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Geology of Northwestern Franklin County, Kansas

by

Dwight J. Laughlin

KANSAS GEOLOGICAL SURVEY
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047

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GEOLOGY OF NORTHWESTERN FRANKLIN COUNTY, KANSAS

by

Dwight J. Laughlin
B. S., University of Kansas, 1952

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Walter Youngquist
Instructor in charge

M. L. Thompson
For the department

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ABSTRACT

The geology of approximately 200 square miles in northwestern Franklin County, Kansas, is described. Rocks exposed in the area are of Pennsylvanian age on the upland and some Tertiary and Quaternary on the flood-plain and in high terrace deposits. The western part of the area is topographically characterized by a series of east-southeast facing escarpments separated by gently sloping valleys. These features are caused by the differential erosion of limestones, shales, and sandstones of the Shawnee group. To the east, the sandstones and shales of the Douglas group, where eroded, form a series of low rounded hills. The rocks are tilted to the northwest, forming a gently dipping homocline upon which is superimposed a few minor flexures. There are three faults in the area. The subsurface rocks range in age from Precambrian to Pennsylvanian. All of the Paleozoic Systems are represented except the Silurian. Mineral resources of the area include oil and gas, limestone, sandstone, gravel, shale, coal, and ground water. At present, these resources support a few small industries.

INTRODUCTION

Location of Area

This report covers approximately 200 square miles in northwestern Franklin County, Kansas (Fig. 1). The area is bounded on the west by the Osage-Franklin County line and on the north by the Douglas-Franklin County line. Combined U. S. Highways 50 and 59 mark the eastern boundary. On the south, the area extends to the northern edge of Township 18 South.

Geography of Area

The area is chiefly a farming region. The principal crops are wheat, corn, and alfalfa. Where the soil cannot be tilled, cattle are raised.

Two small villages and one medium sized town are located within the area. Ottawa, the county seat, has a population of 10,081, Pomona has a population of 453, and Centropolis has a population of 75. Their locations within the area are shown in Figure 1. The area is easily accessible, having all-weather roads along nearly all section lines.

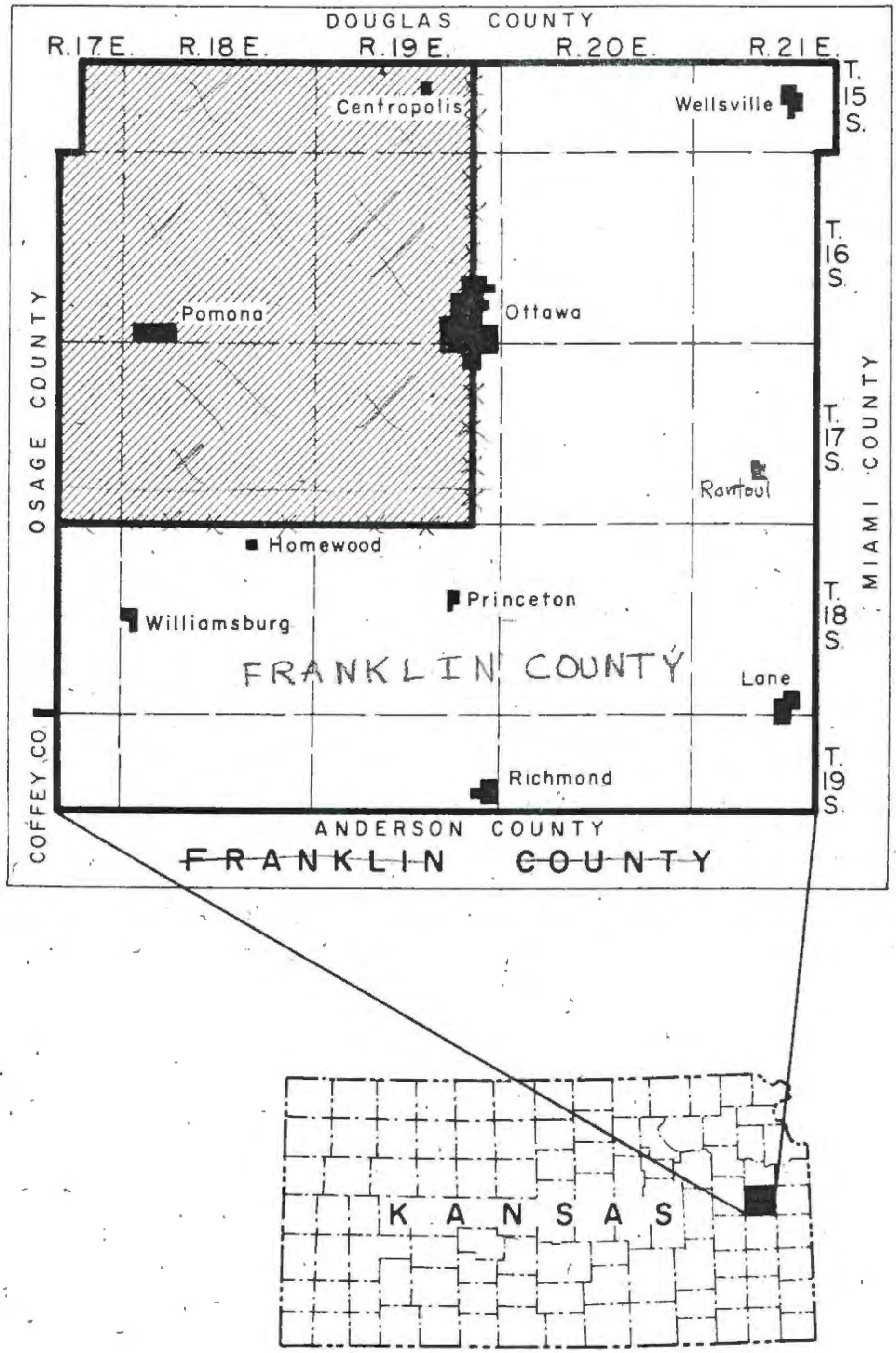


FIG. 1. Index map of Franklin County ~~and an enlargement showing location of the area within the county~~.

The average annual precipitation is 35.85 inches at Ottawa, 70 percent of this falling during the months of April through September (Kansas St. Board of Agri., 1948, p. 75).

Topography and Drainage

Franklin County is in the Osage Plains section of the Central Lowlands physiographic province (Schoewe, 1949, p. 275). The Osage Plains section is further subdivided into four units: Cherokee Lowland, Chautauqua Hills, Osage Cuestas, and Flint Hills (Schoewe, 1949, p. 280). According to Schoewe, the area studied lies in the Osage Cuestas division.

The western part of the area is characterized by a series of east-southeast facing escarpments separated by gently sloping valleys. These cuestas are formed by differential erosion of the limestones, shales, and sandstones that compose the Shawnee group.

East of the Oread limestone escarpment (lowermost member of the Shawnee group) the area is distinguished by a series of low rounded hills caused by the dissection of the thick sandstones and shales of the Douglas group. This topography is similar to the Chautauqua Hills division described by Schoewe (1949, p. 281).

Northwestern Franklin County is drained wholly by the Marais des Cygnes River, which flows eastward through the south-central part of the area. The main tributaries of the river are Appanoose, Kelsey, and Eight Mile Creeks draining from the north and Hardfish, Coal, Mud, and Rock Creeks flowing from the south (Pl. 1).

Purposes of Investigation

For several years the State Geological Survey of Kansas, in conjunction with the United States Geological Survey has been preparing a series of reports on the geology and ground water resources of Kansas. Several graduate students have been assigned parts of counties as thesis projects. The purpose of this report, one of these assignments, is to map and describe the geology of northwestern Franklin County.

Methods of Investigation

Field investigations were conducted during the months of July, August, and September, 1956. The geology was mapped on United States Department of Agriculture aerial photographs (scale 1:20,000). A focalmatic projector was used to transfer the geology from the photographs to a United States Soil Conservation Service drainage and base map (scale 1:40,000). No corrections for distortion due to parallax or tilt were made because of the low relief of the area and the excellence of the photographs.

Field observations were made by walking along outcrops and measuring rock sections using a Locke level, hand rule, and 50-foot tape. Surveys were made with an alidade and stadia rod where more detailed information was needed.

Previous Work

Investigations of the Pennsylvanian rocks of eastern Kansas have been made by many geologists over a period of nearly a century. Mudge (1866) described the Carboniferous strata of eastern Kansas. A generalized section of the Pennsylvanian rocks of Kansas was constructed by Swallow and Hawn (1865) and Swallow (1866). Haworth (1890's) ran several traverses across eastern Kansas. Haworth (1894, 1895) and Haworth and Kirk (1894) made many early classifications of the Pennsylvanian System.

In 1903, Adams, Girty, and White studied the Upper Carboniferous of Kansas, and Haworth and Bennet (1908) summarized the stratigraphy. Pennsylvanian summaries by Moore and Haynes (1917) and Moore (1920) modified earlier classifications.

In the 1930's, because of increased interest in cyclic sedimentation, Pennsylvanian studies were accelerated. Moore and Landes (1937) completed the State Geologic map with the assistance of Newell, Jewett, Schoewe, Elias, and others. Moore (1932, 1936), Newell

(1935), Jewett (1933), and Jewett and Newell (1935), after detailed studies made many reclassifications in the Pennsylvanian System.

Jewett (1941, 1945) studies the upper Desmoinesian and Bowsher and Jewett (1943) investigated the lower Virgilian. Moore and Thompson (1949) discussed the divisions of the Pennsylvanian of Kansas. "The Kansas Rock Column" by Moore, and others, was published in 1951.

Investigations primarily related to the subsurface stratigraphy of eastern Kansas developed as the oil industry obtained more information. Fath (1920) discussed the origin of faults, anticlines, and the buried "granite ridge". Landes (1927) made a petrographic study of the Precambrian of Kansas. Holl (1932) reported on the Cherokee group of the Forest City basin. Howell (1932) mapped the areal geology of the pre-Chattanooga surface in eastern Kansas. Kellett (1932) constructed a geologic cross-section from western Missouri to western Kansas. Ockerman (1935) conducted studies of the subsurface in northeastern Kansas. Bass (1936) presented a theory of the origin of the shoestring sands. Lee (1939, 1940, 1943, 1946) conducted detailed studies of the subsurface rocks of the Forest City basin. Lee and Merriam (1954) presented a series of cross-sections through the basin. Jewett (1949, 1951, 1954) has discussed the oil and gas developments of eastern Kansas.

Acknowledgments

I wish to express my thanks to Dr. J. M. Jewett and Dr. Walter Youngquist, under whose direction this study was made; to the various members of the State Geological Survey for their assistance, especially Mr. Howard O'Connor; and to the Citizens of Franklin County for their interest and courtesy.

This work was made possible by the State Geological Survey of Kansas, who allowed the use of their materials, unpublished files, and field instruments. Aid was also given by the Survey in the form of field expenses and transportation allowance.

The author also wishes to express thanks to Mr. John D. McNeal and Mr. Virgil Burget for the use of State Highway Commission files; to Mr. Darrell Davis, Mr. Rex Reynolds, Mr. Stanton Ball, and Mr. Mahlon Ball for their field assistance; and to my wife, Elizabeth, for her drafting.

STRATIGRAPHY OF SURFACE ROCKS

The surface rocks of northwestern Franklin County are all of sedimentary origin. They are Pennsylvanian in age, except for the stream valley and high terrace deposits, which are probably of Tertiary or Quaternary age. Areal distribution of these rocks is shown on Plate 1. In the following discussion of the stratigraphy, rock descriptions will pertain to the area unless otherwise stated. The strata are described in order from oldest to youngest (Fig. 2).

PENNSYLVANIAN SYSTEM

Missourian Series

Lansing group

Stanton limestone

South Bend limestone member

The South Bend limestone member is named from exposures near South Bend, Platte Valley, Nebraska (Condra, 1927, p. 59). Where the member is exposed in sec. 27, T. 16 S., R. 19 E., it is a gray fine-grained limestone that commonly contains brachiopods and fusulinids.

Pedee group

The Pedee group is defined as the sequence of strata between the top of the Stanton limestone and the unconformity at the top of the

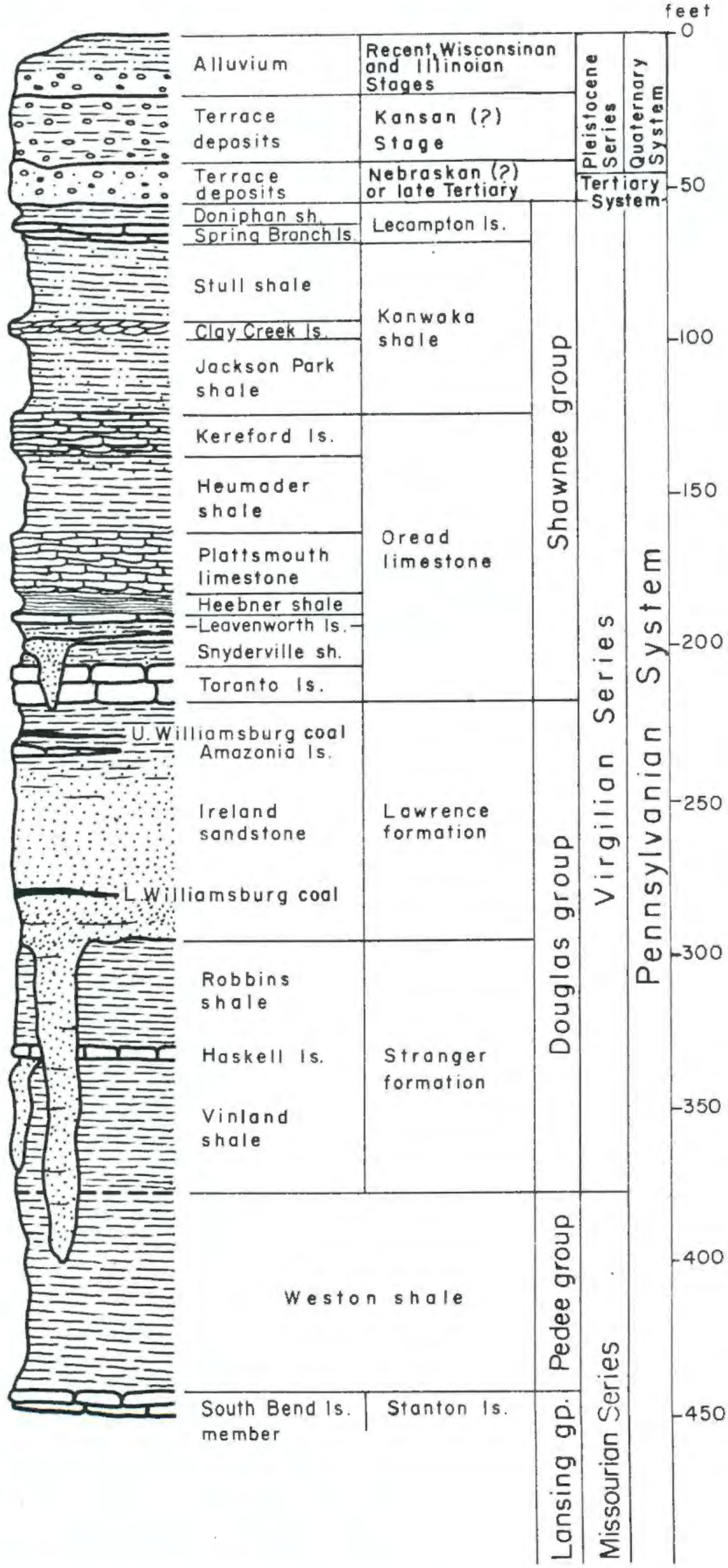


FIG. 2. Generalized rock section.

Missourian Series. Where originally described at Platte County, Missouri (Moore, 1932, p. 93) the group is divided into two formations: Weston shale and Iatan limestone.

Weston shale

As first described from exposures at Weston, Missouri (Keyes, 1899, p. 306), the Weston includes the shale beds between the top of the Stanton limestone and the base of the Iatan limestone. Where the Iatan is absent, as in northwestern Franklin County, the upper boundary of the shale is marked by an unconformity. Here, the beds succeeding the Weston may be sandstone, conglomerate, coal, or shale of the Douglas group (Fig. 3).

The best exposure of the Weston shale in the area is at the Buildex Quarry, sec. 23, T. 17 S., R. 19 E. Here it is composed of blue-gray clay shale containing limonite concretions. Patterson (1933, p. 5) described a varied marine fauna from the shale a few miles further north, but in the area marine fossils are few or absent.

farther

Virgilian Series

Rocks of the Virgilian age are the youngest Pennsylvanian rocks in Kansas. Limits of the series are defined by the unconformity at the top of the Missourian Series at the base and the disputed Pennsylvanian-Permian boundary marked by a similar unconformity at the top. Virgilian rocks in the area are the basal Douglas group

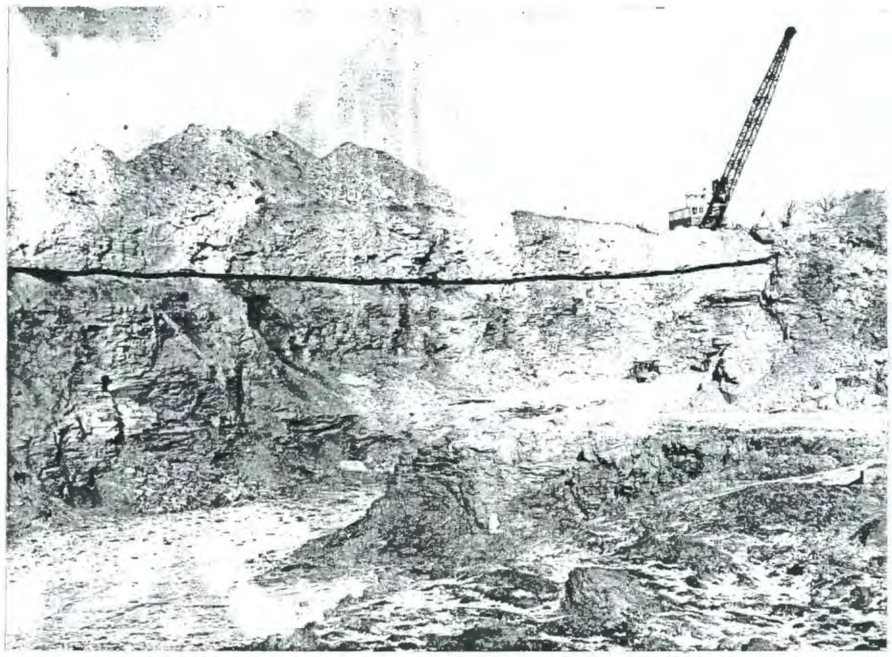


FIG. 3. Contact between Ireland sandstone and Weston shale. The line indicates the contact, drawn on the Ottawa coal. Camera is looking northwest in Buildex quarry, sec. 23, T. 17 S., R. 19 E.

and the lower three formations of the Shawnee group (Fig. 2).

Douglas group

Rocks of the Douglas group (Haworth, 1898, p. 93; redefined by Moore, 1932, p. 93) are named from exposures in Douglas County, Kansas. The group is divided into two formations: Stranger and Lawrence.

Stranger formation

Marine and nonmarine strata between the disconformity at the top of the Pedee group and the base of the Lawrence formation comprise the Stranger formation (Newell, in Moore, 1932, p. 93).

The basal Tonganoxie sandstone and the overlying Westphalia limestone, which occur in other localities, were not observed in the area. The Vinland shale, Haskell limestone and Robbins shale members occur in isolated areas, where they have not been removed by post-Stranger erosion (Pl. 1).

Vinland shale member

Marine shale and sandstone beds above the Weston shale and below the Haskell limestone comprise the Vinland shale. Patterson and Addison (1933, p. 17) named these beds for exposures at the village of Vinland, Douglas County, Kansas.

In some localities, the Vinland is represented by a gray clayey to calcareous marine shale containing brachiopods, crinoid remains, and bryozoans. A zone of abundant *Myalina* occurs near the top in sec. 26, T. 15 S., R. 19 E. and surrounding area (Fig. 4). In other exposures, an unfossiliferous fine-grained micaceous sandstone or sandy shale occupies this interval (sec. 21, T. 16 S., R. 19 E.). The thickness of the shale is as much as 25 feet.

It was impractical to map the contact between the Weston shale and Vinland shale because of the similarity in the lithology of these beds. A definite break could not be recognized and where the Vinland shale is present, an approximation of this contact is shown on Plate 1.

Haskell limestone member

The Haskell, named for the locality around Haskell Indian Institute, Lawrence, Kansas (Moore, 1932, p. 93), is a bluish-gray crystalline blocky limestone, 1 to 2 feet thick. The top surface of the limestone is very irregular or pitted (Fig. 5). Algae (Ottonosia), abundant fusulinids, brachiopods, and Myalina clams are present in most exposures.

Robbins shale member

A marine argillaceous shale lying above the Haskell limestone and below the base of the Ireland sandstone is named the Robbins shale (Moore and Newell, in Moore, 1936, p. 153) for exposures on Robbins farm, Yates Center, Kansas. Miller and Swineford (1956) made a detailed study of the lower part of the Robbins. They found a zone of brown phosphatic nodules containing fossil ammonoid cephalopods and brain casts of fish in the depressions of the upper Haskell surface (Fig. 5). Above the nodules there is a 4-inch layer of light brownish-

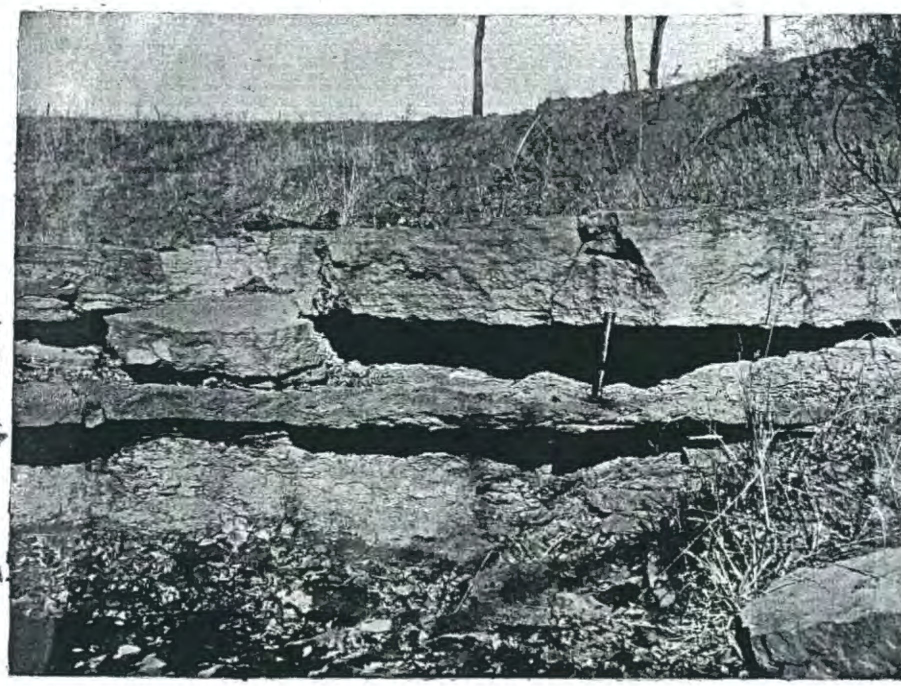


FIG. 4. Haskell limestone and top of the underlying Vinland shale. Hammer indicates Myalina zone. Camera facing west in sec. 26, T. 15 S., R. 19 E.

FIG. 5. Close-up of top of Haskell limestone illustrating irregular surface. Sec. 26, T. 15 S., R. 19 E.

gray clay. Above this a 2-inch layer of relatively hard impure goethite that contains a fauna of marine mollusks was described. Miller and Swineford also give some of the conodont and ostracode genera in the report.

Where the Robbins crops out, as in sec. 26, T. 15 S., R. 19 E., it is a gray clay shale ranging from a feather edge to 25 feet in thickness.

Lawrence formation

As originally defined by Haworth (1894, p. 122), the Lawrence included the strata between the top of the Haskell limestone (then believed to be Iatan limestone) and the base of the Oread limestone. These limits were later redefined (Moore and Newell, in Moore, 1936, p. 154) to include the Robbins shale member in the Stranger formation. The Lawrence formation now includes beds between the unconformity marked by the base of the Ireland sandstone member and the base of the Oread limestone.

In Franklin County, the Lawrence formation consists of conglomerate, sandstone, limestone, coal, and shale, and differs in lithology from one exposure to another. Two members have been defined and both are present in the area. They are the Ireland sandstone and Amazonia limestone.

Ireland sandstone member

The Ireland sandstone is present throughout the area. This bed consists mainly of massive or cross-bedded fine to medium-grained micaceous sandstone containing abundant plant fossils in many exposures (Fig. 6A, B). In some localities, such as sec. 15, T. 17 S., R. 18 E., the sandstone attains a thickness of nearly 150 feet.

The basal part of the Ireland sandstone, which marks a regional unconformity (Moore, 1936, p. 155), has a variety of lithologies. Fine sandstone, pebble conglomerate, calcareous cement conglomerate, and coal interbedded with sand are exposed in various exposures.

Pre-Ireland erosion cut to various depths into the older rocks. Where erosion was deepest, the Ireland overlies the Weston shale. In other places the sandstone is in contact with successively younger beds. In exposures, the Ireland is in contact with the Vinland shale, Haskell limestone, or Robbins shale (Fig. 7A, B). In eastern Kansas the Ireland is a wide spread sandstone deposit that is not only on the surface but in the subsurface to the west. If the sandstone is a channel deposit, as has been postulated, the author believes the area of deposition must have been a broad flat plain with a network of channels.

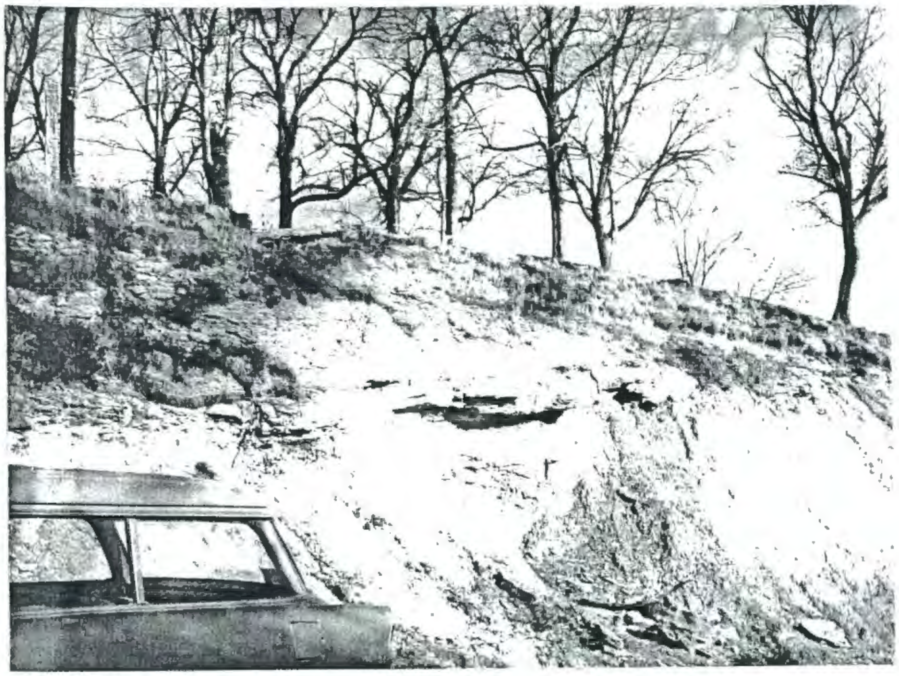
Rich (1933) described "angular coal fragments" at the base of the Ireland sandstone in sec. 15, T. 17 S., R. 18 E., and explained their presence as being derived from the Sibley coal of the Stranger formation and redeposited, forming a coal conglomerate.

The author believes this coal was probably formed in place rather than eroded and redeposited. The basis for this opinion is that some of the coal "fragments" are more than 6 feet in length and one-half

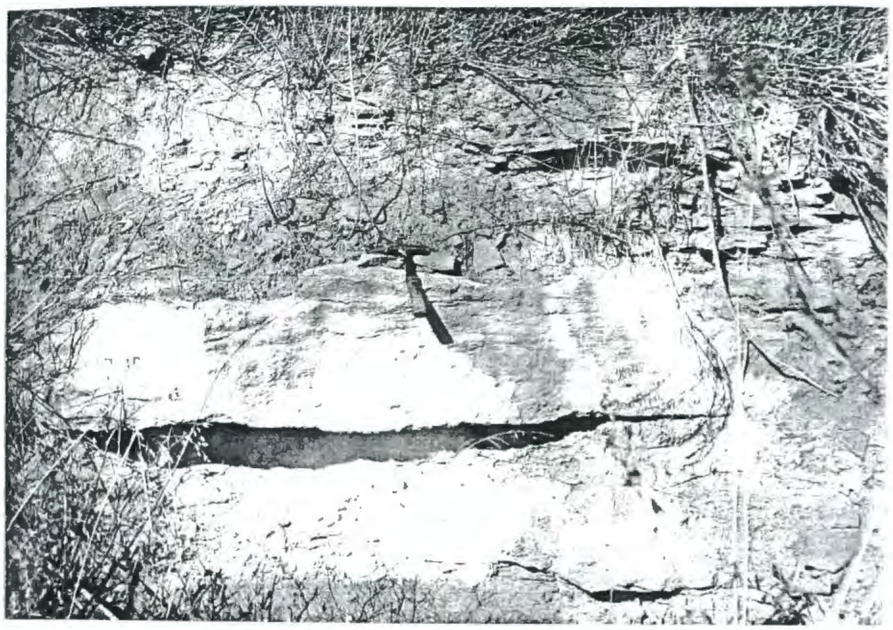
A.

B.

FIG. 6. Exposures of Ireland sandstone. (A) shows massive bluffs along Marais des Cygnes River south of Pomona, sec. 7, T. 17 S., R. 18 E. Camera faces east from bridge. (B) Cross-bedding as seen in sandstone quarry in sec. 14, T. 16 S., R. 19 E. Camera looking south.



A.



B.

FIG. 7. Unconformity at base of Ireland sandstone. (A) shows Ireland overlying Robbins shale in road cut, sec. 7, T. 17 S., R. 19 E., camera facing north. (B) Ireland on Haskell limestone in SW 1/4, SE 1/4, sec. 13, T. 17 S., R. 18 E., camera facing north.

inch in thickness. These coal seams in many cases appear to pinch out (Fig. 8A). Some of the thicker "fragments" do appear to be broken, but the underlying shale also appears to have been deformed (Fig. 8B). It is possible that slight movement after deposition caused the coal to be crumpled and reorientated.

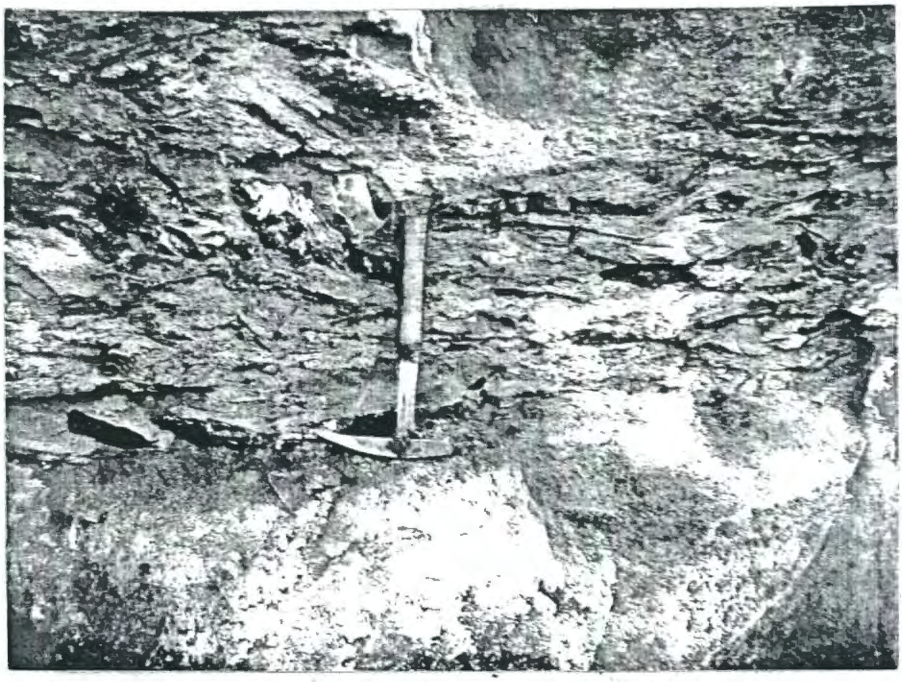
In other exposures, such as in sec. 30, T. 17 S., R. 19 E., the basal conglomerate is composed of limestone, quartz and limonite pebbles, together with reworked marine fossils and fossil plant remains. These consituents are cemented by a calcareous matrix.

Three important coal seams are in the Lawrence shale along with numerous local thin coal zones (Bowsher and Jewett, 1943). These coals are the Upper Williamsburg, Lower Williamsburg, and Ottawa.

The most important seam is the Upper Williamsburg coal which lies 12 to 20 feet below the Toronto limestone. It ranges in thickness from a feather edge to 21 inches and apparently thins toward the north. Thickest exposures of the Upper Williamsburg occur in sec. 16, T. 16 S., R. 18 E., and in the area southwest of Pomona (Fig. 9).

The Lower Williamsburg coal occupies a position 40 to 50 feet below the base of the Oread in or near the top of the Ireland sandstone. The thickness ranges from a feather edge to 18 inches (Fig. 10).

A third important coal occurs at the base of the Ireland sandstone in sec. 14, 15, and 9, T. 17 S., R. 19 E. The Ottawa coal was



A.

coal as seen in sec. 15, T.
taken with camera facing south.

B.

FIG. 8. Coal interbedded with sandstone at the base of the Ireland sandstone. (A) shows coal lenses in the sandstone. (B) illustrates deformation in the Weston shale below the sandstone. Photos taken with camera facing west in SEc sec. 15, T. 17 S., R. 18 E.

FIG. 9. Upper Williamsburg coal as seen in sec. 15, T. 16 S., R. 18 E. Photo taken with camera facing south.

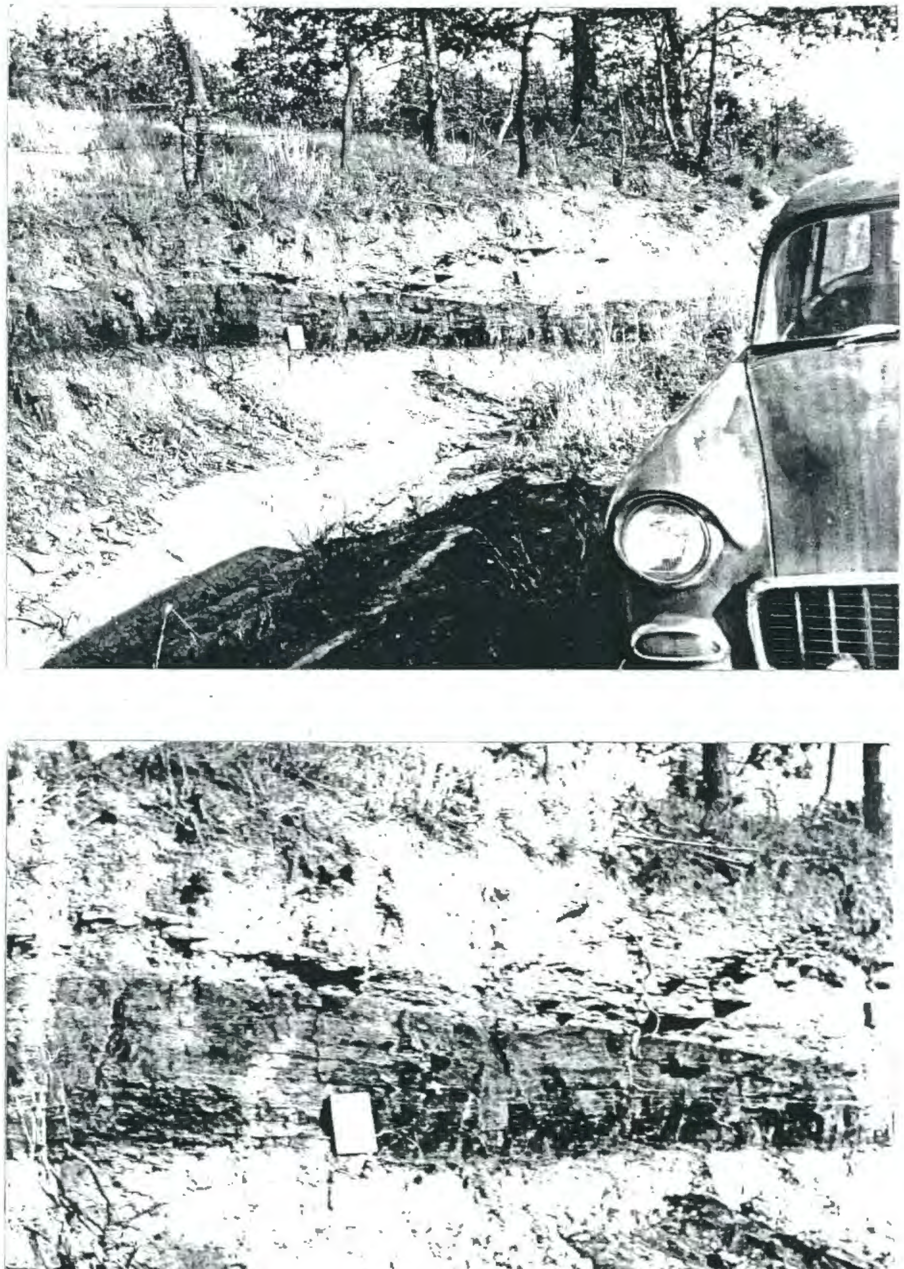


FIG. 10. Lower Williamsburg coal in road cut along south side of sec. 15, T. 17 S., R. 18 E. Bottom photo shows close-up of seam. Camera facing northeast.

named by Bowsher and Jewett (1943, p. 41). They described this bed as being at the base of the Tonganoxie sandstone member of the Stranger formation. Through personal communication and field observation, Jewett agrees with the author that the coal occurs at the base of the Ireland sandstone and that the Tonganoxie is not present in the vicinity (Fig. 11).

Amazonia limestone member

A thin mottled gray unfossiliferous limestone lies a few feet below the Upper Williamsburg coal. This limestone was tentatively correlated by Bowsher and Jewett (1943, p. 35), on the basis of stratigraphic position, as the Amazonia limestone. Exposures of the Amazonia are limited to the area southwest of Pomona.

The maroon clay shale that occurs 10 to 20 feet below the Toronto limestone farther north in Douglas County is found in one location, sec. 29, T. 15 S., R. 18 E. In all other exposures examined, the upper Lawrence consists of silty to sandy shale containing sandy-limestone stringers and limestone concretions. This maroon shale reappears again to the south in Woodson County. No reason could be detected for these differences except that the present map area received coarser clastic deposits during this time instead of fine silt and clay.

Shawnee group

The Shawnee group, as originally named (Haworth, 1898, p. 93), included strata from the base of the Kanwaka shale upward to

FIG. 11. Ottawa coal at base of Ireland sandstone along U. S. Highway 50 southwest of Ottawa, in sec. 23, T. 17 S., R. 19 E. Camera facing south.

the base of the Burlingame limestone. Moore (1936, p. 159) redefined the Shawnee beds to include the Oread, formerly placed in the Douglas group, and to exclude the strata above the top of the Topeka limestone.

Four limestone and three shale formations make up the group. The lower three formations are present in the area. These are: Oread limestone, Kanwaka shale, and Lecompton limestone (Fig. 2).

Oread limestone

The Oread limestone was named by Haworth (1894, p. 123; 1895, p. 461) after the hill where the University of Kansas is located. In early usage the name was applied only to the lower limestone (Toronto), but later Haworth included the upper wavy bedded limestone (Plattsmouth). The middle blue-gray limestone (Leavenworth) was not recognized. Moore (1936, p. 161) included in the Oread, not only these three limestones and intervening shales, but also an upper limestone described and named Kereford by Condra (1927, p. 45).

The Oread, as now defined, contains the following members: Toronto limestone, Snyderville shale, Leavenworth limestone, Heebner shale, Plattsmouth limestone, Heumader shale, and Kereford limestone.

Toronto limestone member

Named for a town in Woodson County, Kansas, by Haworth and Piatt (1894, p. 117), the Toronto limestone is the basal member of the Oread limestone. In most exposures it is a massive-bedded brown-weathering limestone containing abundant brachiopods, crinoid remains, bryozoans, and fusulinids (Fig. 12). Locally, a gray medium-bedded unfossiliferous zone exists in the basal part. The average thickness is 10 feet, but in some areas it attains a thickness of 12 feet.

Locally in southern Douglas County and northwestern Franklin County the Toronto is absent. This matter is more fully discussed in the present report under the section titled Structural Geology.

Snyderville shale member

The lowermost shale member of the Oread is the Snyderville shale (Condra, 1927, p. 38). Named for a town in southeastern Nebraska. In most exposures, the shale is a tan to gray silty clay becoming more clayey toward the top. Where the Toronto is absent, a brown massive fine- to medium-grained micaceous sandstone occurs 15 to 20 feet below the base of the Leavenworth limestone. The average thickness of the shale is 15 feet.

Leavenworth limestone member

Next in the sequence is the Leavenworth, a distinctive blue-gray dense fine-grained limestone. Condra (1927, p. 38) described and named this bed from exposures near Leavenworth, Kansas. Distinctive features of the unit are the blue-gray color and vertical jointing. In weathered exposures the blocks tend to become rounded on the edges giving a boulder-like appearance to the outcrop. Fossils are common, especially fusulinids and brachiopods, but they are not readily broken or weathered out as in softer limestones. The Leavenworth ranges in thickness from 1 to 2 feet.

FIG. 12. Typical exposure of Toronto limestone showing massive bedding, in NWc sec. 32, T. 15 S., R. 18 E. Camera facing east.

Heebner shale member

A persistent and lithologically distinct bed of the Oread limestone is the Heebner shale, named for Heebner Creek, Nehawka, Nebraska (Condra, 1927, p. 37). The lower part is a black thin platy to nearly fissile shale. Conodonts have been described from the lower Heebner in other localities, but none were observed in the map area under consideration. The upper portion is a tan to gray clay shale containing, among other fossils, the brachiopods Productella and Chonetes near the top (Fig. 13). The Heebner averages 7 feet in thickness. In areas where the Toronto limestone is absent, the shale attains a thickness up to 12 feet. This abnormally thick section can be attributed to structural movements that have caused excessive deposition during this time. These movements are discussed more fully in the Structural Geology section of this paper. ?

Plattsmouth limestone member

The type section of the Plattsmouth limestone is at Plattsmouth, Nebraska (Keyes, 1899, p. 306; Condra, 1927, p. 37). This member is a light gray wavy-bedded fine-grained limestone. Fossils are common to abundant and include the brachiopod genera Hustedia, Neospirifer, Dictyoclostus, and Composita, the coral Lophophyllidium and fusulinids (Fig. 14). Many of the fossils have been replaced with calcite. A tooth from a Bradyodont fish of a new species Petalodus jewetti was discovered by J. M. Jewett, and described by H. W. Miller (1956). The thickness of the Plattsmouth averages 18 feet in the area.

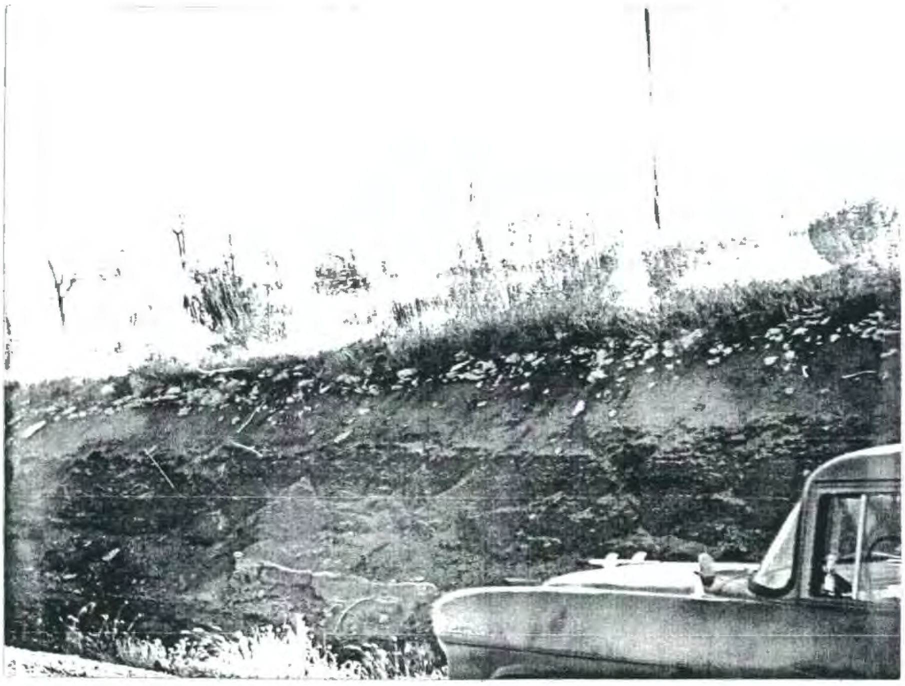


FIG. 13. Leavenworth limestone, Heebner shale and weathered remnants of the Plattsmouth. Note sharp line between lower black shale and upper tan shale of the Heebner. Picture taken with camera looking southeast in NWc sec. 20, T. 15 S., R. 18 E.

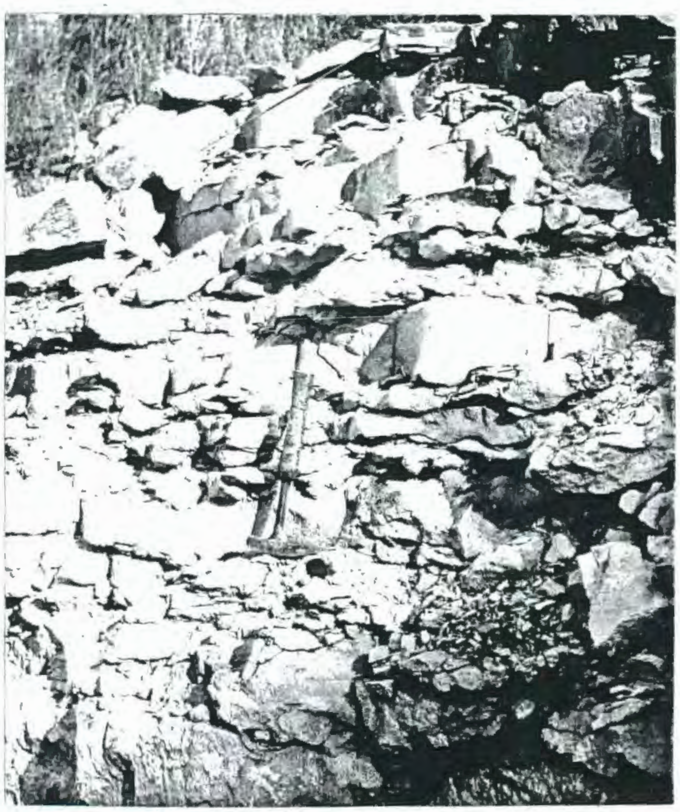


FIG. 14. Plattsmouth limestone illustrating wavy-bedded character. Picture taken in quarry located in SEc sec. 20, T. 15 S., R. 18 E. Photo at bottom is close-up of same exposure.

Heumader shale member

This member is a gray silty laminated shale containing flat to sub-elliptical limonite concretions. The upper 2 to 3 feet is calcareous and fossiliferous, containing bryozoans, crinoid remains and the brachiopods Neospirifer, Dictyoclostus, Dielasma, and Composita. The Heumader was named (Moore, 1932, p. 96) from exposures at Heumader quarry near St. Joseph, Missouri. The thickness ranges from 20 to 30 feet.

Kereford limestone member

The Kereford limestone, named by Condra (1927, p. 45) from Kerford quarry, Atchison, Kansas, is the uppermost member of the Oread limestone. It should be noted that the spelling of the name of the stratigraphic unit differs from the spelling of the geographic place name. Moore (1952, p. 366) has discussed this unusual problem which was first noticed by Jewett and O'Connor (1952) in connection with the spelling of "Bennett" with regard to the Bennett shale member. This shale was named for the village of Bennet, Nebraska. Moore states, "Stratigraphic names established by uniform usage in several publications shall not be subject to change of spelling, whatever the origin of these names or the advocated reasons for change of orthography may be." He concludes, "...discrepancies in names of the sort here discussed are unimportant; essentially they have historical interest only." Therefore, because of the long time usage, the spelling of "Kereford" should not be changed.

In the lower part, the member is a light tan to gray medium-bedded fossiliferous limestone, containing bryozoans, the brachiopods Composita, Neospirifer, Derbyia, and Dielasma, and a profusion of fusulinids. In many outcrops, these fossils weather out in strong relief. The upper part of the Kereford member is a blue-gray medium-bedded fine-grained to nearly lithographic limestone, generally unfossiliferous. The average thickness is 11 feet.

Kanwaka shale

Above the Kereford member is the Kanwaka shale, named for Kanwaka Township, Douglas County, Kansas (Adams, 1903, p. 163). This formation contains the beds (both marine and nonmarine) between the top of the Oread limestone and the base of the Lecompton limestone. The Kanwaka is divided into three members: the Jackson Park shale, the Clay Creek limestone, and the Stull shale. In the area of the present report, the Kanwaka shale averages 80 feet in thickness.

Jackson Park shale member

Named for exposures in a park at Atchison, Kansas (Moore, 1932, p. 94), the Jackson Park shale is the lower member of the Kanwaka. The lower portion is a gray clayey to silty nonmarine shale containing plant fossils that grades upward into a calcareous marine shale. The upper zone contains abundant brachiopods, crinoid remains, and bryozoans. The shale is about 40 feet thick.

Clay Creek limestone member

This member is a blue-gray dense tan-weathering fossiliferous limestone. The type locality is on Clay Creek, west of Atchison, Kansas. In all exposures studied, fossil remains of fusulinids along with brachiopods, crinoid remains, bryozoans, and algae were observed. The thickness of the Clay Creek ranges from 2 to 3 feet.

Stull shale member

The Stull shale was named from a locality near Stull, Douglas County, Kansas (Moore, 1932, p. 94). It is composed of silty to clayey shale that is locally sandy. In most exposures it is nearly devoid of fossils except in the upper portion where brachiopods and bryozoans occur. These shale beds average 29 feet in thickness.

Lecompton limestone

The Lecompton limestone type locality is at Lecompton, Kansas (Bennett, 1896, p. 116). Four limestone and three shale members make up the unit. The formation has a lower brown massive limestone member (Spring Branch), a blue-gray limestone member (Big Springs), a thick wavy-bedded limestone member (Beil), and a dense medium-bedded member (Avoca). Due to cyclical sedimentation, for which the Pennsylvanian of eastern Kansas is noted, this sequence is strikingly similar to the Oread limestone. The shales, Doniphan, Queen Hill, and King Hill, which intervene between the limestone beds also are similar to those in the Oread. The lower two members of the Lecompton limestone are present in the area.

Spring Branch limestone member

This member, named for a creek north of Big Springs, Douglas County, Kansas (Condra, 1927, p. 47), is the lowermost unit of the Lecompton. In the area it is characterized by a dark brown color, massive appearance, and an abundance of fusulinids. Brachiopods and crinoid remains are common in most exposures. The thickness averages 6 feet.

Doniphan shale member

The shale was first described from exposures in northern Doniphan County, Kansas. This unit is composed of silty, clayey, and sandy shale, generally unfossiliferous. In the area, the shale is at least 15 feet in thickness. O'Connor (1955, p. 16) found the thickness as much as 27 feet in Osage County.

TERTIARY AND QUATERNARY SYSTEMS

Pliocene Series(?) or Nebraskan Stage(?)

Isolated terrace deposits were mapped along the highlands north of the Marais des Cygnes River (Pl. 1). They are composed chiefly of chert gravel with a reddish silty-clay matrix (Fig. 15). In Osage County, O'Connor (1955, p. 7) distinguished three terrace levels based on topographic position. He described terraces at elevations of 60 to 75, 80 to 95, and 140 to 160 feet above the present alluvial flood-plain of the river. Deposits of similar lithology are present at an

FIG. 15. Gravel quarry in Pliocene(?) terrace deposits; sec. 27, T. 16 S., R. 18 E. Camera facing north.

elevation of 85 to 100 feet above the flood-plain in the map area. These deposits correspond to O'Connor's highest terrace, which he states is probably late Tertiary or early Nebraskan in age (Fig. 15).

QUATERNARY SYSTEM

Kansas Stage(?)

In sec. 34, T. 16 S., R. 18 E., there is a remnant of a terrace at an elevation of 20 to 30 feet above the flood-plain. This deposit is composed of chert and limestone pebbles in a brown silty-clay matrix. On the basis of topographic position, this deposit is correlated here with O'Connor's Kansan Stage(?) terrace.

Illinoian(?), Wisconsinan(?) and Recent Stages

There are probably remnants of terraces of Wisconsinan and Illinoian Stages in the broad flat plain of the Marais des Cygnes River Valley. No attempt was made to differentiate these low deposits of the flood-plain complex, because without drill-hole information it was not feasible to do so. These deposits are composed of chert, limestone, shale and sandstone detritus, derived from eroded bed rock of the area and interbedded with fine silts and clays.

STRUCTURAL GEOLOGY

The geologic structure in the area is simple as may be seen on Plates 2 and 3. The strata dip gently to the northwest at a rate of 15 to 20 feet per mile. They crop out with a strike of approximately north-northeast to south-southwest (Pl. 1). Some local flexures are superimposed upon this gently dipping homocline. Three faults have also been mapped. These anomalies are small and can be identified in the field only where ideal circumstances exist.

In all of the fault areas, mantle rock covering has obliterated the surface trace of the fault planes. Other faults of small displacement probably are present but can not be detected without very detailed surveying.

Evidence for the fault in sec. 18, T. 15 S., R. 19 E., does not appear in Franklin County. Howard O'Connor (personal communication) found evidence for the fault in Douglas County to the north and believes that it probably extends into the areas as shown on Plate 1.

West of Centropolis, in sec. 24 and 25, T. 15 S., R. 18 E., a fault was mapped trending nearly north-south. The evidence for this movement can best be seen along the east-west couhty road between sec. 24 and 25. On the upthrown side a normal thickness of Toronto limestone is present. On the downthrown side, the Toronto limestone is absent, and a thick section of Heebner shale exists.

The base of the Toronto on the upthrown side is 30 to 40 feet above the top of the Leavenworth on the downthrown side.

Rich (1932) described the same type of structure to the north in Douglas County and explained it as follows:

> South of a curved line, marked by sharp flexing and faulting, which for several miles of its course closely follows the northern arc of a circle of about 4 miles radius, the lower of the three Oread limestones [Toronto] is missing: the middle limestone [Leavenworth] is thicker than average and the shale interval between the middle and the upper limestone [Plattsmouth] is abnormally thick, 16 feet instead of 6. The upper limestone at several places along the arc was faulted down to the south about 20 feet, so that south of the fault it lies at the same level as the lower limestone north of the break.
>
> These relations indicate: (a) Uplift of the area south of the curved line so that the lower Oread either was not deposited or was eroded after deposition; (b) A renewal of movement, causing a relative sinking of the area south of the line while the middle Oread limestone and the overlying shale were deposited; deposition of the upper Oread limestone over both sides, and, finally, post-Oread faulting with downthrow to the south.
>
> The cause of such movements, their reversal in direction, and the plan of the area affected constitutes an interesting problem.

Patterson (1933), working on the Douglas group in the Baldwin area states the problem as follows:

> The Oread limestone has been removed by post-lower Oread-pre-Snyderville erosion for 10 miles southwest of Baldwin at least. Erosion seems to be deepest near Baldwin at locality 245, SWc sec. 35, T. 14 S., R. 20 E., where the upper 80 feet of the Lawrence formation has been removed in addition to the Weepingwater member [now Toronto] of the

> Oread so that a limestone conglomerate followed by 35 feet of shale beds of Snyderville age rests on sandstone low in the Ireland sandstone member of the Lawrence formation. As mentioned by Rich, the Snyderville shale, middle Oread and Heebner shale members of the Oread formation are abnormally thick. Beds of Snyderville age deposited above the unconformity are predominantly shale near Baldwin but to the southwest sand deposition locally took place.

An unpublished map by Rich in the Kansas Geological Survey files shows the fault line in Douglas County bending southward in the area 4 miles north of Centropolis. If extended southward to the present map area, this fault trend lines up with the fault west of Centropolis.

This fault fits Rich's and Patterson's descriptions. Rich's theory on the movements that have occurred, if accepted, explain all of the structural and stratigraphic problems encountered in the area. It would be difficult for the author, as apparently it was for Rich, to postulate any theory on the origin of the force to cause these movements. Detailed mapping and stratigraphic studies along the total length of the fault zone might solve this problem.

The Toronto limestone is missing in other localities in the area (Pl. 1). If faulting has occurred, it was so small that detection of the movement would require detailed work.

Faulting has also occurred northwest of Pomona in sec. 30 and 19, T. 16 S., R. 18 E. Dome shaped structural highs are in the subsurface to the east and west of the fault line. It appears that the fault is located in a saddle between these domes. The fault trend is shown on Plate 1. The apparent displacement is 20 to 30 feet. This fault is aligned with the trend of the fault described by O'Connor (1955, p. 19) north of Quenemo in Osage County. However, evidence for connecting these faults could not be found.

SUBSURFACE GEOLOGY

All subsurface rocks above the Precambrian basement are of sedimentary origin. These strata range in age from Cambrian to late Pennsylvanian (Pls. 2 and 3) and attain a total thickness exceeding 1900 feet.

The area lies on the south edge of the Forest City basin (Fig. 16B). Lee and Payne (1944, p. 13) described the basin as follows:

> The Forest City basin is a low broad structural feature whose central area lies in northeastern Kansas and whose margins extend into adjoining parts of Nebraska and Missouri and into Iowa. The basin is formed by regional warping of the pre-Pennsylvanian rocks, and it was originally both a topographic and structural feature in which the earliest Pennsylvanian rocks of this part of Kansas were deposited.

Precambrian Rocks

Precambrian rocks have not been penetrated by drilling within the area. Drill-hole samples from other eastern Kansas wells show the Precambrian rocks are mainly granite, gneiss, and schists. In addition, Landes (1927, p. 283) reported some basic igneous rocks, quartz porphyry, and quartzites from certain localities.

Early Paleozoic Rocks

In the area, none of the deep drill tests have penetrated below the Ordovician rocks. For the most part, information on the early Paleozoic rocks in the map area was assembled from previously published manuscripts on eastern Kansas subsurface geology.

Keroher and Kirby (1948, p. 26) show that the lowermost Cambrian rocks are the Bonneterre dolomite, which lies unconformably on the Precambrian. Next upward in the sequence are the Arbuckle rocks. The term Arbuckle is used throughout Oklahoma and Kansas for grouping undifferentiated Cambrian and Ordovician limestones above the Bonneterre dolomite and below the St. Peter sandstone. According to Lee (1943, p. 21) the Arbuckle is represented by the Eminence dolomite of Cambrian age, and undifferentiated dolomites representing the Van Buren, Gasconade, Roubidoux, Jefferson City, and Cotter of early Ordovician age. The Arbuckle averages 600 feet in thickness (Jewett, 1954, p. 212).

Lying above the Arbuckle is the St. Peter sandstone of Ordovician age. In the wells examined the St. Peter ranges from 50 to 75 feet in thickness and becomes thinner toward the south (Pl. 3).

Above the unconformity at the top of the St. Peter sandstone lie the Decorah shale and Kimmswick limestone of late Ordovician age. These beds average 75 feet in thickness and are present throughout the area.

According to Jewett (1954, p. 211), a thin section of Devonian strata is present in the northern part of the area. In the wells examined, Devonian rocks are present in the northwest but are absent farther south (Pls. 2 and 3).

Late Paleozoic Rocks

The Chattanooga shale of late Devonian or early Mississippian age lies unconformably on the older rocks which were tilted and eroded before Chattanooga time (Lee, 1943, p. 63). Throughout the area the Chattanooga shale is present and averages 50 to 75 feet in thickness. The shale thins toward the southeast (Pl. 2).

Above the Chattanooga lie 250 feet of Mississippian limestone. Jewett (1954, p. 21) states that these limestones are the Chouteau, Sedalia, and undifferentiated Burlington-Keokuk. Locally Warsaw rocks are present. The unconformity at the top appears to be a peneplane surface gently dipping to the northwest (Pls. 2 and 3).

Above the Mississippian rocks are 1000 feet or more of Pennsylvanian strata of the Desmoinesian and Missourian Series.

Desmoinesian rocks are divided into two groups: Cherokee and Marmaton.

The Cherokee rocks are chiefly of clastic origin. For the most part, the group consists of silty to clayey shales. However, sandstone and sandy shales are also present. Important oil producing sand lenses, "Shoestring sands", occur at various horizons. These lenticular sand bodies represent channel fillings or bar deposits. Moore (1949, p. 39) states that fifteen coal beds have been identified in the group. The Cherokee averages 450 feet in thickness.

Overlying the Cherokee is the Marmaton group. These strata consist mainly of limestones and shales and minor amounts of coal and sandstone. In the area, the thickness of the group is about 100 feet. The group thins southward toward the Bourbon arch (Pl. 2). The top of the Marmaton marks the regional unconformity between the Desmoinesian and Missourian rocks.

The Missourian Series is subdivided into four groups. These divisions are Pleasanton, Kansas City, Lansing, and Pedee.

The Pleasanton group is composed chiefly of clastic material, with silty shale and sandstone predominant. The group averages 175 feet in thickness.

Limestone and shale, with subordinate amounts of sandstone make up the Kansas City and Lansing groups. These groups are of about equal thickness, each averaging 150 feet.

Rocks of the Pedee, Douglas, and Shawnee groups have been discussed in detail in the surface stratigraphy.

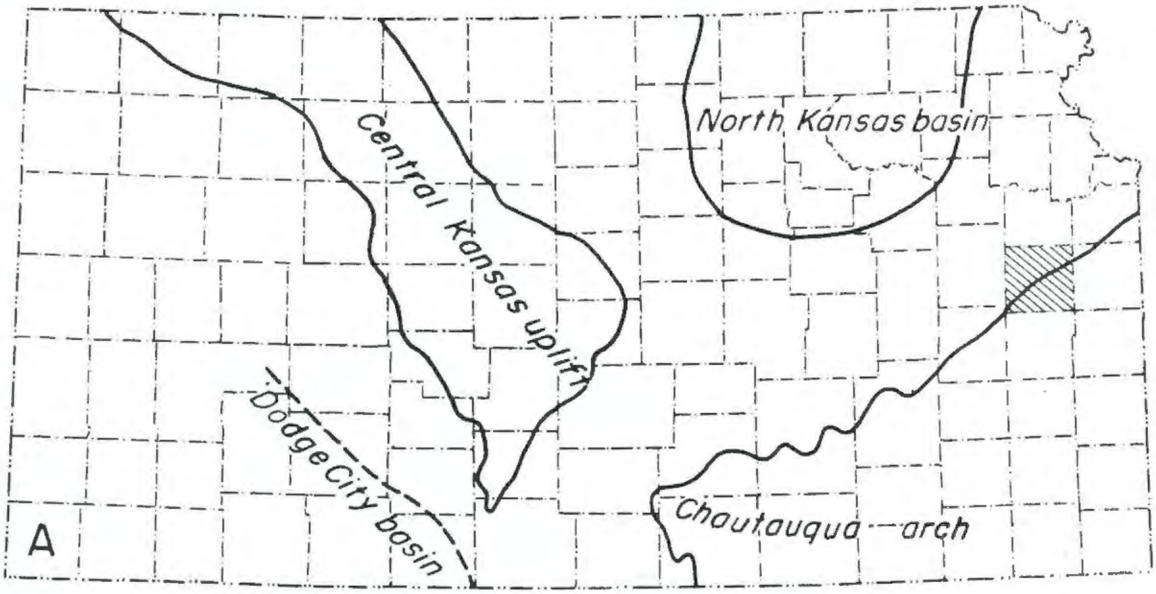
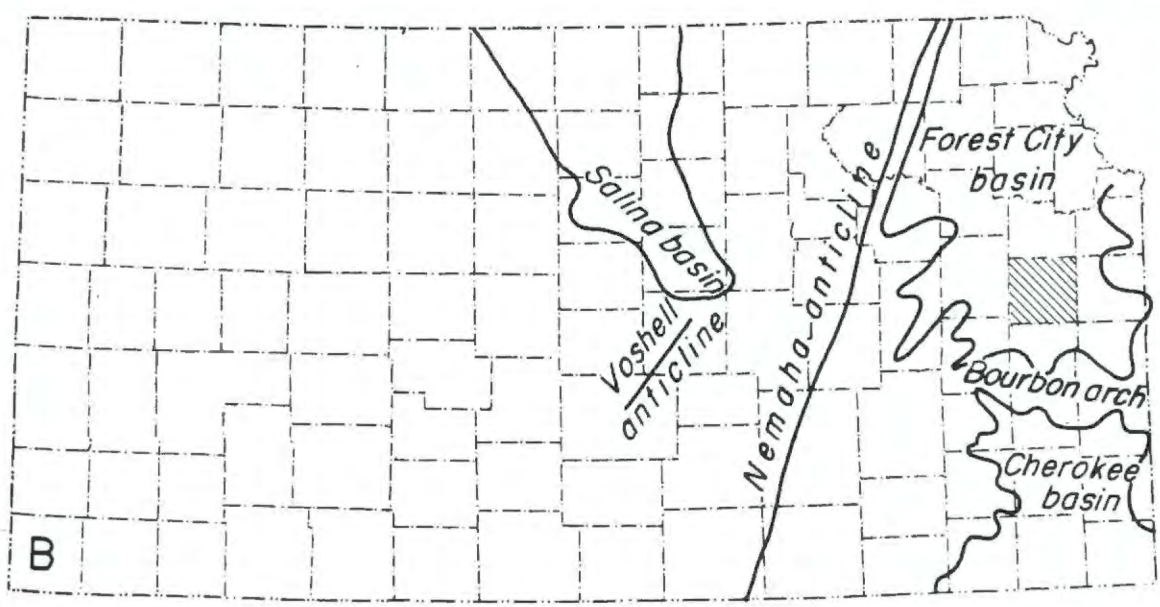


FIG. 16. Maps showing major structural features of eastern and central Kansas. Structures developed before Mississippian time are shown in map A and those developed in post-Mississippian time in map B. (After Moore, et al., 1951, p. 114)



Structural History

Lee (1943) recognized three periods of structural deformation in the Forest City basin. He states that during Late Cambrian and in pre-St. Peter Ordovician time, the Ozark area was sinking slowly and northeastern Kansas was slowly rising, causing several advances and retreats of the sea. After one of these emergent phases, which resulted in warping and later beveling of the older rocks, the area was again submerged and the St. Peter sandstone was deposited. By Late Ordovician time, Lee states, the Ozark area began to rise along with the Chautauqua arch. Also, the North Kansas basin began to form (Fig. 16A). This basin was the main structural feature in northeastern Kansas until the end of Chattanooga time, when movement commenced along the Nemaha anticline (Fig. 16B). This movement culminated at the end of Mississippian time eliminating the North Kansas basin, and forming the Salina basin to the west and an unnamed basin in extreme northeastern Kansas. The Forest City basin was not yet formed. After these folded rocks were peneplaned, Lee further states that renewed movement along the Nemaha anticline was accompanied by a downward movement of the erosion surface to the east, forming the Forest City basin (Fig. 16B). This basin was separated from the Cherokee basin of Oklahoma by a low divide (Bourbon arch) until middle Cherokee time when these two basins were joined by the filling of the Forest City basin and the flooding of the divide (Bourbon arch) joining the Forest City basin to the Cherokee basin. Lee concludes that these structural features were persistent at least until Early Permian time, if not later. The westward dip which is now present was developed prior to Cretaceous deposition.

ECONOMIC GEOLOGY

The mineral resources of economic importance are oil and gas, limestone, sand, gravel, coal, shale, and groundwater. For the most part, these resources do not support large industry, but are important to the local inhabitants for road construction, building material, fuel, and water.

Petroleum

Oil and gas has been produced in Franklin County for more than 60 years; all of the production is from sandstones in the Cherokee group of Pennsylvanian age. The average depth to production is 750 feet.

In the northwestern part of the county, gas has been found in commercial quantities in the Ottawa area and in the area northwest of Pomona. Some small wells have been produced locally by land owners for their private use.

Several wells have been drilled into older Paleozoic rocks, but to date, deeper production has not been discovered. As the price of oil and gas increases, more attempts will probably be made to find deeper oil and gas zones.

Coal

At the present time no active coal mines are located within the area. Since the turn of the century, several mines have been operated intermittently when economic conditions warranted.

Three separate coal seams have been mined. These deposits are thin and not profitably mined on a large scale. Bowsher and Jewetter (1943, p. 17) describe the types of mining methods used. The most common method was the open strip mine, but drift, slope, and shaft type operations have been used in some workings.

The Upper Williamsburg is the most important of the coal beds. This seam has been mined in three areas of northwestern Franklin County. In sec. 16, T. 16 S., R. 18 E., the coal attains a thickness of 25 inches. At this location remnants of at least ten mining operations are present. Bowsher and Jewett (1943, p. 58) state that this area has been thoroughly worked and only a small amount of coal remains. Southwest of Pomona in sec. 14 and 24, T. 17 S., R. 17 E., the Upper Williamsburg has been mined extensively. Here the coal averages 18 inches in thickness. Small amounts of the Upper Williamsburg have been mined west of Pomona in sec. 35, T. 16 S., R. 17 E., and in the northeastern part of the area in sec. 33, T. 15 S., R. 19 E. Bowsher and Jewett (1943, p. 72) estimate the reserves of this coal at 350,000 tons in sec. 14, T. 17 S., R. 17 E., and 200,000 tons in sec. 16, T. 16 S., R. 18 E.

The Lower Williamsburg coal is a soft, bituminous coal, generally of poor quality. Locally several attempts have been made to mine this seam profitably, but these ventures have failed. Bowsher and Jewett did not estimate the reserves of this bed.

The Ottawa coal, at the base of the Ireland sandstone in sec. 9, 10, 14, 15, and 16, T. 17 S., R. 19 E., may be an important reserve. It is a soft bituminous coal averaging 10 to 12 inches in thickness. Only one mine is located in this seam and it is now abandoned. This is in the NW 1/4 sec. 15, T. 17 S., R. 19 E. Bowsher and Jewett (1943, p. 72) estimate that reserves exceeding 1,000,000 tons are available in this area.

Limestone

Several of the exposed limestones have economic value. Crushed limestone is used extensively for concrete aggregate and road metal. Limestone is also quarried for agricultural lime, rip-rap material, and building stone.

The Plattsmouth limestone is quarried extensively for aggregate and road metal. Two abandoned quarries are located respectively in sec. 24, T. 15 S., R. 17 E., and the SEc sec. 20,

T. 15 S., R. 18 E. There is no active quarrying at this time. Locally, the Plattsmouth is used for rip-rap material, agricultural lime and building material.

A small quarry in the Toronto limestone is located in sec. 26, T. 16 S., R. 17 E. This limestone is used by the railroad for rip-rap material.

Every limestone has been utilized locally for road, bridge construction, and building material.

Gravel and Sand

Terrace gravel deposits are found north of the Marais des Cygnes River in sec. 25, 26, 27, 28, and 34, T. 16 S., R. 18 E. and in sec. 21, T. 16 S., R. 19 E. (Pl. 1). These chert gravels with a reddish clay matrix are used in an unwashed condition for surfacing of secondary roads.

The Ireland sandstone is quarried in sec. 14, T. 16 S., R. 19 E. This sand is used for subgrade material for paving projects in the town of Ottawa.

Shale

In sec. 23, T. 17 S., R. 19 E., the Weston shale is quarried by the Buildex Corporation for the manufacture of light weight aggregate.

Groundwater

Aside from the alluvial deposits in the valleys, the most important aquifers are the sandstones of the Douglas group. Many of the farm wells in the upland region are producing from these strata.

SUMMARY

The geology of northwestern Franklin County, Kansas, is mapped and described. Surface rocks in the area are all of Pennsylvanian age, except for some stream valley and high terrace deposits of Tertiary and Quaternary age.

The exposed Pennsylvanian rocks consist of 450 feet of limestones, sandstones, and shales of late Missourian and early Virgilian age.

Missourian strata are divided into two groups (Lansing and Pedee) which are further subdivided into formations and members. The South Bend limestone, upper member of the Stanton limestone, is the oldest stratum exposed in the area. Pedee rocks are represented by the Weston shale.

Rocks of Virgilian age in the area are the Douglas and Shawnee groups. The Douglas group is divided into two formations: Stranger and Lawrence. Strata of the Stranger formation are

divided into the Vinland shale member, Haskell limestone member, and Robbins shale member, all of marine origin. Two members which occur in other localities are not recognized in the area. These beds are the Tonganoxie sandstone and Westphalia limestone.

The Lawrence formation is composed chiefly of sandstone and shale with subordinate amounts of coal and conglomerates. Two members have been defined in the Lawrence: the Ireland sandstone and Amazonia limestone. The Ireland is a massive to cross-bedded sandstone. Pre-Ireland erosion has removed the beds of Stranger age in some parts of the area. In these localities, the Ireland sandstone directly overlies Weston shale. In other exposures, where erosion was less, Ireland overlies various members of the Stranger formation. The Amazonia limestone is a mottled gray unfossiliferous limestone about 1 foot in thickness. Three persistent coal beds are also present in the Lawrence. These are the Ottawa, Lower Williamsburg, and Upper Williamsburg.

Three lower formations of the Shawnee group are present in the area. These formations are the Oread limestone, Kanwaka shale, and Lecompton limestone. In the western part of the area the alternating limestones and shales of this group form eastward facing escarpments separated by low, flat valleys. The Oread limestone is divided into four limestone and three shale members. Because of structural movements, the lower member (Toronto limeston) is absent in some localities. Where this member is missing, an abnormal thickness of the Heebner shale occurs. The overlying Kanwaka shale contains two shale members and one limestone member. The Lecompton limestone is composed of four limestone and three shale members. Only the lower two members occur in the map area. Terrace deposits which occur north of the Marais des Cygnes River are probably of late Tertiary or early Quaternary age.

The strata in the area dip to the northwest at a rate of 15 to 20 feet per mile. Some local anomalies are superimposed on these gently dipping beds. Three faults were also mapped in the area. These movements have been small with the largest having a displacement of 30 to 40 feet.

The subsurface rocks of the area are all of sedimentary origin with the exception of the Precambrian basement complex. The Cambrian, Ordovician, Devonian, Mississippian, and Pennsylvanian Systems are represented by these strata. Silurian strata have not been recognized.

Mineral resources of importance in the area are oil and gas, limestone, sand, gravel, coal, shale, and groundwater. Shallow oil and gas production from Pennsylvanian rock has been continuous for more than 60 years. To date, production from older rocks has not been discovered. Limestone is quarried for aggregate, road metal, agricultural lime, and building materials. Coal mining, although not active at the present time, has been important in the past. Terrace gravel deposits are utilized for surfacing of secondary roads. The Ireland sandstone is quarried at one location for use as subgrade material on paving projects. Weston shale is quarried for the manufacture of light weight aggregate. The Ireland sandstone is also an important aquifer in the upland regions.

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APPENDIX

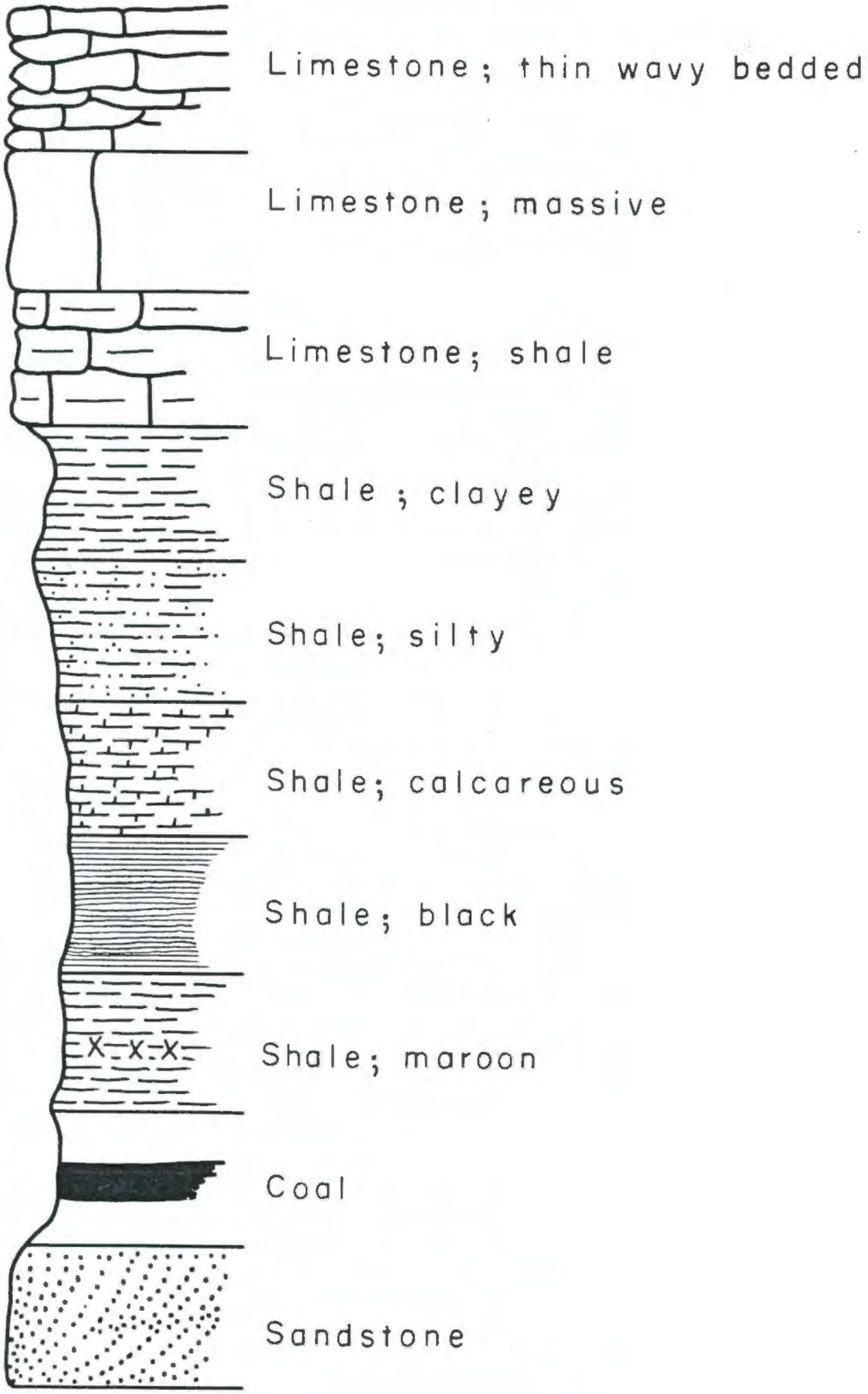
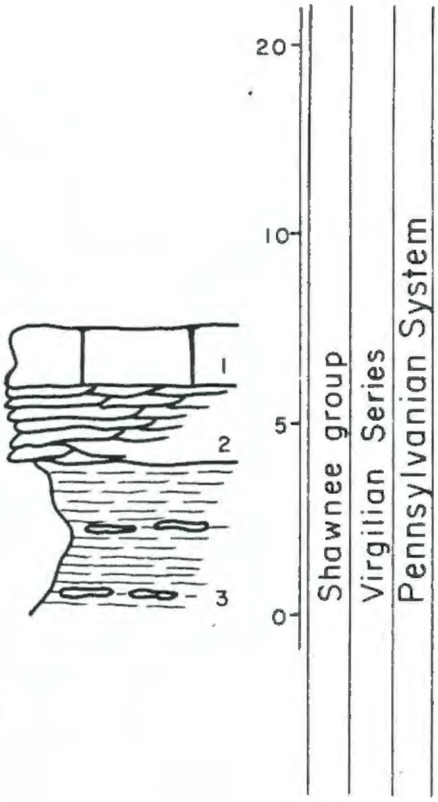


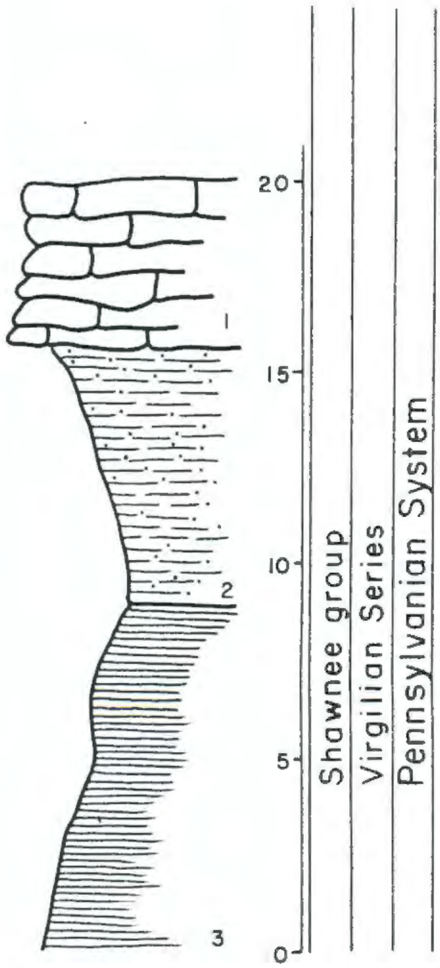
FIG. 17. **Explanation of lithology.**



SEc SW 1/4 sec. 21, T. 15 S., R. 18 E. along east-west county road.

LECOMPTON LIMESTONE
Spring Branch limestone member
1. Limestone; gray, weathers tan-brown, abundant fusulinids, brachiopods, crinoids, algae (Ottonosia)....................1.5
2. Limestone; shaley, tan-brown, fossiliferous..................2.0

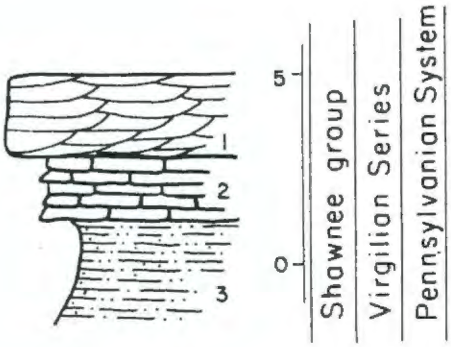
KANWAKA SHALE
Stull shale member
3. Shale; gray, clayey, contains zones of iron stone concretions. 4.0+



Center of North line sec. 24, T. 15 S., R. 18 E., along east-west county road.

OREAD LIMESTONE
Plattsmouth limestone member
1. Limestone; tan to gray, weathers tan, wavy-bedded, abundantly fossiliferous..................7.0+

Heebner shale member
2. Shale; tan-blue gray, clayey to silty, fossiliferous............ 4.5
3. Shale; grayish black, thin platy to near fissile................11.2+



NE 1/4 sec. 14, T. 16 S., R. 17 E., in stream bank east of north-south county road.

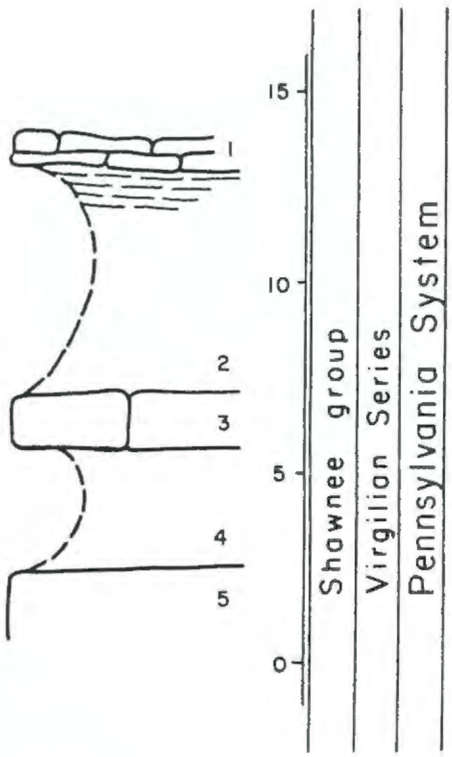
KANWAKA SHALE FORMATION
Clay Creek limestone member

1. Limestone; gray to blue-gray, weathers tan, platy, abundant fusulinids, some brachiopods and crinoid remains........... 2.2

2. Limestone; shaly, light tan to gray, fossiliferous............ 1.5

Stull shale member

3. Shale; light gray, silty to clayey...................... 4.0+



East edge sec. 30, T. 15 S., R. 18 E., along north-south county road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; tan to gray, platy, wavy-bedded, abundant brachiopods, crinoid remains............... 2.0+

Heebner shale member

2. Shale; tan, silty in upper part, remainder covered interval.....6.0

Leavenworth limestone member

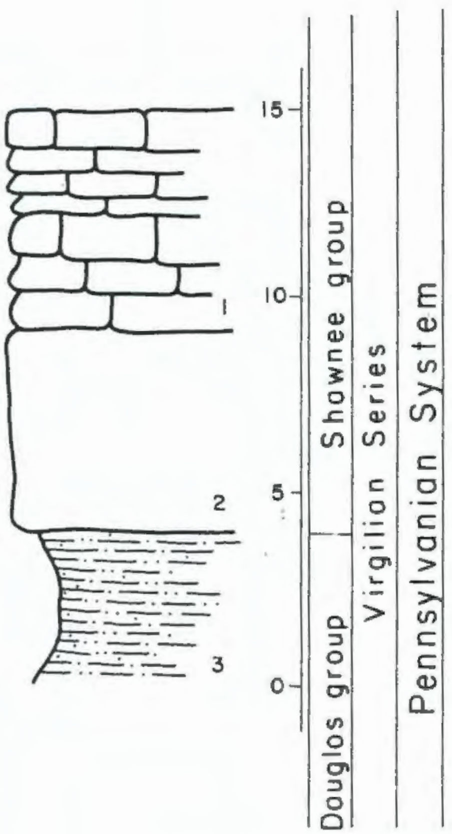
3. Limestone; blue-gray, hard, dense, jointed..................1.5

Snyderville shale member

4. Covered interval.............. 3.0

Toronto limestone member

5. Limestone; tan-brown, weathers dark brown, brachiopods, crinoid remains, bryozoans, fusulinids. 1.0+



Center SW 1/4, sec. 11, T. 17 S., R. 17 E., along county road.

OREAD LIMESTONE

Toronto limestone member

1. Limestone; brown, medium-bedded to massive, brachiopods, crinoid remains, algae?....... 5.8

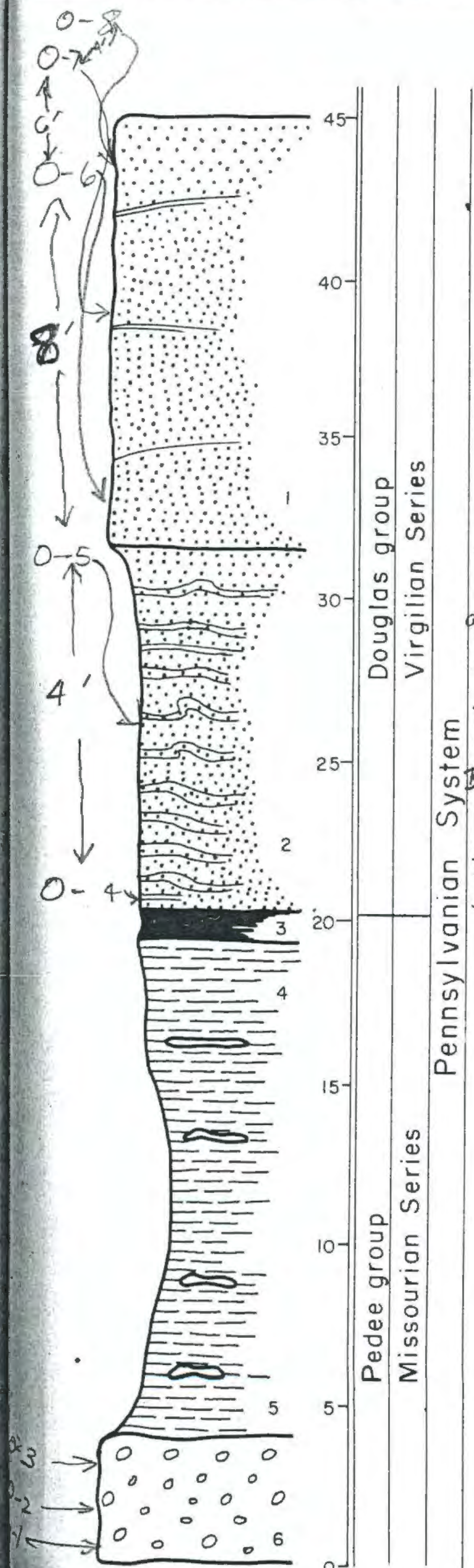
2. Limestone; tan-brown, weathers brown-gray, massive, granular, brachiopods and crinoid remains.................... 5.0

LAWRENCE FORMATION

3. Shale, light gray, clayey to silty, laminated, unfossiliferous................ 4.0+

Cen. W line SW 1/4

SW 1/4 sec. 14, T. 17 S., R. 19 E., Highway cut southwest of Ottawa on U. S. 50 South.



LAWRENCE FORMATION

Ireland sandstone member

1. Sandstone; tan, massive, weathers tan-brown, micaceous, abundant plant fossils......... 20.0+

beds 1-5" thick & cross-laminated within above micro cross-strat.

beds 1"-2.5" thick cross-laminated within

2. Sandstone; alternating light tan bands (1" to 2") separated by 1/2" dark brown bands, fine-grained, micaceous, contains abundant plant fossils......... 11.6

lower 1' - beds 1" or less thick & cross-laminated

3. "Ottawa" coal bed............. 1.0

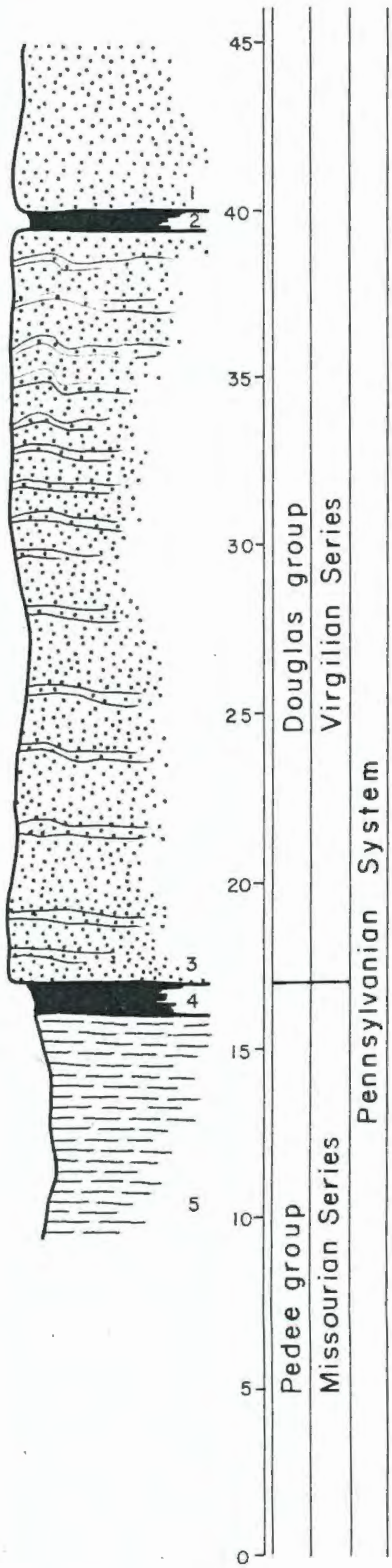
WESTON SHALE

4. Shale, gray, clayey........... 2.0

5. Shale; light gray to tan, silty to clayey, contains numerous limonite concretions.......... 15.4

6. Conglomerate, pebble size, subangular to angular, fragments of limestone, chert, and marine fossils............... 4.0

Distributed throughout a 10' zone ranges from 0 - 1.5'; nowhere 10' - 10' zone ... to about 15' below base of Ottawa

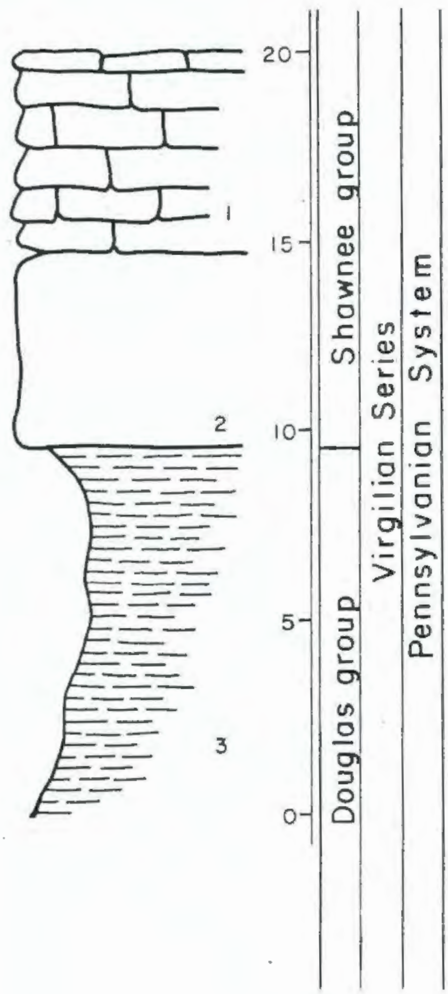


NE 1/4 NW 1/4 sec. 16, T. 17 S., R. 19 E., road cut on east-west county road.

LAWRENCE FORMATION

Ireland sandstone member

1. Sandstone; tan-brown, massive, fine to medium-grained........ 5.0+
2. Coal........................ 0.3
3. Sandstone, light tan, medium to fine-grained, dark brown bands alternating with lighter zones, abundant plant fossils. . 22.3
4. "Ottawa" coal................0.9
5. Shale; blue-gray, clayey to silty, contains limonite concretions..................6.5+



North edge sec. 30, T. 15 S., R. 18 E., along county road.

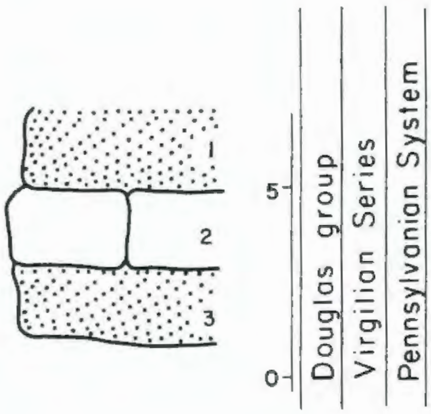
OREAD LIMESTONE
Toronto limestone

1. Limestone; tan, weathers brown, medium-bedded, large fusulinids, scattered brachiopods and crinoid remains...............5.3

2. Limestone; gray-tan, weathers tan-brown, massive, scattered fusulinids, brachiopods and crinoid remains...............5.0

LAWRENCE SHALE

3. Shale; light gray, silty to sandy, fine laminated.........10.0+



Center, sec. 23, T. 16 S., R. 18 E., outcrop in creek in pasture.

LAWRENCE FORMATION
Ireland sandstone

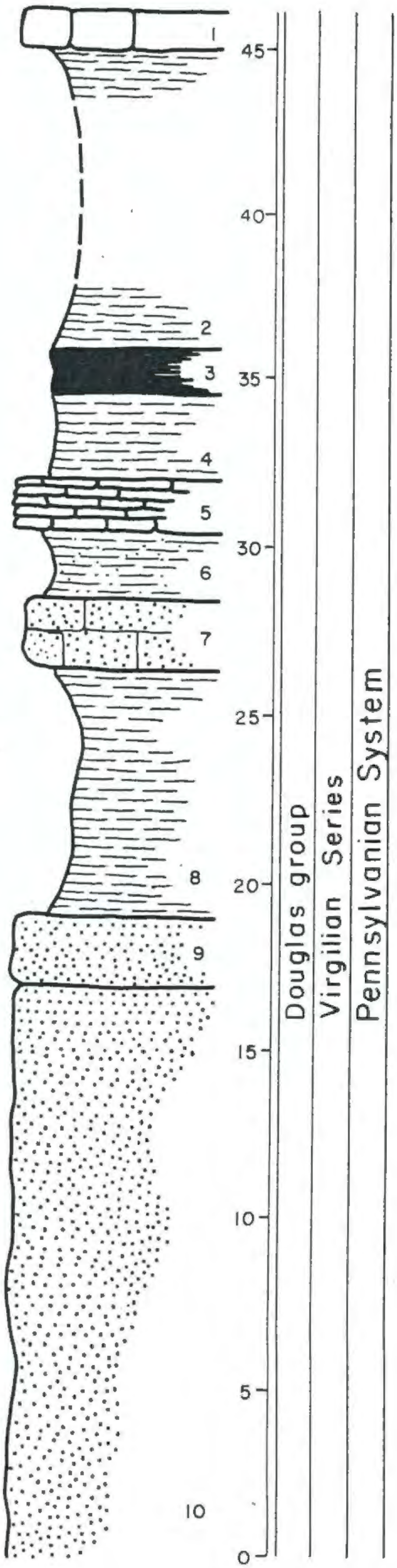
1. Sandstone; brown, fine-grained, micaceous, massive............3.0+

STRANGER FORMATION
Haskell limestone member

2. Limestone; tan-gray, thin brown layer on top, abundant fusulinids, Myalinid clams, algae (Ottonosia), brachiopods........1.5

Vinland shale member

3. Sandstone, fine-grained, tan to brown, micaceous.............2.0+



Center of south line sec. 13, T. 17 S., R. 17 E. along county road.

OREAD LIMESTONE

Toronto limestone member

1. Limestone; tan-brown, platy, badly weathered. . . . . 1.0+

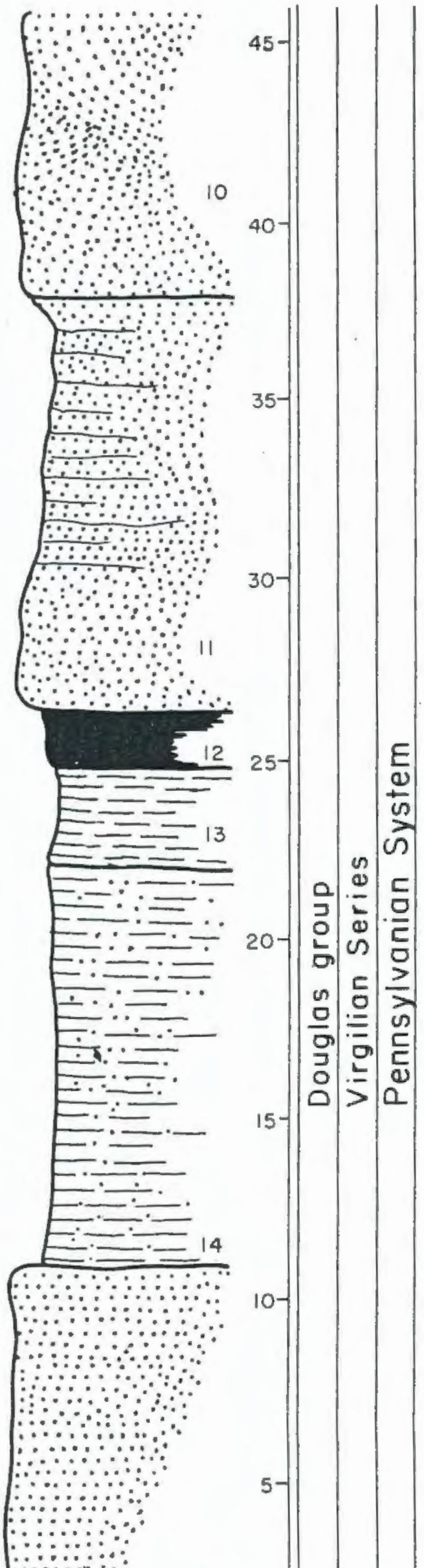
LAWRENCE FORMATION

2. Shale; tan-gray, clayey to silty. 9.2
3. Coal; upper Williamsburg. 1.3
4. Shale; light gray, silty to clayey. 2.7

Amazonia limestone member(?)

5. Limestone; light gray, sandy, unfossiliferous, thin bedded. . . . 1.5
6. Shale; sandy, calcareous. 2.0
7. Sandstone, hard, mottled gray, calcareous. 2.0
8. Shale; light gray, silty to sandy, finely laminated. 7.2
9. Sandstone, brown, fine-grained, massive, micaceous. 2.0
10. Sandstone, light gray to white, fine to medium-grained, massive. 25.2

(continued next page)



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11. Sandstone and sandy shale; fine-grained, micaceous.......11.6

12. Coal; Lower Williamsburg......1.5

13. Shale; light gray, clayey, thin, laminated................2.9

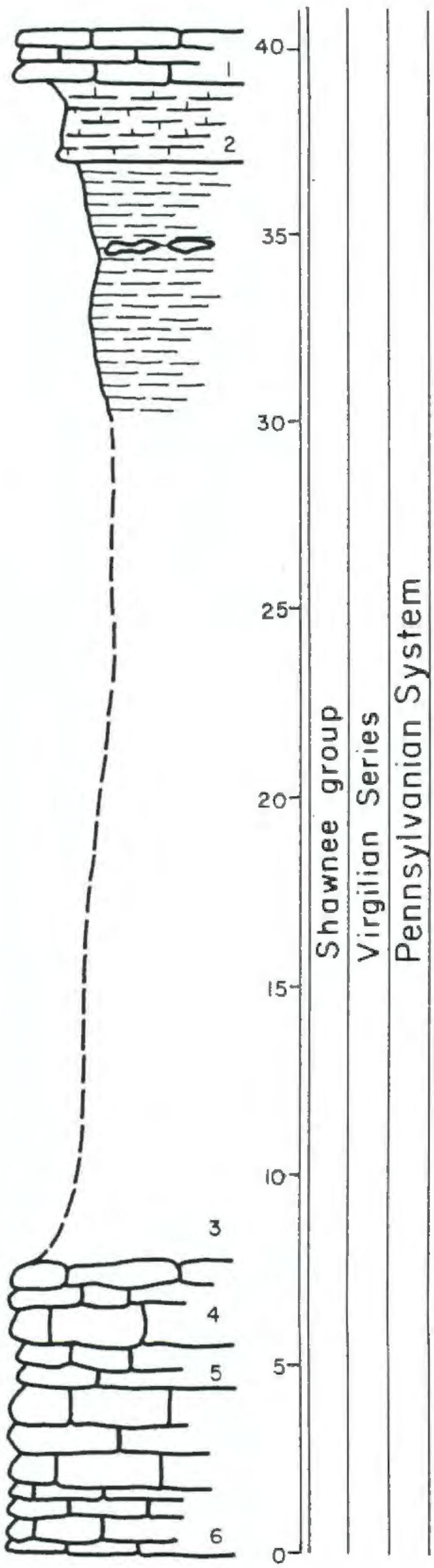
14. Shale; tan, sandy to silty, limonitic concretions......... 11.1

15. Sandstone, light tan, fine to medium-grained, micaceous, massive.......................8.0+

NEc sec. 7, T. 16 S., R. 18 E., along north-south county road and around corner to west.

OREAD LIMESTONE

Kereford limestone member



1. Limestone; tan to gray, mottled, platy, weathering, abundant fusulinids, brachiopods Dielasma, Composita, crinoid remains, bryozoans.................... 3.0+

Heumader shale member

2. Shale; calcareous, tan, fossiliferous, brachiopods, crinoid remains, bryozoans........... 3.0

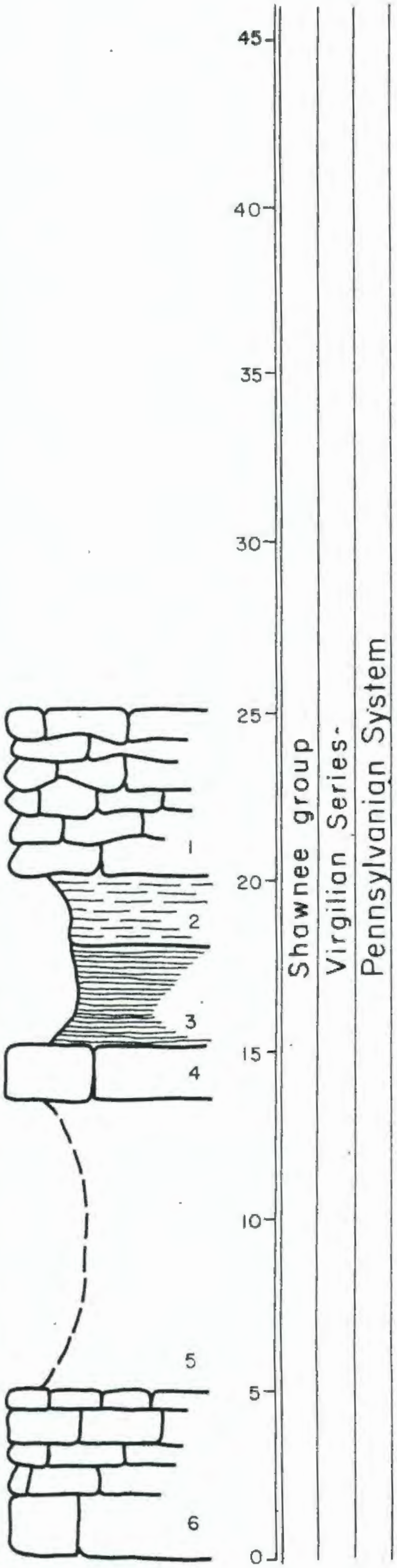
3. Shale; light gray, silty-clayey, limonite concretions. Lower portion covered............. 26.0

Plattsmouth limestone member

4. Limestone; light gray, thin platy, unfossiliferous.......... 2.0

5. Limestone; tan-gray, abundant brachiopods Composita, crinoids, and bryozoans.................3.5

6. Limestone; gray, wavy-bedded, abundant fusulinids, some brachiopods and crinoid remains .... 1.8+



NWc NE 1/4 sec. 30, T. 15 S., R. 18 E., along county road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; tan-gray, wavy-bedded, fossiliferous.......... 5.0+

Heebner shale member

2. Shale, tan, clayey to silty, laminated..................... 2.0
3. Shale; black, fine platy to near fissile.................. 3.1

Leavenworth limestone member

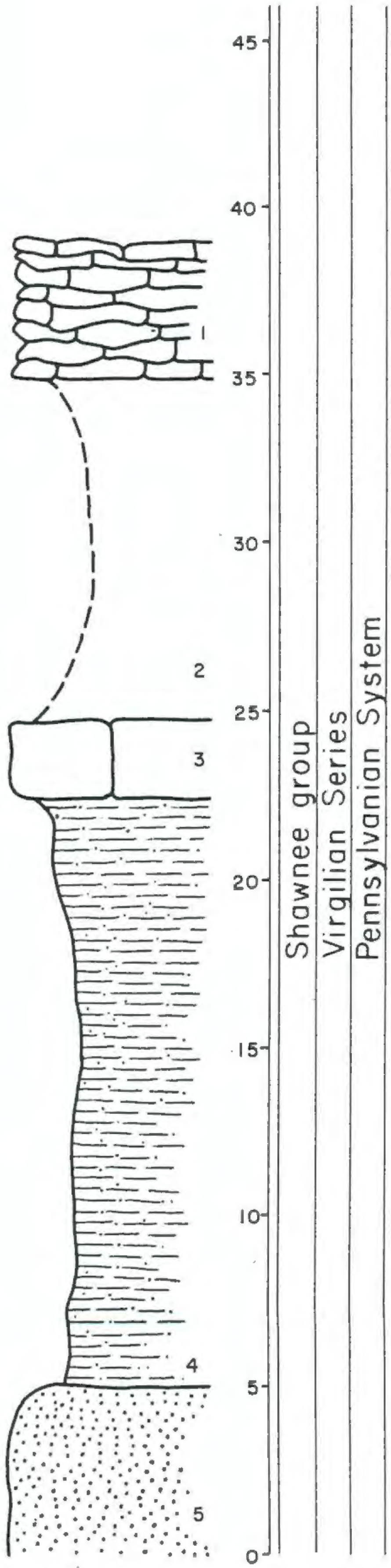
4. Limestone; blue-gray, hard, dense, fossiliferous........... 1.5

Snyderville shale member

5. Covered interval.............. 8.6

Toronto limestone member

6. Limestone; tan to brown, medium-bedded, fossiliferous...5.0+



North side, NW 1/4 sec. 19, T. 15 S., R. 19 E., along east-west county road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; tan-gray, wavy-bedded, medium-grained, fossiliferous.................4.0+

Heebner shale member

2. Covered interval............. 10.1

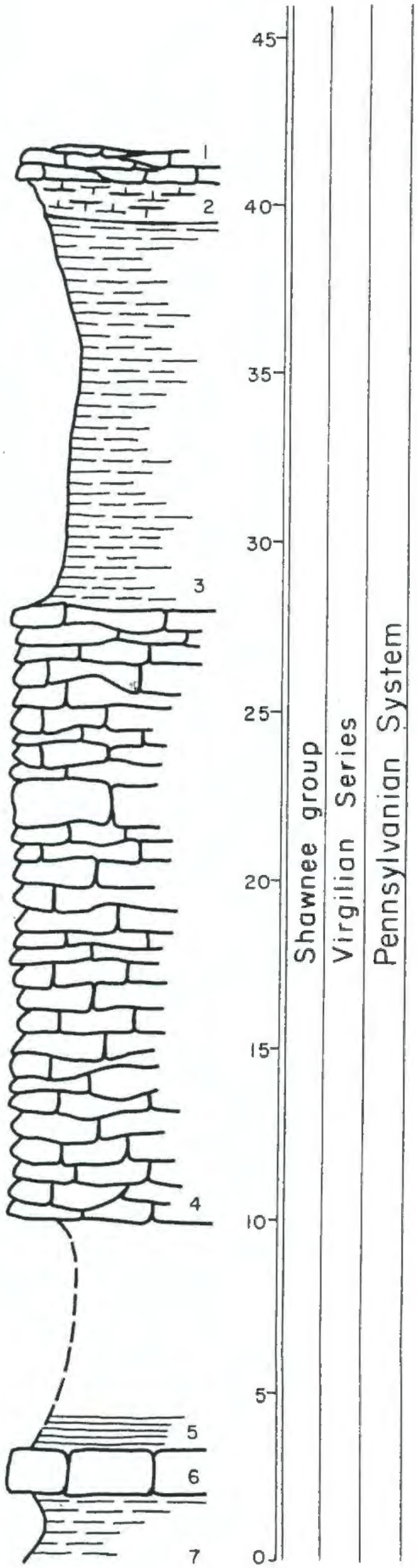
Leavenworth limestone member

3. Limestone; blue-gray, hard, dense, fossiliferous...........2.1

Snyderville shale member

4. Shale; light gray to tan, clayey to silty, fine laminated........17.4

5. Sandstone; tan-brown, medium to fine-grained, micaceous..... 5.0+



Center of NE 1/4 sec. 24, T. 15 S., R. 17 E., in quarry.

OREAD LIMESTONE

Kereford limestone member

1. Limestone; tan, badly weathered, brachiopods, <u>Dielasma</u>, <u>Composita</u>, <u>Neospirifer</u>....................1.0+

Heumader shale member

2. Shale; tan, calcareous, contains fragments of brachiopods and crinoids......................1.0

3. Shale; blue-gray, clayey, blocky......................11.6

Plattsmouth limestone member

4. Limestone; light gray, thin wavy-bedded, fossiliferous....18.0

Heebner shale member

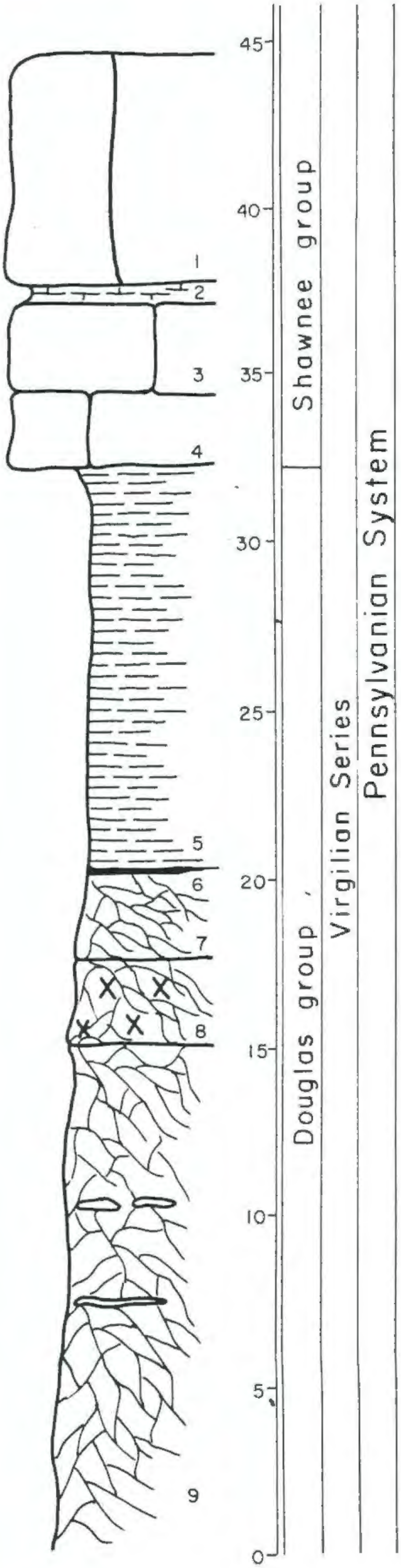
5. Covered interval.............. 7.0±

Leavenworth limestone member

6. Limestone; blue-gray, hard, dense, fossiliferous........... 1.2

Snyderville shale member

7. Shale; gray, clayey to silty.....1.0+



SW 1/4 sec. 5, T. 16 S., R. 18 E., road cut along north-south county road.

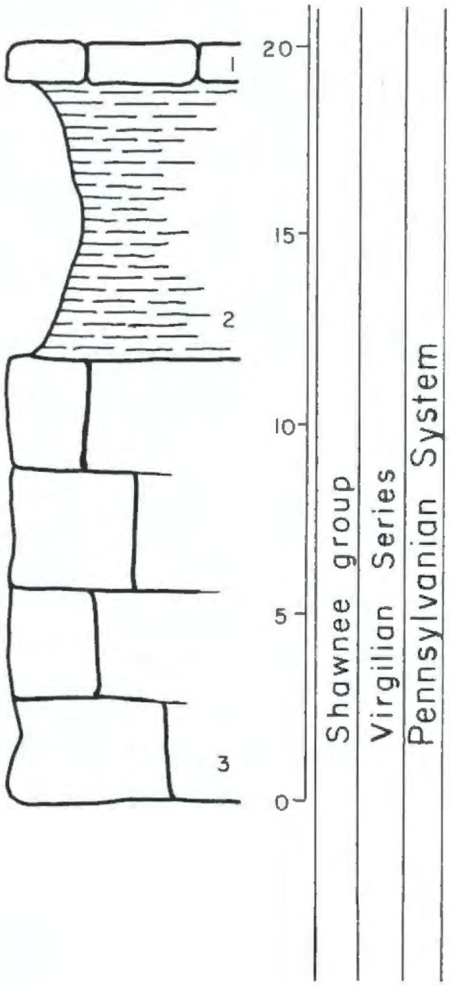
OREAD LIMESTONE

Toronto limestone member

1. Limestone; brown, weathers brown, massive, abundant fusulinids, brachiopods, crinoid remains, and corals........... 6.8
2. Shale; gray-green, calcareous, fossiliferous.................. 0.7
3. Limestone; light gray, fossiliferous, brachiopods, bryozoans, crinoid remains............... 2.8
4. Limestone; light gray, hard, dense, fossiliferous, brown limonite stains on fresh surface. 2.0

LAWRENCE FORMATION

5. Shale, gray, fine platy, clayey to silty...................... 12.2
6. Coal......................... 0.1
7. Shale; gray-green, blocky, clayey to silty................ 2.6
8. Shale; maroon, blocky, clayey to silty.................2.5
9. Shale; gray-green, blocky, thin nodular limonite stringers...................15.0+



SW 1/4 sec. 35, T. 16 S., R. 17 E.,
cut along highway K68, west of Pomona.
OREAD LIMESTONE
Leavenworth limestone member

1. Limestone; blue-gray, hard, dense........................ 1.0

Snyderville shale member

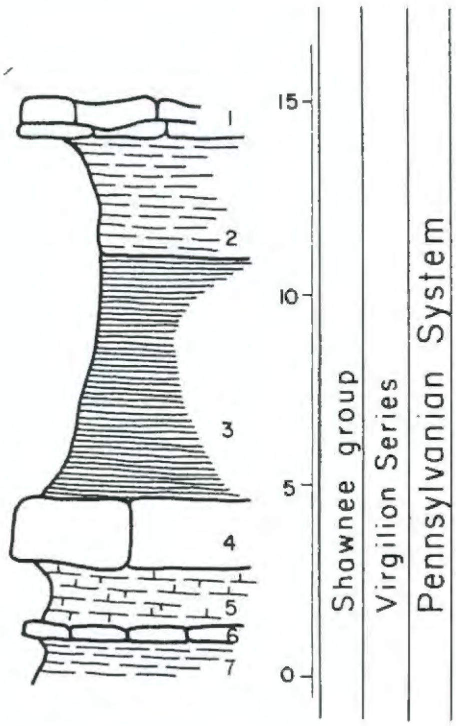
2. Shale; gray-green, clayey to silty, laminated............... 7.2

Toronto limestone member

3. Limestone; brown, weathers brown, massive, fine-grained, scattered fossils............. 11.6

NE 1/4 sec. 7, T. 16 S., R. 18 E., along county road cut.

OREAD LIMESTONE
Plattsmouth limestone member



1. Limestone; light gray, fine-grained, wavy-bedded, brachiopods, crinoids and bryozoans abundant............1.0+

Heebner shale member

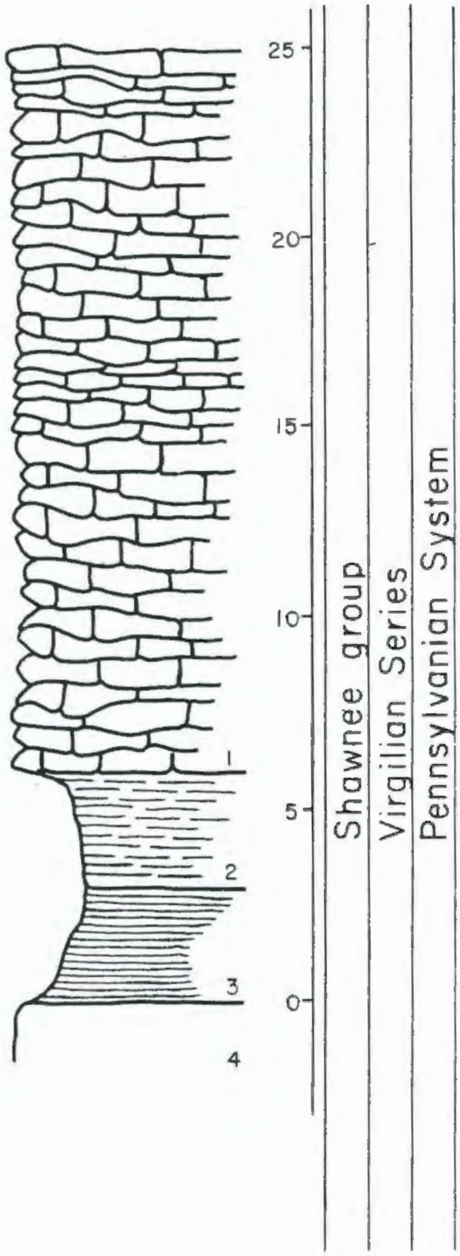
2. Shale; tan-gray, laminated, silty to clayey.................2.9
3. Shale; gray-black, fine platy to near fissile................6.0

Leavenworth limestone member

4. Limestone; blue-gray, hard, dense.......................1.5

Snyderville shale member

5. Shale; light gray, silty to calcareous.................. 1.3
6. Limestone; lensing, light gray, hard, dense.................. 0.4
7. Shale; light gray, silty.........3.0+



SEc sec. 20, T. 15 S., R. 18 E.,
cut on east-west county road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; tan to gray, wavy-bedded, fine crystalline, brachiopods Hustedia, Composita, Neospirifer, horn corals, crinoid remains.......17.4

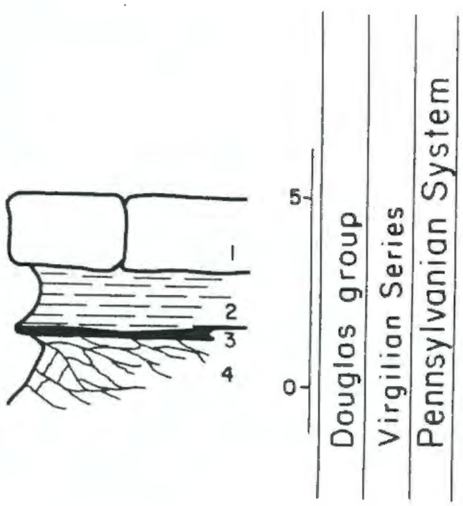
Heebner shale member

2. Shale; tan-gray, platy to blocky, fossiliferous...........3.0

3. Shale; black, thin platy to near fissile...................2.8

Leavenworth limestone member

4. Limestone; blue-gray, hard, dense, fossiliferous........... 1.5



NE 1/4 SW 1/4 sec. 26, T. 15 S., R. 19 E., west of U. S. Highway 50 & 59 bridge in creek.

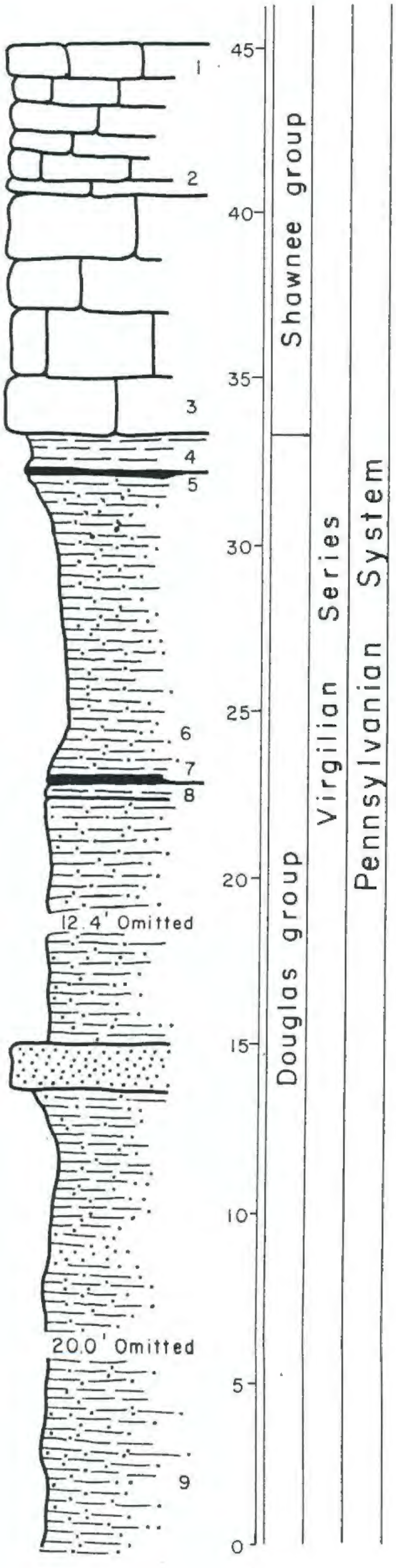
STRANGER FORMATION

Haskell limestone member

1. Limestone; tan-gray, weathers brown, coarse-crystalline, fossiliferous, brachiopods, Neospirifer, Dictyoclostus, algae Ottonosia, Myalina clams........................1.9

Vinland shale member

2. Shale; blue-green, platy, silty to clayey, abundance of Myalina clams........................1.5
3. Coal; thin, soft...............0.1
4. Shale; gray-green, clayey, blocky.......................1.0+



East edge sec. 18, T. 17 S., R. 18 E., along county road 2 1/2 miles south of Pomona.

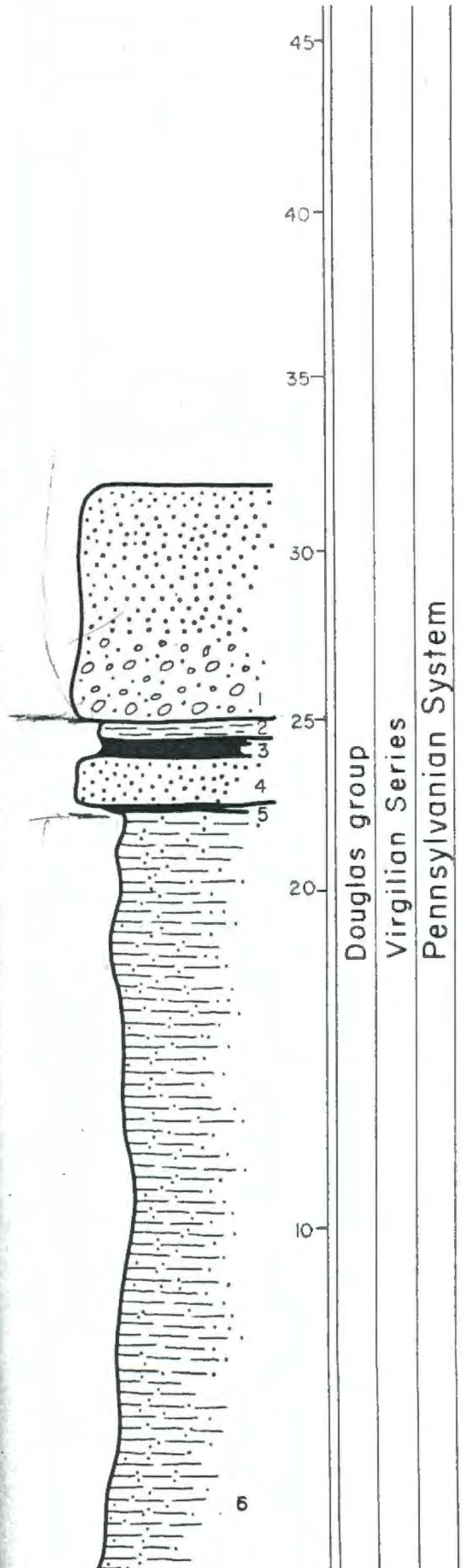
OREAD LIMESTONE

Toronto limestone member

1. Limestone; light gray, weathers tan, granular, fossils scarce...1.0
2. Limestone; tan-brown, medium-bedded, fossils scarce.........3.5
3. Limestone; tan-gray, weathers brown, medium-bedded, fossil brachiopods <u>Dictyoclostus</u> and crinoid remains..............7.2

LAWRENCE FORMATION

4. Shale; gray-green, clayey, laminated.................... 1.0
5. Coal; poorly developed.........0.1
6. Shale; tan-gray, silty to sandy, scattered sandstone stringers...9.2
7. Coal........................0.3
8. Underclay...................0.4
9. Shale; sandy interbedded with sandstone................19.4



Center of south side of sec. 8, T. 17 S., R. 19 E., along east-west county road.

LAWRENCE FORMATION

Ireland sandstone

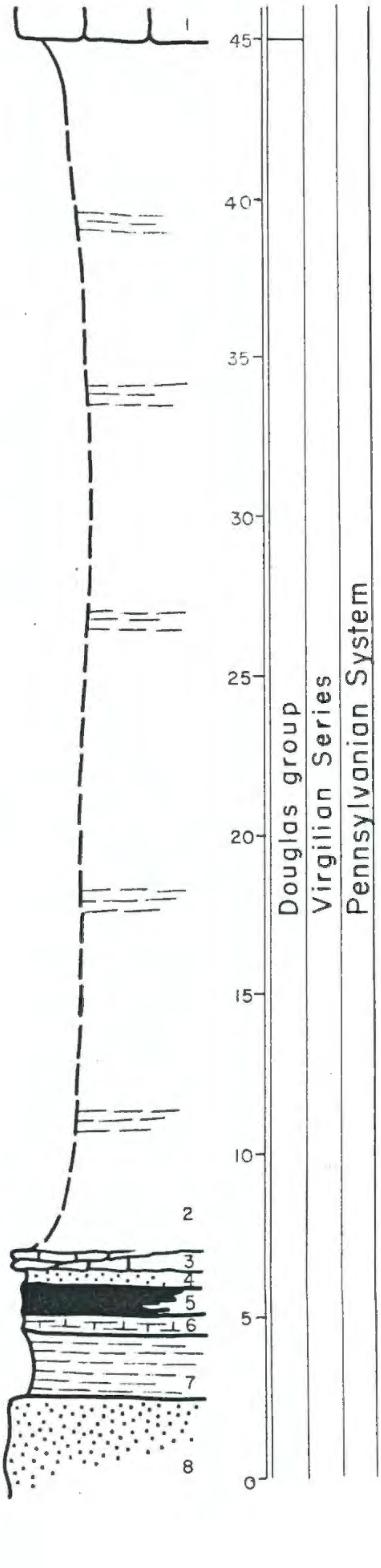
1. Sandstone; medium- to fine-grained, grades downward into a pebble conglomerate, abundant plant remains................ 7.0+
2. Clay; light gray, abundant well preserved plant fossils........ 0.5
3. Coal; Ottawa coal bed(?)....... 0.4
4. Sandstone; light gray, weathers reddish-brown, hard, micaceous....................1.5
5. Carbonaceous zone........... 0.1

STRANGER FORMATION

~~Vinland~~ shale member

6. Shale; blue-gray, weathers tan, fossiliferous, brachiopods <u>Neospirifer</u>, <u>Chonetes</u>, <u>Dictyoclostus</u>, bryozoans, gastropods..................22.5

Check location



Sec. 32, T. 15 S., R. 18 E., along county road starting east of bridge.

OREAD LIMESTONE

Toronto limestone member

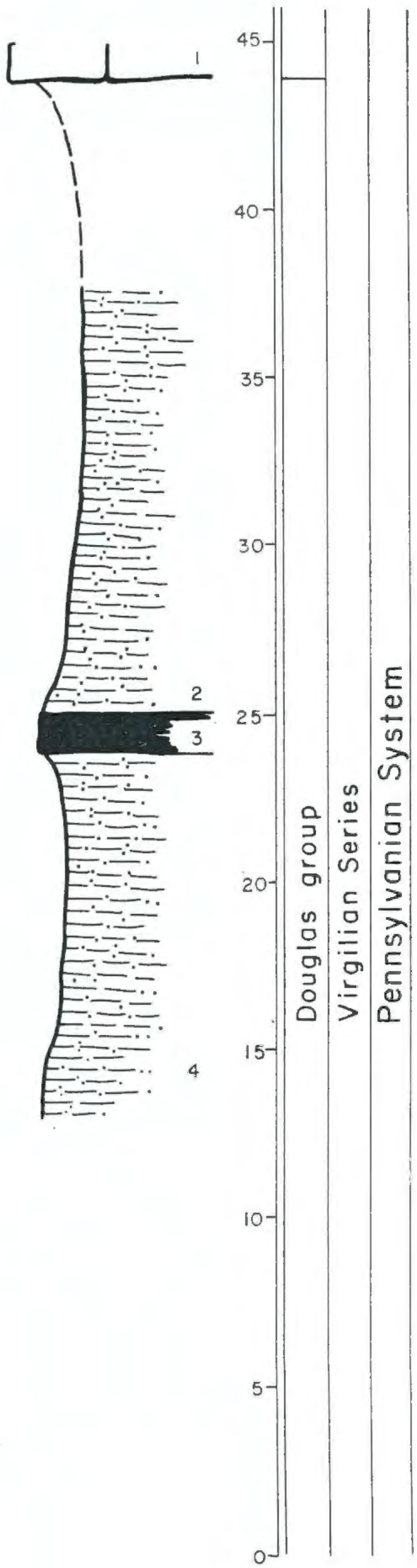
1. Limestone; tan to brown, massive.......................1.0+

LAWRENCE FORMATION

2. Shale; tan to gray, clayey to silty with some sandy zones....38.6

Amazonia limestone member(?)

3. Limestone; blue-gray, fine-grained, sandy.................0.6
4. Sandstone; fine-grained, massive.......................0.5
5. Coal; Upper Williamsburg.......0.8
6. Clay; tan-gray...............0.4
7. Shale; tan to gray, clayey to silty.......................2.0
8. Sandstone; tan, fine-grained, massive.......................5.0+



SE 1/4 sec. 28, T. 17 S., R. 18 E., along east-west county road.

OREAD LIMESTONE

Toronto limestone member

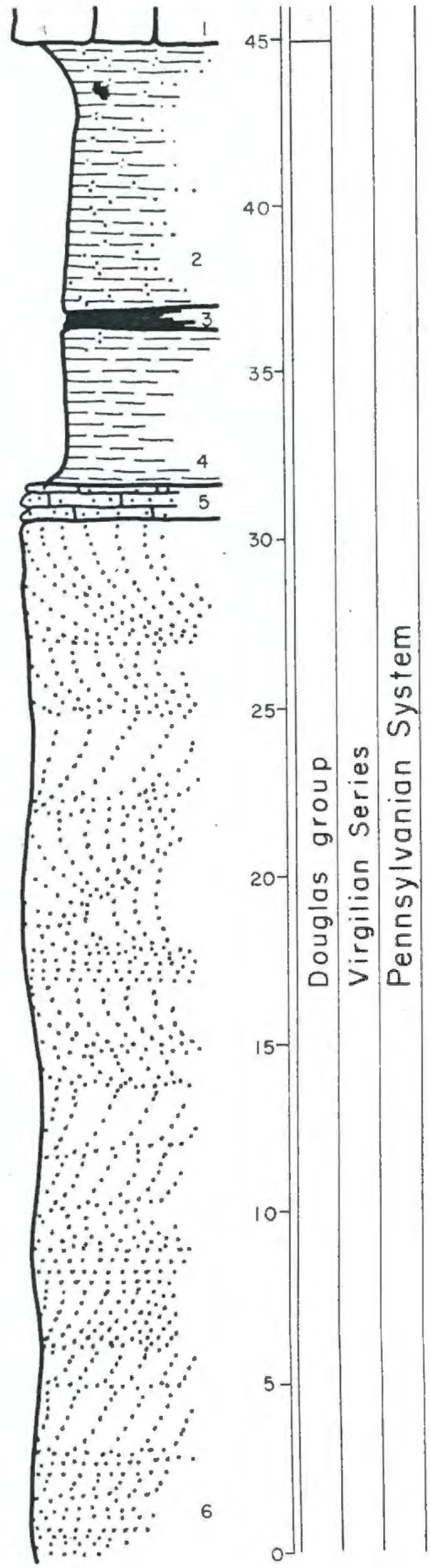
1. Limestone; tan-brown, fine crystalline, massive.......... 1.0+

LAWRENCE FORMATION

2. Shale; blue-gray, sandy to silty, micaceous............ 19.4

3. Coal; Upper Williamsburg......0.9

4. Shale; gray, silty to sandy, micaceous, contains sandstone stringers..................40.0+



South side of sec. 15, T. 17 S., R. 18 E., along east-west county road.

OREAD LIMESTONE

Toronto ~~limestone member~~ ← check description

1. Limestone; tan-brown, badly weathered, platy. . . . . 1.0+

LAWRENCE FORMATION

2. Shale; sandy to silty, laminated, contains plant fossils. 8.2

3. Coal; Upper Williamsburg. 0.5

4. Shale; tan-gray, blocky, clayey, to silty. 4.8

Amazonia limestone member(?)

5. Limestone; gray, sandy, platy. . 1.0

6. Sandstone; light gray to tan, fine- to medium-grained, massive, cross-bedded. 31.2

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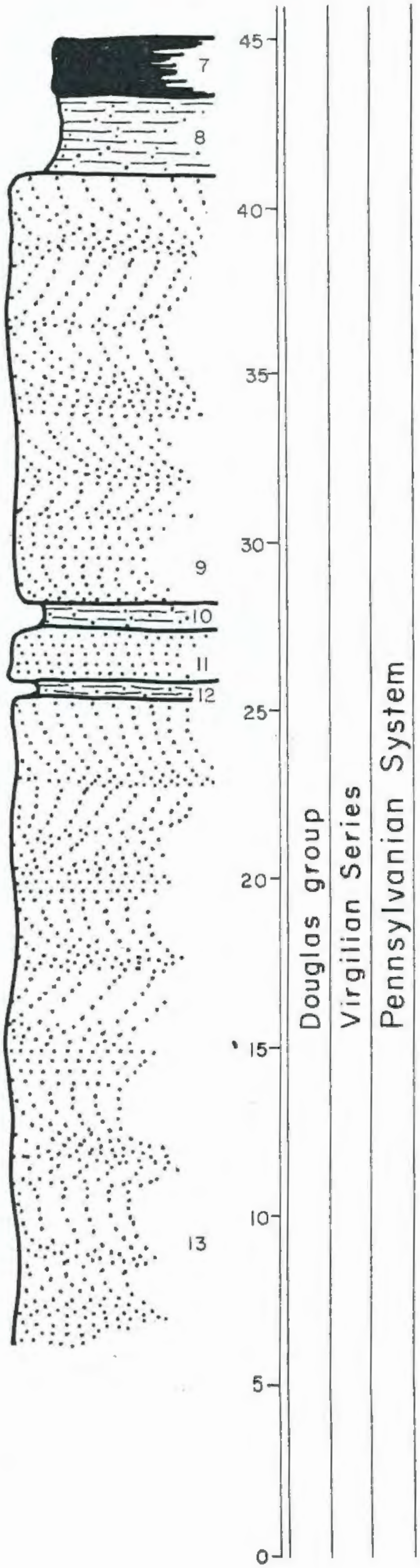


LAWRENCE FORMATION (continued)

7. Coal; Lower Williamsburg......1.6

8. Shale; gray, clayey to silty.....2.5

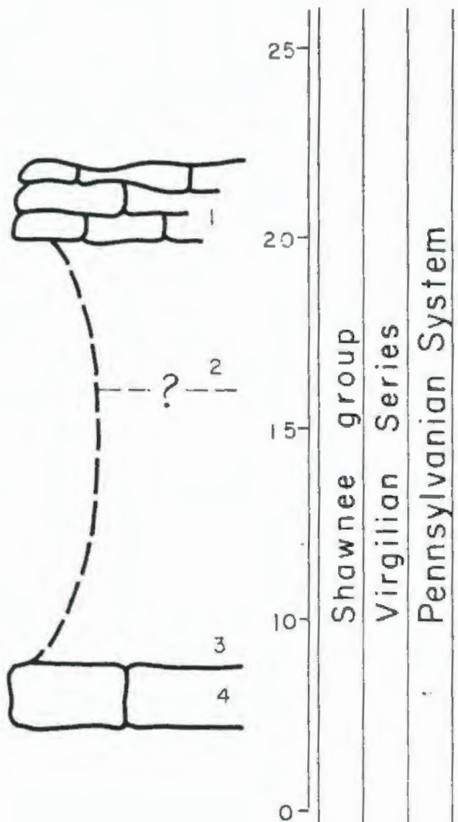
9. Sandstone; light gray to white, fine-grained, cross-bedded....12.9

10. Shale; gray, silty to sandy......1.0

11. Sandstone; gray-tan, massive...1.7

12. Shale; gray, silty to sandy......0.4

13. Sandstone; tan-gray, medium to fine-grained, cross-bedded..17.4+



Center of north side of NE 1/4 sec. 2, T. 16 S., R. 18 E., along county road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; tan-gray, wavy-bedded, fossiliferous.......... 3.0+

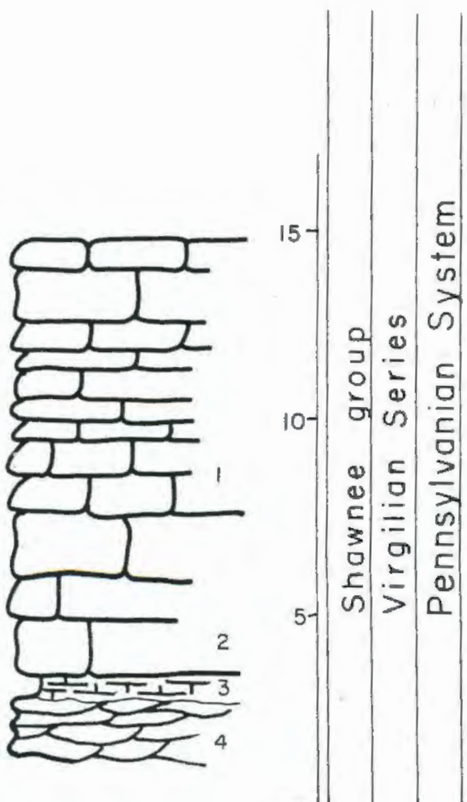
Heebner shale member

2. Shale; tan, clayey to silty.......3.0

3. Shale; black, thin platy.........8.1

Leavenworth limestone member

4. Limestone; blue-gray, hard, dense...................... 1.5



Center of south line of the SE 1/4 sec. 10, T. 16 S., R. 17 E. Location in Osage county

OREAD LIMESTONE

Kereford limestone member

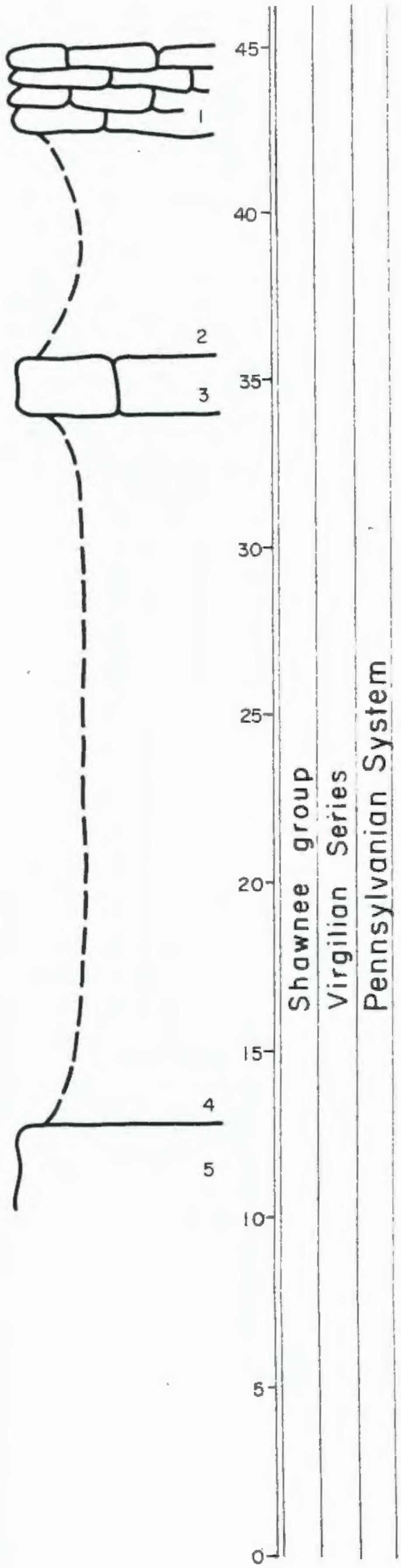
1. Limestone; dark-gray, dense, nearly lithographic, barren of fossils....................7.0

2. Limestone; light tan to gray, fossiliferous, brachiopods Dielasma, Composita and Derbyia, bryozoans and fusulinids.................... 4.0

Heumader shale member

3. Shale; gray, calcareous, fossiliferous..................0.5

4. Limestone; nodular, tan-brown, fossiliferous, brachiopods, bryozoans, fusulinids..........2.0+



SW 1/4 sec. 25, T. 17 S., R. 17 E., along east-west county road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; tan-gray, wavy-bedded, fossiliferous.......... 2.0+

Heebner shale member

2. Covered interval.............. 6.8

Leavenworth limestone member

3. Limestone; blue-gray, hard dense........................ 1.2

Snyderville shale member

4. Covered interval............. 21.3

Toronto limestone member

5. Limestone; brown, massive, fossiliferous.................. 1.0+