	4	115	9
(4). Doniphan Shale, grayish green, dark at base.....	3	10	118	7
(5). Spring Branch Limestone:				
a. Limestone, earthy		10	119	5
b. Shale, green, very fossiliferous.....		2	119	7
c. Limestone, light colored.....	4	10	124	5
3. Kanwaka Shale member, 35' 9":				
(1). Shale, gray, dark gray, and greenish gray	16	10	141	3
(2). Limestone, dark, shaly (error in thickness)	3	2	145	5
(3). Shale, gray to greenish.....	13	1	158	6
(4). Limestone, dark gray.....	2	8	161	2
(5). Shale, gray, calcareous		5	161	7

II. Douglas Formation, 256' 6":

1. Oread Limestone member, 51' 11":				
(1). Plattsmouth Limestone	27	8	189	3
(2). Heebner Shale	3	10	193	1
(3). Leavenworth Limestone.....	2	6	195	7
(4). Snyderville Shale	11	3	206	10
(5). Weepingwater Limestone	6	8	213	6

¹ The Stratigraphy of the Pennsylvanian Series in Missouri: Mo. Bur. Geol. and Mines, Vol. XIII, 2nd series, pp. 215-239.

2. Lawrence Shale member, 134' 4" :				
(1). Shales	19	1	232	7
(2). Amazonia Limestone.....	4	11	237	6
(3). Shales	99	4	336	10
(4). Limestone, very fossiliferous.....	1		337	10
(5). Shale	10		347	10
3. Iatan Limestone member	9		356	10
4. Weston Shale member.....	51	3	418	1

II. Lansing Formation, 124' 2" :

1. Stanton Limestone member, 39' 3" :				
(1). Limestone	8	5	426	6
(2). Clay shale, green.....	2	1	428	7
(3). Limestone (error in thickness, 10')....	7	2	445	9
(4). Shale, black and gray	8	5	454	2
(5). Limestone	3	2	457	4
2. Vilas Shale member.....	12	1	469	5
3. Plattsburg Limestone member, 27' 6" :				
(1). Limestone	4	9	474	2
(2). Shale, black, calcareous.....		11	475	1
(3). Limestone	9	6	484	7
(4). Shale, gray or darker.....	1	10	486	5
(5). Limestone, dark gray to light gray.....	8	3	494	8
(6). Shale, greenish		7	495	3
(7). Limestone, light gray.....	1	8	496	11
5. Lane Shale member, 45' 4" :				
(1). Shale, dark blue.....	2	3	499	2
(2). Limestone	4	4	503	6
(3). Shale, dark, green, etc.....	38	9	542	3

IV. Kansas City Formation, 182' 10" :

1. Iola Limestone member.....	11		553	3
2. Chanute Shale member, 29' 2" :				
(1). Limestone	5	8	558	11
(2). Shale, upper portion very dark, lower gray	15	3	574	2
(3). Limestone	4	1	578	3
(4). Shale, green, calcareous.....	4	2	582	5
3. Drum Limestone member.....	8	6	590	11
4. Cherryvale Shale member, 29' 8" :				
(1). Shale, gray, calcareous	1	11	592	10
(2). Limestone, shaly.....	1	11	594	9
(3). Shale, dark, bituminous, calcareous....		10	595	7
(4). Limestone, mottled light and dark gray	1	3	596	10
(5). Shale, dark gray	23	9	620	7
5. Winterset Limestone member, 48' 9" :				
(1). Limestone, light gray.....	7		627	7
(2). Shale, calcareous.....	7	2	634	9
(3). Limestone	34	9	669	6

6. Galesburg Shale member.....	5	8	675	2
7. Bethany Falls Limestone member, 23':				
(1). Shale, green, calcareous.....	3	3	678	5
(2). Limestone, gray.....	19	9	698	2
8. Ladore Shale member, 14':				
(1). Shale, dark.....	3	5	701	7
(2). Limestone, very argillaceous.....		7	702	2
(3). Shale, greenish, slickensides.....	5	4	707	6
(4). Limestone, argillaceous.....		10	708	4
(5). Shale.....	1	2	709	6
(6). Limestone, argillaceous.....		6	710	
(7). Shale, calcareous.....		6	710	6
(8). Limestone, argillaceous.....		4	710	10
(9). Shale.....	1	4	712	2
9. Hertha Limestone member.....	12	11	725	1

DES MOINES SERIES

I. Pleasanton and Henrietta Formations, 110' 11":

1. Shale, blue gray, fossiliferous.....	1	6	726	7
2. Sandstone, very calcareous.....	4	11	731	6
3. Coal (Ovid), contains fossil plants.....		6	732	
4. Clay, blue gray.....	2	4	734	4
5. Sandstone, grayish.....	8	6	742	10
6. Sandstone, blue to greenish gray.....	9	4	752	2
7. Shale, grayish blue.....	19	7	771	9
8. Limestone, dark gray, fossiliferous.....	3	5	775	2
9. Shale, dark to greenish, calcareous.....	4	2	779	4
10. Limestone, light-colored.....	1	9	781	1
11. Shale, green.....	1	3	782	4
12. Clay and shale.....	9	2	791	6
13. Limestone and shale, nodular.....	3	2	794	8
14. Shale, greenish, calcareous.....	4	5	799	1
15. Limestone, somewhat crystalline.....	1	5	800	6
16. Sandstone, light green to dark green.....	9	6	810	
17. Shale, gray.....	2	6	812	6
18. Clay, dark gray.....	2	8	815	2
19. Limestone, greenish, fossiliferous.....	5	4	821	6
20. Shale, light to dark gray.....	3	8	825	2
21. Clay shale, greenish.....	1	4	826	6
22. Shale, greenish, fossiliferous.....	9	6	836	

II. Cherokee Shale, 785' 11":

1. Shale, black.....		10	836	10
2. Clay shale, dark gray to light gray.....	6	7	843	5
3. Limestone, gray, fossiliferous.....	5	7	849	
4. Clay, light gray, calcareous.....	2		851	
5. Shale, green, micaceous.....	1	4	852	4
6. Shale, reddish brown, slickensides.....	3	7	855	11
7. Shale, slaty, dark gray.....	10		865	11
8. Limestone, medium dark gray, very fossiliferous.....	2		867	11

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9. Sandstone, dark bluish gray	5	5	873	4
10. Shale, black	15	8	889	
11. Summitt Coal, bony		4	889	4
12. Sandstone	5	7	894	11
13. Shale, dark gray.....	3	4	898	3
14. Clay, calcareous.....	1		899	3
15. Limestone, fossiliferous.....	8	9	908	
16. Shale, gray and black.....	8	10	916	10
17. Clay, gray.....	3		919	10
18. Limestone, greenish, argillaceous.....	2	2	922	
19. Shale, green, calcareous.....	4	2	926	2
20. Limestone, light gray.....	2	3	928	5
21. Shale, green to black.....	1	6	929	11
22. Limestone		8	930	7
23. Shale, dark.....	3		933	7
24. Shale, greenish	3		936	7
25. Sandstone	7	5	944	
26. Shale, green to black, fossiliferous.....	40	6	984	6
27. Limestone, very fossiliferous.....	1	8	986	2
28. Bedford Coal, rotten		4	986	6
29. Shale, gray.....	6	9	993	3
30. Sandstone, micaceous.....	1	3	994	6
31. Bevier Coal, pyritiferous	1	2	995	8
32. Shale, bluish-gray.....	1	4	997	
33. Sandstone, gray, fossiliferous.....	7		1004	
34. Shale, dark, fossiliferous.....	25	7	1029	7
35. Shale, black	1		1030	7
36. Limestone, greenish gray.....		8	1031	3
37. Shale, slaty.....	1	10	1033	1
38. Limestone, dark, fossiliferous.....		11	1034	
39. Shale, black	1	1	1035	1
40. Limestone		4	1035	5
41. Shale, black	1	9	1037	2
42. Limestone		8	1037	10
43. Shale, black.....	2	2	1040	
44. Coal (Tebo?).....	1	3	1041	3
45. Clay, dark gray to light gray.....	4		1045	3
46. Sandstone	6	3	1051	6
47. Shale	4	3	1055	9
48. Shale, black.....	3	8	1059	5
49. Coal	1		1060	5
50. Shale, slickensided		4	1060	9
51. Sandstone, fossiliferous.....	4		1064	9
52. Shale, black	5	8	1070	5
53. Coal		9	1071	2
54. Shale, gray, fossiliferous, and slickensided	8	9	1079	11
55. Shale, dark green to black.....	2	7	1082	6
56. Clay	2	4	1084	10
57. Sandstone, light to dark.....	25	10	1110	8
58. Shale	16	11	1127	7
59. Shale, black, fossiliferous.....	13	5	1141	
60. Coal, pyritiferous.....		9	1141	9
61. Clay, gray.....	4	3	1146	
62. Shale		5	1146	5

63. Sandstone, dark, slickensided.....	1	2	1147	7
64. Shale, dark.....	10	6	1158	1
65. Clay, light colored	1	11	1160	
66. Sandstone	8	2	1168	2
67. Shale, dark colored.....	2	6	1170	8
68. Sandstone	1	10	1172	6
69. Shale, dark gray, slickensided.....	1	3	1173	9
70. Shale, black	8	9	1182	6
71. Sandstone		6	1183	
72. Shale, nearly black.....	3	4	1186	4
73. Wasted core.....	2	2	1188	6
74. Sandstone, fossiliferous.....	2	3	1190	9
75. Shale, black, calcareous.....	16		1206	9
76. Shale	7	5	1214	2
77. Sandstone, light gray.....	1	6	1215	8
78. Shale, greenish gray		10	1216	6
79. Sandstone, greenish	1	4	1217	10
80. Shale, greenish gray, slickensided.....	4	6	1222	4
81. Sandstone	5	3	1227	7
82. Shale, black	2		1229	7
83. Sandstone, gray, fossiliferous	6	9	1236	4
84. Shale, dark.....	3	8	1240	
85. Shale, black	11	4	1251	4
86. Coal		5	1251	9
87. Clay with coal partings.....		4	1252	1
88. Sandstone	5	11	1258	
89. Shale, black	5	5	1263	5
90. Coal, rotten		3	1263	8
91. Sandstone, gray	5	10	1269	6
92. Shale, grayish, clayey.....	2	6	1272	
93. Sandstone	6	4	1278	4
94. Shale, black, hard.....	3		1281	4
95. Sandstone, banded		5	1281	9
96. Shale, dark to light colored.....	5	2	1286	11
97. Sandstone, gray	4	9	1291	8
98. Shale, dark.....	10		1301	8
99. Sandstone	42	1	1343	9
100. Shale, dark gray.....	1	7	1345	4
101. Shale, black	11	3	1356	7
102. Sandstone	1		1357	7
103. Shale	3	5	1361	
104. Sandstone	6	4	1367	4
105. Sandstone, dark gray	15	9	1383	1
106. Shale, black	1	4	1384	5
107. Coal		5	1384	10
108. Clay	2	6	1387	4
109. Shale, black	2	9	1390	1
110. Coal		10	1390	11
111. Clay, gray	1	1	1392	
112. Wasted core.....	1	4	1393	4
113. Clay, gray to black.....	1	4	1394	8
114. Shale, black	17	11	1412	7
115. Sandstone, black to gray.....	11	5	1435	
116. Shale, black	5		1440	

PENNSYLVANIAN SYSTEM

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117. Clay-shale	4		1444	
118. Sandstone, dark gray.....	1	8	1445	8
119. Shale, dark gray.....	8	4	1454	
120. Sandstone		3	1454	3
121. Clay	3	6	1457	9
122. Sandstone		7	1458	4
123. Shale, dark gray.....	7	5	1465	9
124. Shale, black, slickensided	22	9	1488	6
125. Sandstone, light colored	4	8	1493	2
126. Shale	2	4	1495	6
127. Sandstone, light colored	11	2	1506	8
129. Shale, black	11	6	1518	2
130. Sandstone	11	10	1530	
131. Coal		2	1530	2
132. Shale, dark.....		4	1530	6
133. Sandstone, light to dark gray.....	15	3	1545	9
134. Shale, banded	6	2	1551	11
135. Sandstone, gray to buff.....	5	4	1557	3
136. Shale, black	2	10	1560	1
137. Sandstone, with plant fossils, slickensided	6	2	1566	3
138. Shale, dark gray to black.....	14		1580	3
139. Sandstone	1	11	1582	2
140. Shale, black	4	3	1586	5
141. Sandstone, black.....	1	3	1587	8
142. Shale, black	25	8	1613	4
143. Sandstone, light gray to white.....	4	10	1618	2
144. Limestone, argillaceous.....		7	1618	9
145. Sandstone, light gray.....	3	2	1621	11

MISSISSIPPIAN SYSTEM

I. St. Louis Limestone

1. Limestone, gray and brown, some fossils	39	3	1661	2
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II. Warsaw Shale

1. Limestone, dark.....		3	1661	5
2. Shale		2	1661	7
3. Limestone, light gray.....	4	7	1666	2
4. Dolomite, gray.....	1	6	1667	8
5. Shale, dark.....	4	5	1672	1
6. Sandstone, blue green	1	1	1673	2
7. Shale, blue green	5	1	1678	3
8. Sandstone, few fossils.....	1	7	1680	
9. Limestone	10	11	1690	11
10. Shale, dark greenish gray (error in thickness)	1	9	1693	8
11. Limestone	5	4	1698	
12. Wasted core.....	2		1700	
13. Sandstone, argillaceous.....	1	6	1701	6

III. Burlington and Keokuk limestones

1. Limestone, light gray, fossiliferous.....	112	2	1813	8
2. Wasted core.....	7	5	1821	1

IV. Kinderhook group ¹

1. Dolomite	16		1837	1
2. Chert, light and dark gray.....	1	9	1838	10
3. Limestone, cherty, fossiliferous.....	75	1	1913	11
4. Shale, blue green, etc., fossiliferous.....	39	6	1953	5
5. Hematite, dark red.....	4	1	1957	6
6. Shale, green gray, calcareous.....	83	7	2041	1

DEVONIAN (?) SYSTEM ²

1. Limestone, gray, dolomite	15	8	2056	9
2. White, dark bluish gray.....	5	11	2062	8

DEVONIAN SYSTEM

I. Upper Devonian

1. Limestone, light to dark gray, shale partings	71	10	2134	6
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II. Middle Devonian

1. Dolomite, dark to light gray, crystalline	98	1	2232	7
2. Chert, chalky appearance.....	1	8	2234	3
3. Dolomite, brownish gray.....	130	10	2365	1

SILURIAN SYSTEM

(Lockport group of Niagaran Series)

1. Dolomite, bluish gray, very fossiliferous	34	11	2400	
2. Wasted core.....		6	2400	6
3. Dolomite, bluish gray.....	99	6	2500	

¹ May include other beds below 1800 feet.² Correlations below 2041-1 by E. O. Ulrich.

INTER-REGIONAL CORRELATION

Starting in Pennsylvania, the Pennsylvanian beds have been studied in their distribution throughout the country. The State Surveys have worked more or less independently in this investigation, naming the subdivisions without much regional correlation. Consequently some formations and members of the system are now known by several names, given from place to place in their distribution, and the literature on the subject has been complicated. It seems, in view of these conditions, that regional and inter-regional correlation should be undertaken by some agency in order to establish the relative ages of the members, to select the names having priority, to determine the exact distribution of the subdivision for an intensive study of their physical and faunal features throughout their distribution, and to serve as a basis for further study in historical and economic geology. This work of correlation might be done by independent agencies, by the State Surveys co-operating across State lines, by the U. S. Geological Survey, or through the co-operation of the State and Federal Surveys.

The Mid-continent regions have been separated by erosion, and modified by some faulting and warping. Most of them are further complicated by erosional unconformities. The northern part of the Western Interior region is comparatively uniform in the sequence of beds compared with the Appalachian provinces and the mountain uplift regions in Oklahoma and Texas. The succession of strata is complete, not much affected by breaks. It would seem, then, that the correlation might be started in this part of the region and carried southward and southwestward across Oklahoma to north-central Texas, and from Iowa eastward via Illinois to Kentucky and Indiana, beyond which the inter-state correlation is quite well known.

The following brief review, based somewhat on field observations, and more largely on the literature of the subject, is given in order to show the age relation of Nebraska's Pennsylvanian beds to those of other states. Bulletin 35 of the Oklahoma Survey; Bulletin 3 of the Kansas Survey; Volumes XI and XIII, 2nd Series, of the Missouri Survey; various reports of the Iowa, Illinois, Kentucky, Ohio, Pennsylvania, and West Virginia Surveys; the Twenty-third Annual report of the Indiana Survey; Professional Paper 71 and a number of the Geological Atlases and Bulletins of the U. S. Geological Survey, and other publications, have been consulted in the preparation of this statement.

The Pottsville, Allegheny, Conemaugh, and Monongahela subdivisions of the Pennsylvanian, made in Pennsylvania, have been recognized generally in the Appalachian and Eastern Interior provinces, but they have not been correlated in the regions west and southwest until the past few years. It is now known that these groups or formations extend through the Western Interior province to Texas, and it is generally agreed on the part of the State Geological Surveys that their identification and correlation should be made in this distribution.

The Pottsville Group.—This, the oldest division of the Pennsylvanian, was defined from Pottsville, Pennsylvania. It is quite thick in parts of the Appalachian province and at places around the west margin of the Ozarks in Arkansas and Oklahoma. The group, represented by one or more formations, occurs in all of the states between Pennsylvania and Texas. The Caseyville formation of Kentucky and Illinois is said by Weller¹ to be of middle Pottsville age, and the Tradewater formation of these states, according to Weller, probably is upper Pottsville.

David White and others have recognized that the Murphysboro Coal (Illinois No. 2) and beds of its age probably mark the upper boundary of the Pottsville group in a number of

¹ Weller, Stuart, Bulletin 41, Illinois Geological Survey, 1920, pp. 225-229.

states. White, according to Shaw,² has shown that the Murphysboro bed corresponds approximately to the Brookville or perhaps to the Clarion Coal bed of Pennsylvania. The Bevier Coal of Iowa, Missouri, Nebraska, and Kansas is said by White to be of about the same age as the Illinois No. 2, which correlation has been accepted by most of the State Surveys in which the Bevier bed occurs. It is generally agreed, therefore, that the Bevier and its equivalents mark the top of the Pottsville in the northern part of the Western Interior region as does the Murphysboro farther east. In other words, the Cherokee below the Bevier probably is of Pottsville age. Its thickness in this region is about as follows: Appanoose County, Iowa and Putnam County, Missouri, 200' to 300'; in the Forest City Basin, 627'; the extreme southeastern Nebraska, approximately 300'; southwestern Missouri and southeastern Kansas, 200' or more. It thickens southward in Oklahoma to 3,000' or more in the vicinity of McAlester, where, according to Gould, it is represented by the following divisions established by Taff:

Hartshorne Shale, 100' to 200'.

Atoka formation, 3,000'.

The Morrow formation or early Pottsville, occurs at places in Arkansas, Oklahoma, and Texas. The age of some of its members is in dispute. Gould³ correlates this formation as follows: "Upper part of Caney Shale and Wapanucka Limestone; lower part of Glenn formation; also the Marble Falls Limestone and Smithwick Shale of Texas." The Marrow is separated from the Cherokee by erosional unconformity.

Allegheny Formation.—This was defined by Platt in 1875. It carries several important coals of which the Brookville bed is near the base, and the upper Freeport Coal is at the top. Edward Orton, I. C. White, and others have shown that the Allegheny formation has a number of units which persist across Ohio from Pennsylvania to Kentucky, a distance of 250 miles, the thickness of the formation decreasing from 300' to 170' in this distribution.

² Shaw, E. W., Geologic Atlas 213, U. S. G. S., 1921.

³ Gould, C. N., Bulletin 35, Oklahoma Geological Survey, 1925.

The base of the Allegheny in the eastern interior region is the under clay of Coal II in Indiana and of Coal No. 2 in Illinois. The Herrin Coal (Illinois No. 6), which David White assigns to about the age of the upper Freeport bed of Ohio and Pennsylvania, is the top. The strata of this interval in Illinois have a thickness of 160' to 225'. They constitute the Carbondale formation by Shaw.

Just where the top of the Allegheny formation lies in the Western Interior region is not known to the writer. It may be at the top of the Cherokee, marked by the base of the Fort Scott Limestone or the Lexington Coal just below it. The upper division of the Cherokee in northern Missouri carries about four coals, with the Bevier-Murphysboro bed marking the base. The section is similar to that of the Carbondale (Allegheny) formation of Illinois. If these beds of northern Missouri constitute the Allegheny formation and are equivalent to the Carbondale of Illinois, the Lexington coal is of about the age of the Herrin Coal (Illinois No. 6). Shaw ⁴ states that the Carbondale may pinch out westward from certain exposures in Illinois. More likely, however, the Allegheny beds, together with the Pottsville and higher strata, formerly extended across the area between Illinois and Iowa, from which they have been removed by erosion in much of this occurrence. The thickness of the upper Cherokee is about 100' in Appanoose County, Iowa, and in Putnam County, Missouri, increasing to 150' in west-central Missouri, and about 157' in the Forest City Basin. The approximate thickness in the extreme southeastern corner of Nebraska is about 100'.

In Oklahoma, Dr. Gould ⁵ places the top of the Allegheny at the Altamont Limestone in the Pleasanton formation. His subdivisions of the Allegheny or their equivalents named in descending order, are as follows:

1. Pleasanton formation:
 - (1). Altamont Limestone.
 - (2). Bandera Shale.

⁴ Shaw, Geologic Atlas 213, U. S. G. S., p. 5.

⁵ Gould, C. N., Bulletin 35, Oklahoma Geological Survey, 1925.

2. Henrietta formation:
 - (1). Pawnee Limestone.
 - (2). Labette Shale.
 - (3). Fort Scott Limestone.
3. Cherokee Shale, the subdivisions defined by Taff:⁶
 - (1). Calvin Sandstone, 145'-240'.
 - (2). Senora Formation, 140'-485'.
 - (3). Stuart Shale, 90'-280'.
 - (4). Thurman Sandstone, 80'-250'.
 - (5). Boggy Shale, 2,600'. (6). *Savanna sandstone, 1,000'*
 - (7). McAlester Shale, 2,000'.

Correlation:

1. The seven subdivisions next above, together with the Hartshorne, 100'-200', and the Atoka formation, 3,000', probably are of Cherokee age.
2. The Atoka formation, Hartshorne Shale, and the McAlester Shale constitute the Winslow formation of Oklahoma, which probably correlates with the lower portion of the Strawn formation of Texas.
3. The Savanna Sandstone, Boggy Shale, and Thurman Sandstone are thought to be in the Strawn formation of Texas.
4. The Fort Scott of Kansas probably is in the upper portion of the Wetumka Shale of Oklahoma, which correlates with the lower portion of the Grayford formation of Texas.
5. The merged beds from the base of the Labette Shale to the top of the Nowata Shale in the Pleasanton formation constitute the Broken Arrow formation of Oklahoma, south of Broken Arrow.

The Bandera Shale thins out southward near Talala, Oklahoma, bringing the Pawnee and Altamont limestones into contact. These united limestones, called the Oologah, continue southwestward to the vicinity of Broken Arrow where they in turn pinch out and the Nowata and Labette shales come into contact and are called the Broken Arrow formation. The age elements in the Broken Arrow (named upward) are, therefore, the Labette Shale, Pawnee Limestone, Bandera Shale, Altamont Limestone, and the Nowata Shale, the last named of which, according to Gould, may be of early Conemaugh age.

The Conemaugh Group.—The writer has not been able to definitely locate the upper and lower boundaries of this group in the Western Interior province. Gould, if I am correct, places all of the section between the base of the Nowata Shale

⁶ Taff, J. A., U. S. G. S., 19th Annual Report, Part 3, 1899; Geologic Atlas No. 74.

(in the Pleasanton formation) and near the top of the Shawnee formation in this group. This succession of members in the central and northern parts of the region named in descending order, is as follows:

- | | |
|--------------------------|------------------------------|
| 1. Scranton Shale. | 16. Plattsburg Limestone. |
| 2. Howard Limestone. | 17. Lane Shale. |
| 3. Severy Shale. | 18. Iola Limestone. |
| 4. Topeka Limestone. | 19. Chanute Shale. |
| 5. Calhoun Shale. | 20. Drum Limestone. |
| 6. Deer Creek Limestone. | 21. Cherryvale Shale. |
| 7. Tecumseh Shale. | 22. Winterset Limestone. |
| 8. Lecompton Limestone. | 23. Galesburg Shale. |
| 9. Kanwaka Shale. | 24. Bethany Falls Limestone. |
| 10. Oread Limestone. | 25. Ladore Shale. |
| 11. Lawrence Shale. | 26. Hertha Limestone. |
| 12. Iatan Limestone. | 27. Dudley Shale. |
| 13. Weston Shale. | 28. Lenapah Limestone. |
| 14. Stanton Limestone. | 29. Nowata Shale. |
| 15. Vilas Shale. | |

Members 27-29 of the above are in the Pleasanton formation of the Des Moines Series. Members 18-26 constitute the Kansas City formation; ~~16-17~~, the Lansing^s, and 1-9, the Shawnee formations.

Correlation with Oklahoma and Texas. This correlation, after Gould, is as follows:

1. Nowata Shale, equivalent to the top portion of the Broken Arrow formation. It becomes a part or all of the Seminole conglomerate of Texas.
2. Nowata, Lenapah, and Dudley members equivalent to the upper portion of the Pleasanton formation of Missouri.
3. Members from the upper portion of the Dudley Shale to the top of the Cherryvale Shale, equivalent to the Coffeyville formation, the Curl formation of Oklahoma, and the upper portion of the Conyon group, and lower portion of the Graham group of Texas.
4. Drum member, equivalent to the Hogshooter Limestone, Nellie Bly formation, and the Dewey (Belle City) Limestone of Oklahoma. The Nellie Bly is in the upper portion of the Francis formation, and probably is a part of the Graham formation of Texas.
5. Chanute (above the Elgin sand), Iola, Lane, Plattsburg, Vilas, and Stanton members, equivalent to the Ochelata formation of Oklahoma, and some portion of the Canyon group of Texas.
6. Weston Shale, Iatan Limestone, Lawrence Shale, and Oread members, i.e., the Douglas formation, equivalent to the Nelagoney formation of Oklahoma and a portion of the Thrifty formations of Texas.
7. The Elgin Sandstone (in the lower portion of the Kanwaka Shale), equivalent to a portion of the Cisco group of Texas.

8. Members from near the basal portion of the Chanute to the top or near the top of the Scranton, equivalent to the Pawhuska formation of Oklahoma. All of these members extend from Iowa to Oklahoma. They probably are above the middle of the Cisco group of Texas.

Just what the relation of the beds of Conemaugh age in northern Missouri and southern Iowa may be to the strata in the Illinois section above the Allegheny formations is not known. All strata above the Allegheny (Carbondale) formation in Illinois are assigned to the McLeansboro formation, most of which may be of Conemaugh age. The leading limestones in the McLeansboro of Illinois, in ascending order, are the so-called Fusulina bed, the Lonsdale, La Salle, Carlinville, and Shoal Creek members. It would seem that one or more of these may persist between Illinois and Iowa, probably in the sections at or near Peoria and Centerville.

If the Carbondale formation of Illinois is equivalent to the Upper Cherokee of Iowa and Missouri, the so-called Fusulina Limestone exposed near Peoria, Illinois, probably is in the horizon of the Fort Scott Limestone, or of the Fort Scott and Pawnee united. More likely, however, the Lonsdale Limestone and about 14 feet of shale and thin limestones below it, exposed near Sparland, Illinois, represent the Henrietta formation. The Lonsdale near Sparland, Illinois, and the Pawnee limestones west of Centerville, Iowa, carry about the same fossils and are similar in color, thickness, and lithology. If they are equivalent, the shale between the Lonsdale and La Salle limestones in Illinois is in the horizon of the Pleasanton formation. Yet this formation may be represented in the shales between the Lonsdale and the Fusulina bed above Illinois Coal No. 6, which would place the Lonsdale in the horizon of the Hertha Limestone.

The La Salle Limestone of Illinois has a fauna much like that of the combined Bethany Falls and Winterset members of Iowa and Missouri. In other words, its affinity is with the Kansas City formation.

Should the Fort Scott horizon be found in Illinois, it will be difficult to carry the detailed correlation much higher, because the limestones are much thinner than in Iowa and

northern Missouri, and more especially because the bed rock is concealed generally by thick deposits of loess and drift.

Monongahela Beds.—These, which seem to be the equivalent of most of the Wabaunsee formation, are correlated in part after Gould as follows:

1. Lower Wabaunsee (probably the Nemaha beds), equivalent to the Buck Creek formation and the lower portion of the Pontotoc formation of Oklahoma, and in the upper Cisco group of Oklahoma.
2. Middle Wabaunsee formation, equivalent to the Sand Creek formation of Oklahoma, which is equivalent to part of the Pontotoc formation of east-central Oklahoma and a part of the Cisco group of Texas. In Oklahoma this includes the Grayhorse Limestone at the base, and the Foraker, 60' or more thick, at the top. The latter, or a portion of it, seems to be the horizon of the Americus Limestone.
3. Elmdale member, equivalent to the middle Wabaunsee, equivalent to the middle Pontotoc of central-southern Oklahoma and in the upper portion of the Cisco group of Texas.

Strata probably of late Pennsylvanian age:

1. Neva Limestone member, equivalent to the upper Pontotoc in Oklahoma, and in the upper portion of the Cisco of Texas; merges into red beds in central-southern Oklahoma. This is held by some to be Permian.
2. Eskridge Shale member, equivalent to the upper Pontotoc of Oklahoma, and in the upper Cisco of Texas; merges into the red beds south of Ripley. This is thought by some to be Permian.

The upper beds of the Cisco group in Texas may be younger than strata assigned to the top of the Pennsylvanian in Nebraska and Kansas. No persistent unit, horizon, or a break in the section has been found to mark the upper boundary of the Pennsylvanian in the areas from Kansas to north-central Texas. The Cottonwood limestone is used as this marker to the north, i.e., in parts of the Western Interior Province. However, this limestone does not mark either a lithologic, a physiographic, or a faunal break. Its selection is arbitrary to show a so-called though somewhat convenient contact. The normal sequence in the sediments, and many of the faunal species continue here from the Pennsylvanian beds to quite high in the so-called Permian section, and everyone who studies the beds above and below the Cottonwood is impressed with this fact. It is evident, therefore, that close inter-regional study, supplemented by the evidence of other coun-

tries, will be required to solve the problem of the Permian-Pennsylvanian contact in these Mid-continent regions. Dr. Raymond C. Moore of the Kansas Geological Survey, in cooperation with the State and Federal Surveys, is conducting a correlation study of the Pennsylvanian beds from Kansas to Texas. This investigation is intended to contribute to the problem of the upper limit of the Pennsylvanian.

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