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Geology of Southwestern
Leavenworth County, Kansas

by

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TABLE OF CONTENTS

Page

Page

LIST OF ILLUSTRATIONS

Figure Page

ABSTRACT

This report describes the geology of approximately 170 square miles in southwestern Leavenworth County, Kansas. The topography consists of east-facing cuestas and gently rolling plains. Rocks that crop out in the area are all of sedimentary origin and range in age from Pennsylvanian to Recent. The dominant structure consists of strata that dip to the west at approximately 20 feet per mile. Small folds occur locally on this gentle homocline. There are no known surface faults in the area. The mineral resources of the area consist of oil, gas, coal, limestone, shale, sandstone, and ground-water.

INTRODUCTION

Location of Area

The area of 170 square miles in southwestern Leavenworth County, Kansas (Fig. 1) considered in this report is bounded on the west by the Douglas and Jefferson County lines, and on the north by township 9 south. Stranger Creek east of Linwood, and the Kansas River define the eastern and the southern boundaries respectively. This area is readily accessible, having three major east-west highways, and all-weather roads exist along approximately one-third of the section lines.

Geography of Area

Agriculture is the most important industry in the area. Hay, corn, and wheat are the principal crops grown in the lowlands, whereas livestock and poultry raising are predominant in the uplands.

The largest town in the area is Tonganoxie, which has a population of 1,138 (1950 Census). The only other town of any consequence in the area is Linwood, population 261.

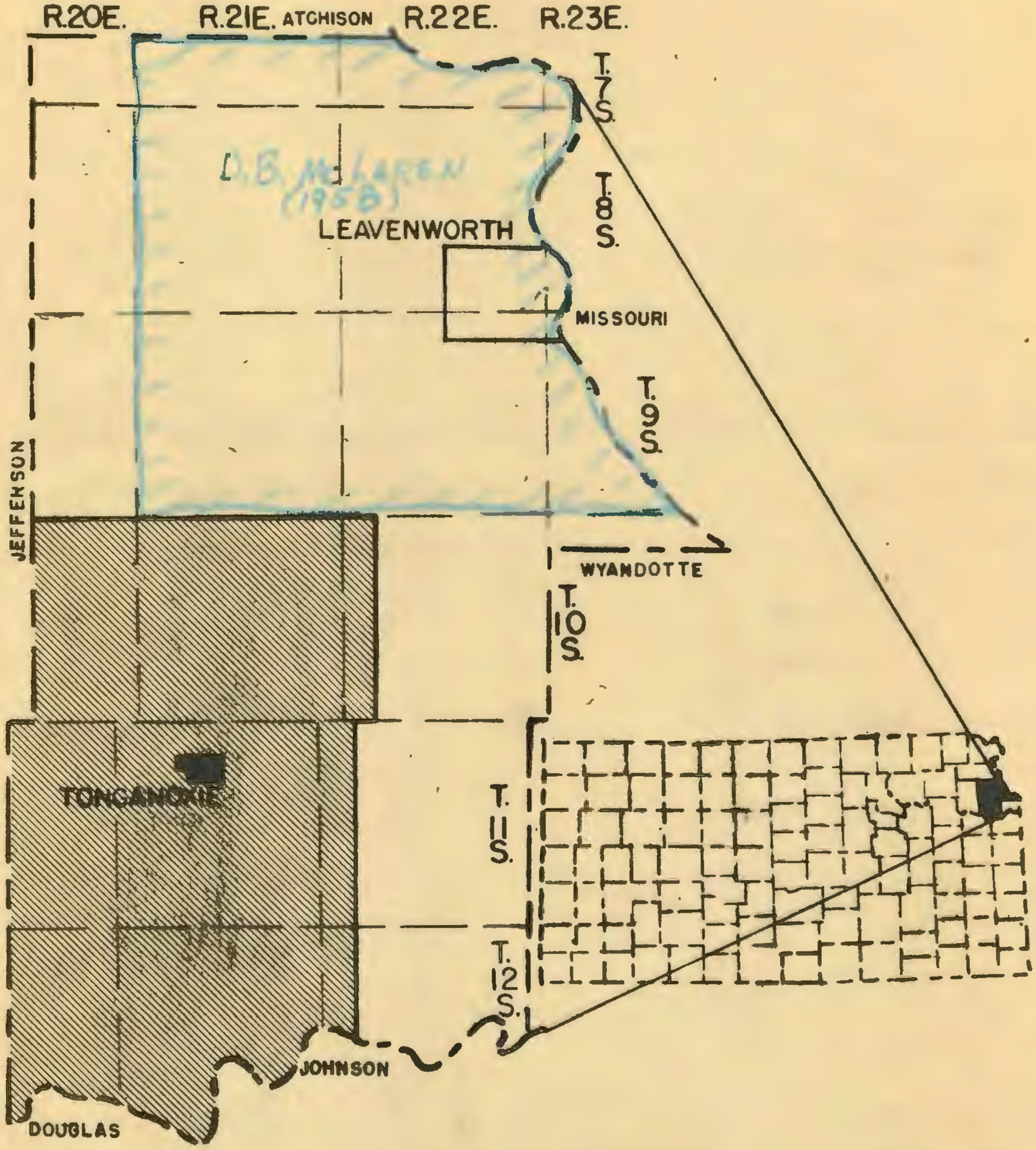


FIG. 1. Index map of Leavenworth County showing location of thesis area.

The normal annual precipitation at Tonganoxie is 34.98 inches, 70 percent of which falls during the spring and summer months.

According to Schoewe (1949, p. 275) Leavenworth County is placed within the Kansas Drift Plain and the Attenuated Drift Border. These are the two minor subdivisions of the Dissected Till Plain, which lies within the Central Lowland of Kansas, as defined by Fenneman (1931, Fig. 2, pp. 6-7).

The topographic features in the area are formed mainly by the Kansas River and its tributaries. These streams have deeply dissected a plain which is underlain by limestone, shale, and sandstone dipping gently to the northwest. In the western part of the area, erosion has produced a series of east-facing cuestas (Fig. 2) and one conspicuous outlier, the Jarbalo Mound in T. 10 S., R. 21 E. These physiographic features are capped by the northeast-southwest striking formations of the Shawnee group. East of these cuestas and outliers gently rolling topography is developed on the sandstones and shales of the Douglas group, with some local low escarpments formed by the Haskell limestone of the Stranger formation (Fig. 3). A large percentage of the area has been somewhat masked and modified by the Kansan Drift.

Purpose of Investigation

The purpose of this investigation is: (1) to provide a detailed areal geologic map of southwestern Leavenworth County; (2) to describe the lithology, stratigraphy, and to note the fossil content of the exposed rocks (including those of Pleistocene age) in the area; and (3) to aid in the preparation of a report on the geology and ground-water resources of Leavenworth County.

Methods of Investigation

The field work on which this report is based was conducted during the months of September, 1956, through March, 1957. The geology was mapped on U. S. Department of Agriculture photographs (scale 1:20,000) and U. S. Geological Survey topographic maps (scale 1:24,000), both furnished by the State Geological Survey of Kansas. These maps and photographs were then reduced by means of a Focalmatic projector, and the geology was transferred to a base map (scale 1:40,000) adapted from a Kansas State Highway Commission map. The thickness and stratigraphic position of the rocks were determined by

FIG. 2. East-facing Oread escarpment. Benches are formed by the Toronto and Plattsmouth limestone members. Camera facing south in sec. 8, T. 11 S., R. 20 E.

FIG. 3. Low escarpment formed by the Haskell limestone, camera facing north in sec. 24, T. 11 S., R. 21 E.

means of the hand level and steel tape. Larger intervals requiring more detailed work were surveyed by alidade and stadia rod. Notes were taken as to lithology, weathering features, and the faunal and floral assemblages. All rock colors were described using the Rock-Color Chart of the Geological Society of America.

Previous Work

The Pennsylvanian rocks which crop out in eastern Kansas were first described by Meek and Hayden (1859), and were later studied by many other geologists: Mudge (1866); Swallow (1866); Haworth (1894); Prosser (1895); Adams, Girty, and White (1903); Haworth and Bennett (1908); Hinds and Green (1917); and Moore (1920).

In later years, additional generalized studies have been made by Jewett (1933); Newell (1935); Jewett and Newell (1935); Moore (1932 and 1936); Moore and Landes (1937); Jewett (1941); Moore, Frye, and Jewett (1944); Jewett (1945); Moore and Thompson (1949); Moore (1949); and Moore and others (1951). Patterson (1933) and Lins (1950) did detailed stratigraphic work on the Douglas group in Leavenworth and Douglas Counties.

Coal deposits in eastern Kansas have been studied by the following geologists: Haworth (1898); Crane (1898); Landes (1937); Whitla (1940); Jewett and Schoewe (1942); Bowsher and Jewett (1943); and Abernathy, Jewett, and Schoewe (1947).

Lee and Payne (1944); Jewett and Abernathy (1945); Ver Wiebe and others (1948, 1949); and Jewett (1949, 1954) have all made investigations relating to oil and gas.

The subsurface and structural geology has been described by: Fath (1920); McClellan (1930); Hall (1932); Kellett (1932); Ockerman (1935); Bass (1936); Lee (1939, 1940, and 1943); Lee and others (1946); and Jewett (1951).

The only report that deals specifically with the area is a study of the Quaternary geology and ground-water resources of the Kansas River valley between Bonner Springs and Lawrence, by Dufford (1953). Dufford's report included the southern portion of the area. The author has drawn freely from this report.

Acknowledgments

The writer is indebted to Dr. J. M. Jewett and Dr. Walter Youngquist, under whose direction this study was made. He wishes to express his appreciation to the State Geological Survey of Kansas which furnished the materials and transportation making this work possible, and to the citizens of Leavenworth County for their hospitality.

Mr. Howard O'Connor and Mr. R. O. Kulstad, members of the State Geological Survey, and Mr. Darrell Davis, Mr. D. J. Laughlin, Mr. Stanton Ball, and Mr. William Brown, of the Department of Geology, also have given many helpful suggestions and valuable field assistance.

Special thanks are also due to the writer's wife, Winifred, who aided in the preparation of this manuscript.

STRATIGRAPHY

General Statement

The rocks exposed in southwestern Leavenworth County are all of sedimentary origin, and range in age from Pennsylvanian to Recent. The oldest formation that crops out belongs to the Lansing group, Missourian series, Pennsylvanian system. This formation is overlain by limestones, shales, and sandstone of the Lansing, Pedee (Missourian series), Douglas and Shawnee groups (Virgilian series). The alluvium now being deposited in the stream valleys is the youngest sediment in the area.

Owing to the very low dip of the beds in the map area (less than ½ degree), and the slight relief, only about 650 feet of strata are exposed. Lying between these exposed rocks and the Precambrian are approximately 2,300 feet of sediments. According to Lee and Payne (1944) the following rock units are found in the subsurface in southwestern Leavenworth County.

Pennsylvanian rocks	Thickness
Missourian series	
Lansing group	
Plattsburg limestone	19
Kansas City group	
Bonner Springs shale	28
Wyandotte limestone	51
Lane shale	19
Iola limestone	24
Chanute and Quivira shale (Drum limestone not identified)	25

Westerville limestone	3
Wea shale	15
Block limestone	5
Fontana shale	5
Bronson group	
Dennis limestone	36
Swope limestone	41
Hertha limestone	24
Bourbon group	
Desmoinesian series	
Marmaton group (undifferentiated)	124
Cherokee group	463
Mississippian rocks	400
Devonian or Mississippian rocks	
Chattanooga shale	75
Ordovician rocks (Formation named not applied	700
Cambrian rocks (by Lee and Payne	190
Total	2,346

The exposed portion of the rock column of southwestern Leavenworth County is treated systematically in the following discussion.

Because the regional stratigraphy of the Pennsylvanian in Kansas has been discussed and summarized by Moore (1936, 1949), the stratigraphic descriptions of this report pertain only to the strata of southwestern Leavenworth County unless otherwise stated. The strata are described in ascending order. Their areal distribution is shown by the geologic map (Plate I). A generalized stratigraphic section of the exposed rocks in this area is shown by Fig. 4.

PENNSYLVANIAN SYSTEM

Missourian Series

The term Missouri was introduced by Keyes (1893) to include the "Upper Coal Measures" in northwestern

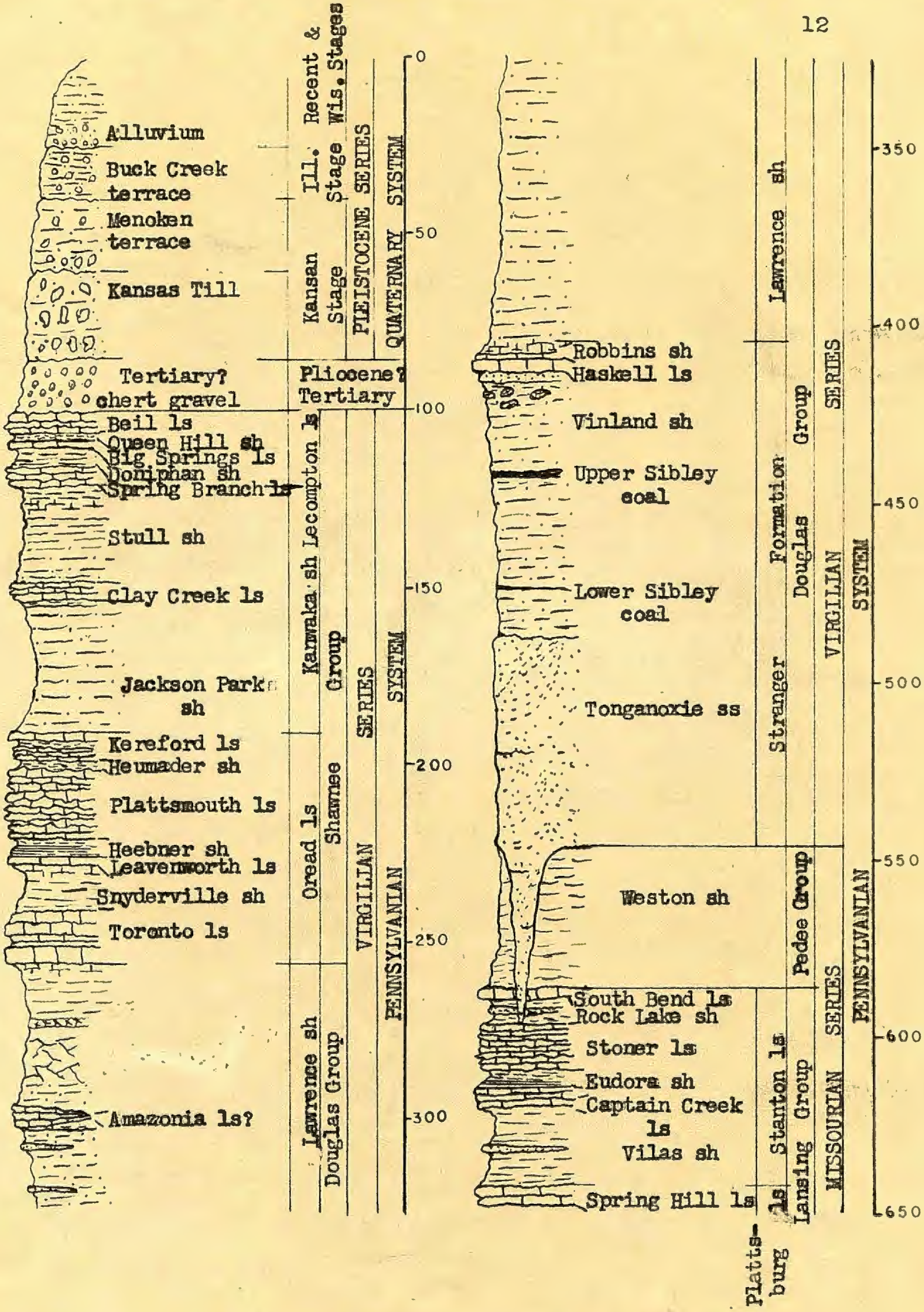


FIG. 4. Generalized stratigraphic section of rocks exposed in southwestern Leavenworth County.

Missouri. The interstate conference of geological surveys, held in Lawrence, Kansas, in May, 1947 (see Moore, 1949, p. 66), recognized the following groups in the Missourian (in ascending order): Pleasanton, Kansas City, and the Lansing and Pedee groups. Of these groups only the upper two are found in southwestern Leavenworth County.

Lansing Group

The term Lansing was introduced by Hinds (1912) to include strata between the Argentine limestone and the Weston shale. These boundaries were redefined by Moore (1932) to include only the Plattsburg, Vilas, and Stanton formations. These three formations crop out in the area, but the Plattsburg formation is represented by only its uppermost member.

Plattsburg limestone

Spring Hill limestone member.— The uppermost member of the Plattsburg formation is the Spring Hill limestone (Newell, in Moore, 1932, p. 93). In the NE¼ sec. 11, T. 12 S., R. 21 E, the Spring Hill member consists of a fine-grained, thin-bedded, wavy-bedded, light olive-gray limestone, weathering to a dusky yellow color. At the two localities where this member is exposed, the upper beds are arenaceous. Fossils include the brachiopods Composita, Enteletes, Marginifera, and Dictyoclostus;

crinoid columnals, echinoid spines, and fenestrate bryozoans.

Vilas Shale

The Vilas shale, named by Haworth (1898, p. 51), lies between the Plattsburg and Stanton limestones. The only exposure of this shale is in a road cut on the west bank of Stranger Creek, in NE¼ sec. 11, T. 12 S., R. 21 E. Here the Vilas is represented by 15 feet of bluish-gray, silty and clayey shale, with brown to yellowish limonite stains on the bedding planes.

Stanton Limestone

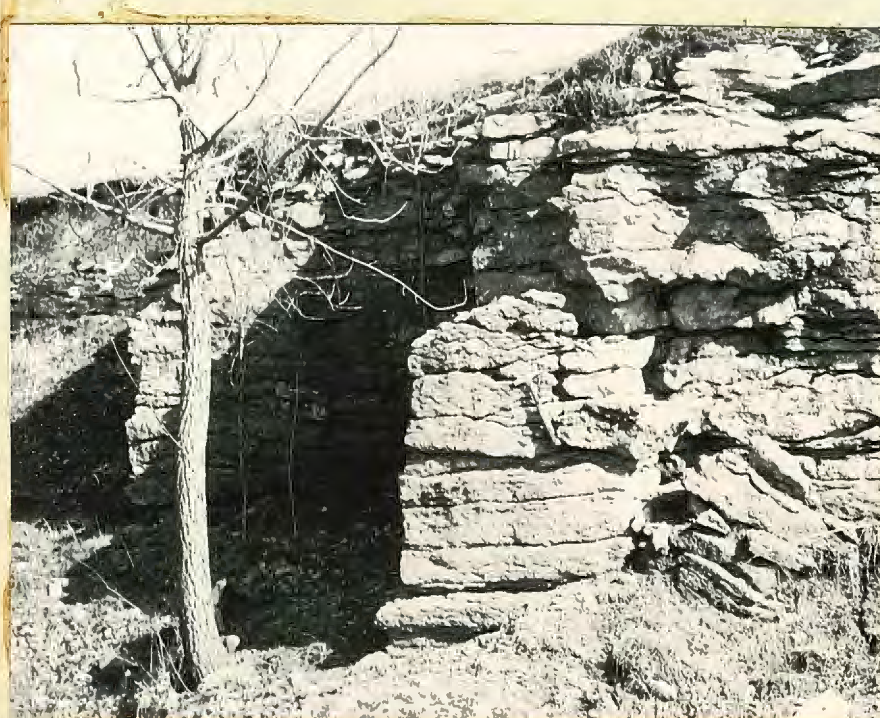
The Stanton limestone (Swallow and Hawn, 1865, p. 6; redefined by Newell, 1935, p. 76) is comprised of five members (in ascending order): the Captain Creek limestone, the Eudora shale, the Stoner limestone, the Rock Lake shale, and the South Bend limestone.

Captain Creek limestone member.— The Captain Creek limestone (Newell, 1935, p. 76) is the most easily recognized member of the Stanton formation. This limestone is jointed, fine-grained, massive, even-bedded, pale yellowish-brown, and weathers grayish-orange. It has a constant thickness of about 5.5 feet throughout the area (Fig. 5). Typical fossils include robust fusulinids, and the brachiopods Enteletes Pugnoides, Composita, and Hustedia.

FIG. 5. Captain Creek limestone illustrating its rectangular, jointed appearance. Section 11, T. 11 S., R. 21 E. Camera facing south.

<u>Eudora shale member</u>.— The Eudora shale was named by Condra (1930, p. 12) from exposures near Eudora, Kansas. This unit, a grayish-green shale, is easily recognized by the thin, black, platy, shale layer that persists near the middle of the member. The Eudora shale ranges in thickness from 5 to 7 feet, and apparently is barren of fossils.

<u>Stoner limestone member</u>.— The middle member of the Stanton formation was termed the Stoner limestone from exposures northwest of South Bend, Cass County, Nebraska (Condra, 1930, p. 11). This member is the thickest limestone in the Stanton formation. In the Haigwood quarry, in NW¼ sec. 11, T. 12 S., R. 21 E., it has a thickness of 16 feet. The light-gray limestone appears massive and blocky on fresh exposures, but as a result of weathering develops a flaggy, thin-bedded, wavy-bedded character (Fig. 6). Newell (1935, p. 77) states that the Stoner limestone "is strikingly unfossiliferous as compared to other limestone members of the Stanton." The author found this to be generally true, but at the Haigwood quarry this limestone contained many fossiliferous zones. One zone in the upper portion is a virtual graveyard for echinoids. Other representative fossils are snails, fusulinids, and the large brachiopods <u>Linoproductus</u> and <u>Dictyoclostus</u>.



A.

B.

FIG. 6. Exposures of the Stoner limestone. (A) shows weathered Stoner (note wavy-bedding) in sec. 13, T. 12 S., R. 22 E. (B) illustrates the massive appearance of the Stoner in unweathered exposures in a quarry, sec. 11, T. 12 S., R. 21 E.

Rock Lake shale member.— The only complete exposure of the Rock Lake shale is at the Haigwood quarry. Here it is comprised of a blocky, olive-brown shale 1 foot in thickness, overlain by 3.5 feet of moderate-brown sandstone. The abrupt and uneven contact of the shale with the sandstone indicates an unconformity. The Rock Lake member appears to be unfossiliferous at this locality. The Rock Lake shale was named by Condra (1927, p. 59) from exposures at Rock Lake in Sarpy County, Nebraska.

South Bend limestone member.— The South Bend limestone (Condra, 1927, p. 59) is named for exposures near South Bend, Nebraska. It is a dark-gray limestone comprising the uppermost member of the Stanton formation. The South Bend along the Kansas Turnpike (SE¼ sec. 26, T. 11 S., R. 21 E.) consists of three limestone beds with shale partings. Here the total thickness is 6 feet. Fossils are common, especially fusulinids, and the brachiopods Meekella and Chonetes.

Pedee Group

The Missourian and Virgilian series in southwestern Leavenworth County are divided by an unconformity that cuts downward through the Weston shale and the upper two members of the Stanton limestone (Fig. 8). The shale deposits that lie above the Stanton limestone and below this regional unconformity belong to the Pedee group. The term Pedee, from a stream near Weston, Missouri, was introduced by Moore (1932) to include two formations: the Iatan limestone and the Weston shale. The Iatan limestone has been eroded from the area, and the Weston shale is now the youngest Missourian deposit exposed.

Weston Shale

There is only one good outcrop of the Weston shale in the area, and it is in the Haigwood quarry. Here a sparsely fossiliferous limonite-stained, bluish-gray clay shale comprises a total thickness of 67 feet. The Weston shale was named (Keyes, 1899, p. 306) from exposures near Weston, Missouri.

Virgilian Series

The name Virgil, adopted from the town of Virgil, Kansas, was introduced by Moore (1932) to include the youngest Pennsylvanian rocks that crop out in the midcontinent region. The upper and lower boundaries of this series are defined by unconformities in the type area. The Virgilian series is subdivided into three groups (in ascending order): Douglas, Shawnee, and Wabaunsee. The Douglas group and the lower three formations of the Shawnee group are exposed in the area.

Douglas Group

The Douglas group (Haworth, 1898, p. 93; redefined by Moore, 1932, p. 93), consists mostly of clastic sediments and is named from exposures in Douglas County, Kansas. The Douglas group contains the Stranger formation and the overlying Lawrence shale.

Stranger Formation

Newell (in Moore, 1932, p. 93) named the Stranger formation from exposures along Stranger Creek in the eastern part of the area discussed in this report. In southern Leavenworth County the formation consists of marine and non-marine beds which lie unconformably upon the Lansing and Pedee groups. Inasmuch as it is not practical to attempt to map the contact of the Stranger and Lawrence formations, as defined by Newell, the contact of the Haskell limestone with overlying beds has been mapped as the upper boundary of the Stranger formation because the Robbins shale member (uppermost Stranger) is inconspicuous and cannot be traced in the field.

Tonganoxie sandstone member.— In southwestern Leavenworth County much erosion and trenching preceded the deposition of the Tonganoxie sandstone. This member was named by Moore, Elias, and Newell (1934) from exposures near Tonganoxie, Kansas. The Tonganoxie member (Fig. 7) varies in thickness from 4 to 70 feet and is made up of massive, brown, cross-bedded sandstones, sandy shales, and thin coal beds. This sandstone lies between the top of the Upper Sibley coal and the Stanton limestone.

A.

B.

FIG. 7. Typical exposures of Tonganoxie sandstone. (A) shows cross-bedding in sec. 36, T. 11 S., R. 21 E. Camera facing north. (B) shows massive bluffs of Tonganoxie sandstone along Stranger Creek. Camera facing south in sec. 36, T. 10 S., R. 21 E.

In other areas where the Upper Sibley coal is absent, the Westphalia limestone, not definitely identified in this area, marks the upper boundary. Locally a conglomerate of silt stone, claystone, and limestone pebbles with an average thickness of 4 feet is found at the base of the Tonganoxie sandstone (Fig. 8). Marine fossils occur only in the conglomerate and basal part of the sandstone, but carbonized plant remains are common throughout the formation. The two well developed coal units in this unit are the Upper and Lower Sibley coals (Patterson, 1933; redefined by Bowsher and Jewett, 1943, p. 43). In the NW¼ sec. 24, T. 11 S., R. 21 E. the Lower Sibley coal lies 89 feet below the Haskell limestone, and averages 18 inches in thickness. The Upper Sibley coal lies from 6 to 35 feet below the Haskell member, and varies from 5 to 20 inches in thickness (Fig. 9, and Fig. 21). Persistence and stratigraphic position of the coal make it easy to locate and identify.

Vinland shale member.— The Vinland shale was named for the town of Vinland, Kansas by Patterson and Addison (1933, p. 17). It consists of a basal sandstone overlain by a marine shale. In sec. 16, T. 12 S., R. 21 E. its total thickness is 34 feet. The Vinland member is characterized by bluish-gray clayey to silty shale containing abundant Myalina, brachiopods, and bryozoans (Fig. 9).

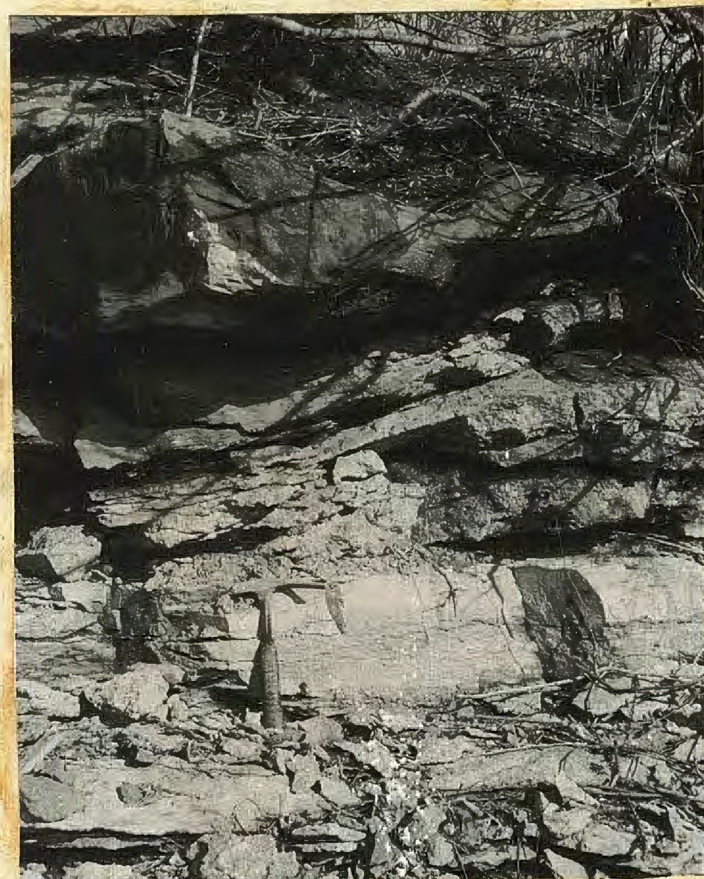


FIG. 6. Unconformity at base of Tonganoxie is shown by the contact between the Tonganoxie sandstone and the Stoner limestone in sec. 29, T. 11 S., R. 22 E. The line indicates contact. Note the basal conglomerate. Camera faces east.

A persistent zone of dark-gray argillaceous septarian limestone concretions occurs near the top of the shale.

Haskell limestone member.— Overlying the Vinland shale is the Haskell member, the only limestone unit of the Stranger formation. Moore (1932, p. 93) named this member from exposures at Haskell Institute at Lawrence, Kansas. The low escarpments in central Leavenworth County are formed by this persistent and distinctive stratigraphic unit, which ranges in thickness from 2 to 9 feet. This limestone (Fig. 9) is a compact, bluish-gray, hard, massive rock which contains abundant algae (Ottonosia), fusulinids, and brachiopods (Marginifera) (Fig. 9). The lower portion of this unit is composed of a sandy limestone which contains abundant specimens of Myalina (Fig. 10).

Robbins shale member.— The upper member of the Stranger formation, called the Robbins shale (Moore and Newell, in Moore, 1936, p. 153), is thin and discontinuous throughout the area. This condition and the lithology make it impossible to recognize a break between this shale and the shales of the overlying formation. The author has chosen to map the top of the Haskell member as an arbitrary boundary between the two formations, and therefore the Robbins member is included in the lower part of the Lawrence shale on Plate I. The Robbins shale includes a zone of phosphatic nodules, overlain by gray

FIG. 9. Typical exposures of the Upper Sibley coal, Vinland shale, and overlying Haskell limestone. Camera facing south in sec. 3, T. 11 S., R. 21 E.

FIG. 10. Close-up of the base of Haskell limestone showing *Myalina* zone. Sec. 9, T. 10 S., R. 21 E.

to yellowish-gray massive shale, brown clay, and a "two-inch layer of goethite" (Miller and Swineford, 1956). The paleoecology of the basal Robbins shale was discussed by Miller and Swineford (op. cit.) and they report that this shale contains ganoid fish remains, cephalopods, conodonts, and Forminifera. The shale is 5 feet thick along the Kansas Turnpike in sec. 15, T. 12 S., R. 20 E.

Lawrence Shale

The Lawrence shale, as now defined, includes strata between the Robbins shale and the base of the Oread formation (Haworth, 1894a, p. 122; redefined by Moore and Newell in Moore, 1936, p. 154). Although lithologies and thicknesses (60-150 feet) of the Lawrence shale differ from place to place four units (listed in ascending order) can generally be recognized.

Unit one consists of approximately 40 feet of light olive-gray silty shale, sandstone lenses, and small channels filled with brown sandstone (Fig. 11). The channels and lenses occur at irregular intervals above the base. The basal Ireland sandstone member, exposed in other areas, was not definitely identified in southwestern Leavenworth County. The small channels and lenses of unit one may be correlative with the Ireland member.

Unit two is a persistent coal seam. This coal lies from 56 to 53 feet below the Oread limestone and ranges

FIG. 11. Sandstone channel in basal portion of the Lawrence shale. Along Nine Mile Creek in sec. 10, T. 11 S., R. 20 E.

FIG. 12. Exposure of the Amazonia limestone member(?) showing its rough and pitted appearance. Camera facing west in sec. 10, T. 11 S., R. 20 E.

in thickness from a feather edge to 8 inches. The author believes that, because of its stratigraphic position, this coal might represent the lower Williamsburg coal found in counties south of the area.

Unit three (Amazonia limestone member?) is well exposed in NW¼ sec. 10, T. 11 S., R. 20 E., where it consists of 5 feet of thin-bedded, light-gray, compacted, sandy, detrital limestone (Fig. 12). Thin veinlets of bituminous material occur irregularly through the limestone. Representative fossils are gastropods, fenestrate bryozoans, pelecypods, and the brachiopods Dictyoclostus and Juresania. This limestone is not persistent and is exposed at only scattered localities in other parts of the area. The Amazonia ranges in thickness from a feather edge to 5 feet.

Unit four consists of 30 to 40 feet of thin-bedded brown sandstone, grading upward into blocky olive-gray and greenish-gray clay shales. A maroon clay shale is present approximately 21 feet below the base of the Oread limestone throughout the area. This shale is often banded with lighter colors and ranges from 6 inches to 2 feet in thickness.

Shawnee Group

As originally defined by Haworth (1898, p. 93), the Shawnee group included beds from the base of the Kanwaka shale to the top of the Scranton shale. Later in the stratigraphic classification of Pennsylvanian rocks in Kansas, Moore (1936, p. 159) restricted the group to the strata between the base of the Oread limestone and the top of the Topeka limestone. The Shawnee group contains the following formations (listed in ascending order): Oread limestone, Kanwaka shale, Lecompton limestone, Tecumseh shale, Deer Creek limestone, Calhoun shale, and Topeka limestone. Only the three lower formations are present in the area.

Oread Formation

The Oread formation (Haworth, 1894a, p. 123; 1895, p. 461; redefined by Moore, 1936, p. 161) lies conformably on the Lawrence shale and is named after the hill on which the University of Kansas is located. This formation consists of the following four limestone and three shale members (named in upward order): Toronto limestone, Snyderville shale, Leavenworth limestone, Heebner shale, Plattsmouth limestone, Heumader shale, and Kereford limestone.

Toronto limestone member.— The Toronto limestone was named by Haworth and Piatt (1894, p. 117) from a town in Woodson County, Kansas. This lowermost member of the Oread formation is characterized by massive, deeply-weathering, brownish-yellow limestone (Fig. 13). At one locality (NE¼ sec. 25, T. 11 S., R. 20 E.) a

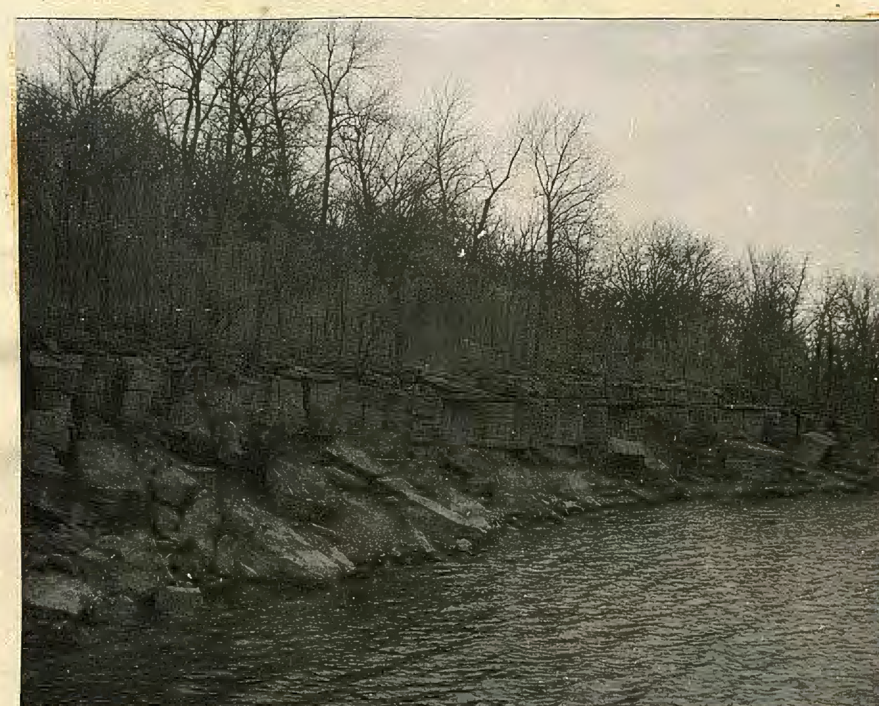


FIG. 13. Typical exposure of the Toronto limestone showing massive bedding. Picture taken along the west bank of Lake Tonganoxie, sec. 2, T. 11 S., R. 20 E.

light-gray, lithographic unfossiliferous limestone occurs at the base of the Toronto. Because this limestone is not similar to characteristic Toronto, either lithologically or faunally, and because of the sharp change vertically, the author believes that this limestone represents a localized distinctive facies, developed perhaps because of conditions induced by slight irregularities of the depositional bottom. In this case, the limestone appears to represent an added thickness of rock at the base of the normal sequence of the Toronto limestone. Yellowish-brown chert nodules are common in the upper portion of the member at many of the outcrops. Typical fossils, in order of abundance, are crinoids, brachiopods, fusulinids, and bryozoans.

Snyderville shale member.— The shale overlying the Toronto limestone derives its name from exposures near the town of Snyderville in southeastern Nebraska (Condra, 1927, p. 36). The Snyderville member is an olive-gray, blocky, clay shale that is almost barren of fossils throughout the area. Thickness of this shale is commonly 10 to 12 feet but may be as much as 23 feet.

Leavenworth limestone member.— The middle member of the Oread formation, the Leavenworth, is a single, massive, pale yellowish-brown compact limestone which has a uniform

?

thickness of about 2 feet. Moore (1949, p. 148) described this key bed as "very distinctive in physical characters and for hundreds of miles along the out-crop is rarely found to have a thickness less than 1 foot or more than 2 feet." The flat even top and rectangular jointed appearance (Fig. 14) make it one of the easiest members to recognize in the area. The fossils in the Leavenworth consist of fusulinids, brachiopods, and mollusks. The name Leavenworth was first applied to this member by Condra (1927, p. 38) from exposures near Leavenworth, Kansas.

Heebner shale member.— The Heebner shale is named for Heebner Creek near Nehawka, Nebraska (Condra, 1927, p. 37). This shale member is readily divisible into two parts. The lower consists of 2.5 feet of black, fissile, platy shale that differs little along the outcrop (Fig. 14). Small phosphatic nodules are distributed throughout this lower unit. The upper part of the Heebner is olive-brown, calcareous, clay shale that averages 3 feet in thickness. At some exposures there are conodonts and fish spines in the black shale.

(can't be both fissile + platy)

Plattsmouth limestone member.— Named for exposures at Plattsmouth, Nebraska (Keyes, 1899, p. 306; Condra, 1927, p. 37), the Plattsmouth limestone, with an average thickness of 17 feet, is the thickest limestone

FIG. 14. Leavenworth limestone, overlying Heebner shale, and remnants of the Plattsmouth limestone in a road cut one-half mile east West of Tonganoxie (sec. 8, T. 11 S., R. 21 E.). Note the vertical jointing and rectangular appearance of the Leavenworth limestone.

member of the Oread formation. Fresh exposures (Fig. 16) are bluish-gray in color and consist of massive units separated by thin beds of very fossiliferous shale. Weathered exposures are yellowish-gray, with the thin limestone beds and intervening shale partings causing it to appear wavy and irregular (Fig. 15). Two chert zones each approximately 1 foot in thickness persist 8 and 12 feet above the base of the Plattsmouth. This member has an abundant fauna, consisting of fusulinids, crinoids, clams, corals, gastropods, bryozoans, and a large variety of brachiopods. The following genera are common at all exposures: *Triticites*, *Myalina*, *Lophophyllidium*, *Bellerophon*, and *Fistulipora*.

Heumader shale member.— The uppermost shale member of the Oread formation derives its name from exposures in the Heumader quarry near St. Joseph, Missouri (Moore, 1932, p. 96). A typical exposure of the Heumader consists of medium light-gray, calcareous, clay shale approximately 3 feet in thickness (Fig. 16). Fossils that are abundant include bryozoans, fusulinids, crinoids, and brachiopods.

Kereford limestone member.— The Kereford, being the upper limestone of the Oread formation, is most susceptible to erosion. This member often crops out a few yards down dip of the prominent Oread escarpment. The limestone is pale brown, consisting of an upper

FIG. 15. Illustrating the wavy-bedded and irregular appearance of the Plattsmouth limestone in weathered exposures.

FIG. 16. Plattsmouth limestone, Heumader shale, and Kereford limestone in a quarry in sec. 6, T. 11 S., R. 21 E. Note that the Plattsmouth member (lower limestone) is massive bedded in unweathered exposure.

massive unit and lower flaggy beds with shale partings. The thickness of the Kereford ranges from 4 to 7 feet (Fig. 16). In Leavenworth County the abundant fossils in the Kereford have a peculiar reddish-purple tint. These marine invertebrates weather in relief and are represented by fenestrate bryozoans, crinoid columnals, fusulinids, and the brachiopods Dielasma, Composita, Neospirifer, Derbyia, and Dictyoclostus.

The Kereford limestone is named for the Kerford quarry at Atchison, Kansas (Condra, 1927, p. 45). The discrepancy in the spelling of the member and the quarry was noted and discussed by Laughlin (1956, p. 32).

Kanwaka Shale

Seventy feet of marine and non-marine deposits comprise the lower shale formation of the Shawnee group. The name Kanwaka is applied to these beds after Kanwaka Township, Douglas County, Kansas (Adams, 1903, p. 164). Included in this formation are two shale and one limestone members (from base up): the Jackson Park shale, the Clay Creek limestone, and the Stull shale.

Jackson Park shale member.— Medium-gray clayey to sandy shale and sandstone beds, averaging about 40 feet in thickness and occurring between the Kereford and Clay Creek limestones, constitute the Jackson Park shale. In the area northeast of Tonganoxie a considerable part of the shale consists of gray sandy shale containing thin brown sandstone stringers. Nonpersistent zones of carbonized plant remains and thin coal seams are found at various levels in the upper part of the shale. Moore (1932, p. 96) named this member after Jackson Park at Atchison, Kansas.

Clay Creek limestone member.— The name Clay Creek was introduced by Moore (1932, p. 96) for the limestone succeeding the Jackson Park member, as exposed on Clay Creek west of Atchison, Kansas. The pale yellowish-brown color and abundant fusulinid fauna are typical at all exposures. The Clay Creek is thin- to massive-bedded and its average thickness is 2 feet (Fig. 17).

Stull shale member.— The Stull shale was named by Moore (1932, p. 94) from exposures near Stull, Kansas. This member is typically shown in the SE¼ sec. 3, T. 10 S., R. 20 E. Here it is chiefly a light-gray, clayey, silty, and sandy shale, containing 6 feet of thin-bedded brown sandstone near the top. Locally a thin coal bed occurs above the sandstone. In most exposures there are plant fossils and a few marine invertebrates.

Lecompton Limestone

In comparing the Lecompton formation with the Oread formation we find that there is a remarkable cyclic repetition of lithologies and ecologies. The "second" (counting up from the base of the formation) limestone members of the Lecompton (Big Springs member)

FIG. 17. Typical exposure of the Clay Creek limestone, in sec. 10, T. 10 S., R. 20 E. Camera facing west.

and Oread (Leavenworth member) are very similar in character. Both members are massive, thin, blue limestones overlain by black platy shale.

The type locality of the Lecompton is at Lecompton, Kansas (Bennett, 1896, p. 116). The formation is divided into four limestones and three shale members. The lower five members were found in the area mapped. In order of deposition they are: Spring Branch limestone, Doniphan shale, Big Springs limestone, Queen Hill shale, and the Beil limestone.

Spring Branch limestone member.— The Spring Branch limestone (Condra, 1927, p. 47), oldest member of the Lecompton formation, is characterized by massive deep-weathering beds of a dark yellowish-orange color. A profusion of fusulinids dominates the fauna of this member (Fig. 10). Other fossils that are common to abundant are crinoid columns, ramose and fenestrate bryozoan, clams (*Myalina*), brachiopods (*Dictyoclostus* and *Juresania*), and echinoid spines and plates. The thickness of this member ranges from 4 to 5 feet.

Doniphan shale member.— This member is a 7-foot olive-gray, clayey, blocky shale with limonite stains scattered along the bedding planes. In all exposures examined, this shale is unfossiliferous. The Doniphan was named (Condra, 1927, p. 47) from exposures in northern Doniphan County, Kansas.

FIG. 18. Exposure of the Spring Branch limestone showing the massive bedding. Note the similarity to the Toronto limestone (Fig. 13). Camera facing east in sec. 10, T. 10 S., R. 20 E.

Big Springs limestone member.— Next in sequence above the Doniphan shale is the Big Springs limestone member (Condra, 1927, p. 47). This 2-foot limestone unit occupies the same cyclic position as the Leavenworth (second limestone from base of Oread limestone) and Captain Creek (second limestone from base of Stanton limestone) limestone members. Lithologically and faunally similar to "second" limestones, it consists of dark-bluish compacted limestone containing abundant fusulinids. The member has rectangular jointing at all outcrops.

Queen Hill shale member.— The Queen Hill shale is not exposed in the area.

Beil limestone member.— Isolated outcrops of the Beil limestone occur in the northwestern part of the area. This section of Leavenworth County is partly covered by thick glacial till, and the bed rock is exposed only in deep gullys orwhere excavated. Mantle of this member is common on topographic highs as it is more resistant than the underlying Queen Hill shale (not exposed in the area). On exposure the Beil weathers pale yellowish-orange and is abundantly fossiliferous. Brachiopods, echinoid remains, bryozoans, corals, fusulinids, and algae are common at all localities.

TERTIARY SYSTEM(?)

Pliocene Series(?)

Deposits of gravel, composed of sub-angular chert embedded in a matrix of red sandy clay, lie above Paleozoic bedrock and below Kansan till in sec. 19 and 20, T. 11 S., R. 21 E. Glacial erratics are known to overlie these high terrace deposits (elevation 940-950 feet), thus proving a pre-Kansan age. Frye and Walters (1940, p. 148) state that "those gravels on high topographic positions have been considered to be of late Tertiary age, and to correspond to the Pliocene Ogallala formation in Western and Central Kansas."

QUATERNARY SYSTEM

Pleistocene Series

Kansan stage

<u>Kansan till</u>

Deposits of glacial till cover a considerable part of the upland in the area. This till consists largely of clay with pebbles, cobbles, and boulders of granite, chert, limestone, quartzite, and dark-colored igneous and metamorphic rocks. The areal distribution is shown on Plate I.

<u>Meade formation</u>

The Meade formation (Frye and Leonard, 1952) is correlated with the Menoken terrace deposits in the area

(Dufford, 1953, p. 64). These fluvial glacial deposits occur at elevations of 850 to 900 feet along the area north of the Kansas River. Except for the degree of sorting, these deposits have the same lithology as those of the Kansan till.

Illinoian stage

Buck Creek terrace deposits

Remnants of an alluvial terrace occur 20 to 30 feet above the flood plains of Stranger and Nine Mile Creeks. Dufford (1953) correlated those terrace remnants with the Buck Creek terrace in the Kansas River Valley west of Lawrence. The Buck Creek was originally named by Davis and Carlson (1952). The Buck Creek is composed of a partly consolidated conglomerate (Fig. 19) at the base, overlain by gravel, sand, and red clayey silt.

Wisconsin and Recent stages

Newman terrace and Alluvium deposits

Alluvium that averages about 55 feet in thickness occurs in major and tributary valleys of the area (Plate I). In the larger stream valleys three separate surfaces can usually be recognized. The higher level is 8-10 feet above the flood plain and is named the Newman terrace (Davis and Carlson, 1952). A lower surface, called the Intermediate Surface Complex (Dufford, 1953), grades into the modern flood plain. Locally, the boundaries between these valley deposits are indistinct and differentiation is not possible. These deposits are composed of material

FIG. 19. A poorly consolidated conglomerate in the basal portion of the Buck Creek terrace as seen in sec. 11, T. 10 S., R. 21 E. Camera faces south.

derived from High Plains Tertiary deposits (Rocky Mountain derived), bedrock, and the glacial deposits of the area.

Thin deposits of loess occur at scattered localities throughout the area, but no attempt was made to show these deposits on the geologic map.

STRUCTURAL GEOLOGY

Present structure

The area lies on the southeastern side of the Forest City basin, and consists of Paleozoic beds that dip westward at approximately 20 feet to the mile. This westward dip is predominant in the midcontinent region, and is known as the Prairie Plains monocline. Superimposed on this broad gentle structure are smaller anticlinal and synclinal folds which are inconspicuous because closure is small (no more than 30 feet) and the dip of the limbs rarely exceeds 70 feet per mile. Locally small compactional folds exist in the Vinland shale and overlying Haskell limestone (Fig. 20). No faults were observed on the surface, but Lee reported faulting in the subsurface (1944, p. 78) of the McLouth anticline (T. 10 S., R. 20 E.).

Plate II shows the pre-erosional structure of the Haskell limestone in southwestern Leavenworth County.

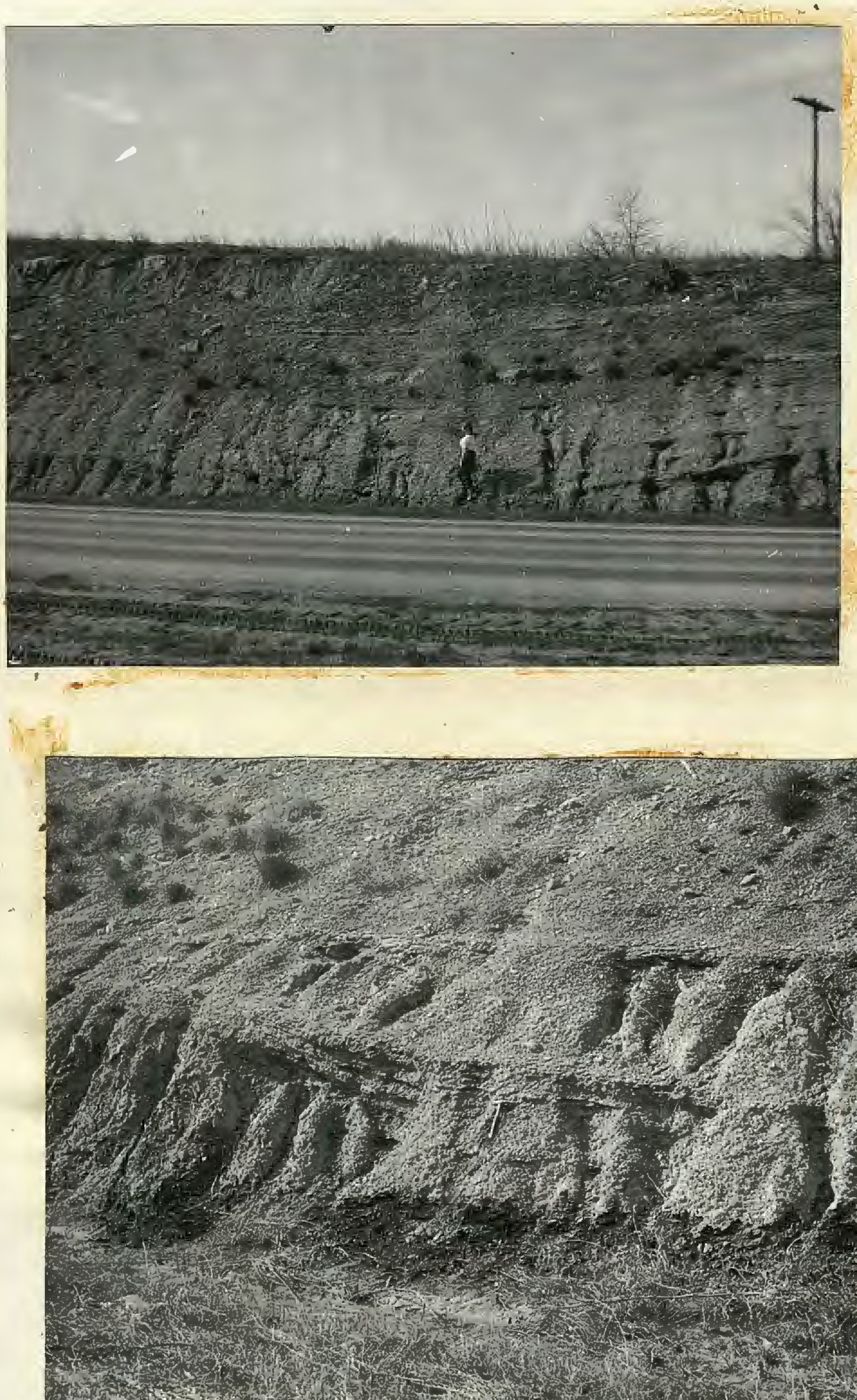


FIG. 20. Compactional folding in the Vinland shale as seen along K 32 in sec. 13, T. 12 S., R. 20 E. Bottom photo shows a close-up of folds. (Note upper Sibley coal). Camera facing north.

The Haskell was selected as a key horizon because of its stratigraphic position between the Lawrence shale and the Stranger formation. The Haskell was deposited on an irregular surface and is therefore somewhat inaccurate for mapping underlying structures. The principal purpose of the map was to aid the writer in determining whether the sandstone exposures in the eastern half of the area were stratigraphically above or below the eroded Haskell limestone. The dashed lines indicate areas where the Haskell has been eroded. Control points used in this interpretation were taken from drillers' logs, electric logs, and surface exposures. The small anticlines shown in the northwestern and southwestern areas correspond to depleted oil and gas fields.

Structural history

The structural history of the area is interpreted (by Lee, 1943) from the subsurface rocks of northeastern Kansas. Lee states that during late Cambrian and pre-St. Peter time the central Ozark area was slowly sinking, and that northeastern Kansas was slowly rising. After extensive erosion the area sank, and the St. Peter sandstone was deposited. In late Ordovician time the structural movements were reversed, resulting in an uplift in the Ozark region and the formation of the Chautauqua arch and North Kansas basin in eastern Kansas. The next important movement occurred at the end of Mississippian time when the Nemaha anticline developed. This divided the North Kansas basin, forming the Salina basin on the west and an unnamed structural basin to the east. After these folded rocks became peneplained, renewed movement along the Nemaha anticline was accompanied by a gentle downwarp of the erosion surface to the east. This downwarping formed the Forest City (in Kansas) and Cherokee (in Kansas and Oklahoma) basins. At this time a low broad divide (the Bourbon arch) separated these two basins, but, as regional subsidence continued, the Forest City basin became filled (middle Cherokee time) and the two basins were joined. Later movement in the area occurred between Permian and Cretaceous time, when the strata were gently tilted in a westward direction. Tertiary movements that rejuvenated the Rockies also had a slight effect on Kansas, as the area generally was raised, and detrital materials were spread eastward from the Rockies across the Great Plains.

ECONOMIC GEOLOGY

The mineral resources of the area include oil and gas, limestone, coal, sand, gravel, shale, and ground-water.

Oil and Gas

Small amounts of gas have been produced in Leavenworth County for nearly 40 years. The discovery of oil and gas in the McLouth field in 1940 (T. 10 S., R. 20 E.) intensified the testing for petroleum in the area. The oil and gas in the northwest area occur at 1,300 feet in the McLouth sand (lower Cherokee). In the Southern part of the area, shallow production is obtained from the "Squirrel sand" (drillers' term for the upper part Cherokee shale) at a depth of approximately 700 feet. In recent years the production of gas and oil has been declining, and in 1950 was practically nil.

Gas storage has been common in depleted fields of the area for many years. In 1927 gas was stored in the Six Corners field (T. 12 S., R. 20 E.). The Cities Service Company has a large amount of gas stored in the McLouth field at the present time.

Limestone

The Plattsmouth limestone which crops out in western Leavenworth County has been extensively quarried because of its thickness and accessibility. The principal uses of the Plattsmouth have been for road metal, agricultural lime, concrete aggregate, and building material. One quarry is operating in the Stoner limestone in sec. 11, T. 12 S., R. 21 E. The stone crushed here is used mainly in the construction of highways. Other limestones in the area have been quarried for local projects.

Coal

The coal resources of the area have been discussed thoroughly by Bowsher and Jewett (1943). They state that deposits of coal in the Stranger formation have been mined intermittently for the last century. Most of this coal has been taken from the Upper Sibley coal (underlying the Vinland shale); however the Lower Sibley coal has also been mined at one locality. Bowsher and Jewett further state that an important area of coal reserves lies in the NW¼ sec. 24, SW¼ sec. 13, and the W½ sec. 14, T. 11 S., R. 21 E., along the west bank of Stranger Creek. They estimate that approximately 266,000 tons of coal can be mined from both the Upper and Lower Sibley coals in this locality.

Sand and Gravel

There are three sources of sand and gravel in the area. The thick deposits of sand and gravel in the Kansas River Valley are the most important source. Here is an inexhaustible supply that can be profitably mined on a large scale. A second source consists of the glacial and terrace deposits. Another source of sand is in the massive, loosely cemented Tonganoxie sandstone that crops out in the eastern part of the area.

Shale

The abundant quantities of shale in the area could probably be adapted for use in the manufacture of cement and clay products. In sec. 11, T. 12 S., R. 21 E., a considerable amount of Weston shale could easily be quarried for the manufacture of light-weight aggregate.

Ground-water

The most important aquifer in the area is the Tonganoxie sandstone. Many farms and the town of Tonganoxie obtain their water supply from this bed. Another source of ground-water is in the alluvial deposits which occur in the valleys.

SUMMARY

The geology of approximately 170 square miles in southwestern Leavenworth county, Kansas is mapped and described. The area lies within the Dissected Till Plain of the Central Lowland physiographic province, and consists of east-facing cuestas and gently rolling topography.

The bed rock is alternating limestone, shale, and sandstone of Pennsylvanian age. The Missourian series, is represented by the Lansing and Pedee groups. The oldest formation that crops out is the Plattsburg limestone of the Lansing group. The Vilas shale and the Stanton limestone comprise the other formations of the Lansing group. The Weston shale is the only formation of the Pedee group identified in the area.

The Douglas and Shawnee groups (Virgilian series) are exposed in the area. The Douglas group consists of clastic sediments of the Stranger formation and overlying Lawrence shale. All members of the Stranger formation, with the exception of the Westphalia limestone, are recognized in the area. The Haskell limestone is mapped as the upper boundary of the Stranger formation, because the Robbins shale (uppermost Stranger) cannot be traced in the field. The Lawrence shale is divided into four units (in ascending order): a lower sandy shale with local channels filled with sandstone,

a thin coal bed, Amazonia limestone member?, and an upper thin-bedded sandstone which grades into a clay shale. The Ireland sandstone member of other areas is not exposed in southwestern Leavenworth County.

The three lower formations of the Shawnee group, Oread limestone, Kanwaka shale, and Lecompton limestone, crop out in the area. The lowermost Oread formation is divided into four limestone and three shale members (in order of deposition): Toronto limestone, Snyderville shale, Leavenworth limestone, Heebner shale, Plattsmouth limestone, Heumader shale, and Kereford limestone. The Kanwaka shale consists of approximately 70 feet of marine and non-marine deposits. The Jackson Park shale, Clay Creek limestone, and Stull shale members are included in the Kanwaka shale.

The Spring Branch limestone, Doniphan shale, Big Springs limestone, Queen Hill shale, and Beil limestone members of the Lecompton formation crop out in the area mapped.

High chert-gravel deposits, lying at an elevation of 940-950 feet, are assigned to the Pliocene series.

Glacial till covering parts of the upland is evidence of the Kansan stage. The fluvial-glacial deposits that form the Menoken terrace are correlated with the Meade formation.

Remnants of an alluvial terrace 20 to 30 feet above the flood plains are named the Buck Creek terrace, and represent the Illinoian stage.

The youngest deposits in the area are found in the stream valleys. These deposits represent the Wisconsin and Recent stages.

Three major periods of deformation are recorded in the area. These movements occurred during the Ordovician, Mississippian, and post-Permian, pre-Cretaceous time. The present structure consists of strata that dip westward at about 20 feet per mile. Small anticlinal and synclinal folds are superimposed on the broad gentle structure. No faults were mapped in the area.

The mineral resources of southwestern Leavenworth county include small amounts of oil, gas, and coal. Abundant supplies of sand, gravel, shale, limestone, and ground-water are found throughout the area.

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APPENDIX

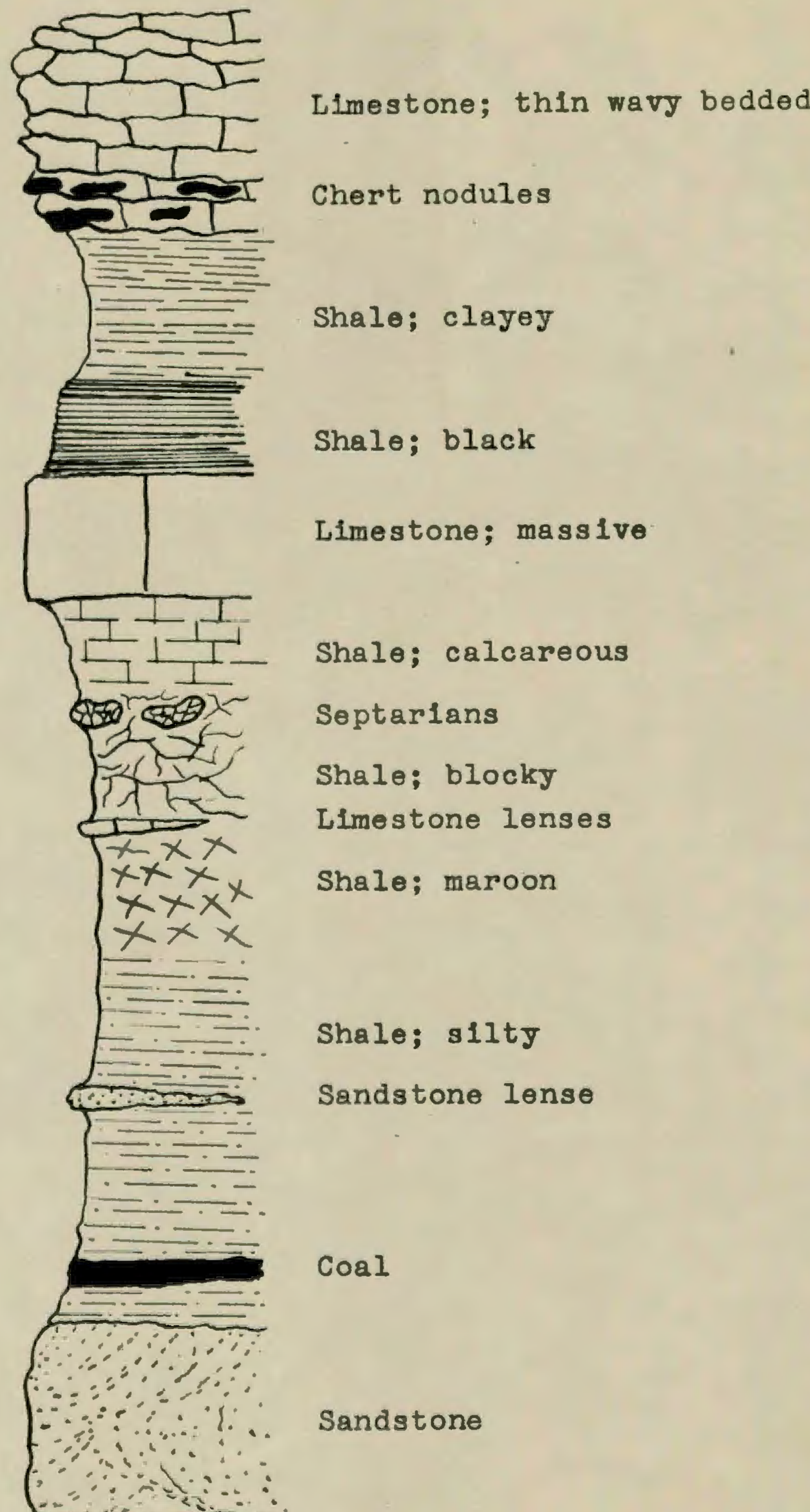
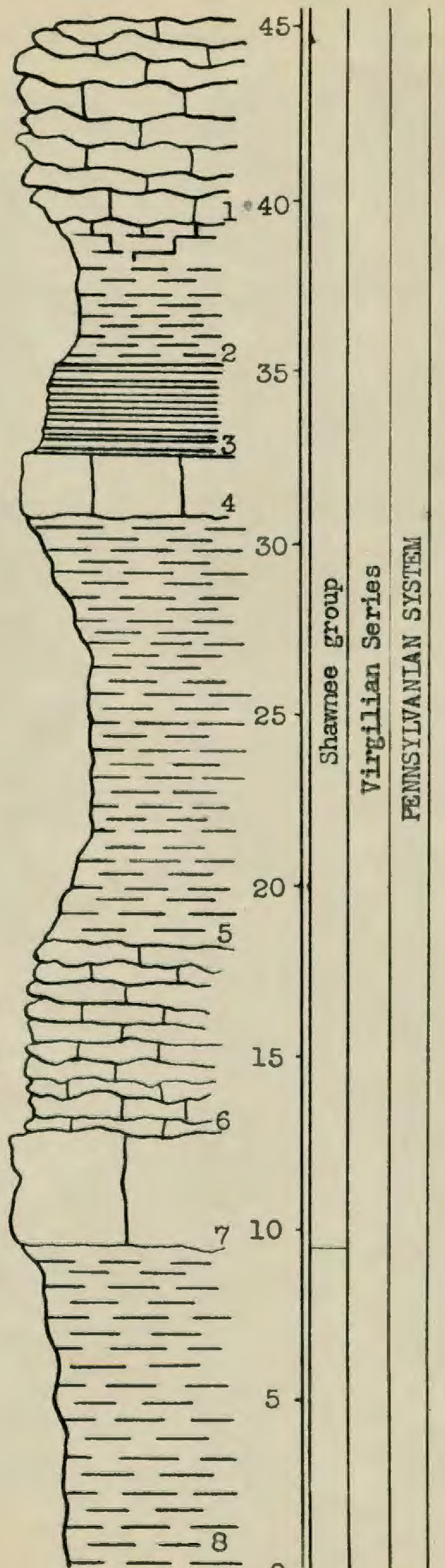


FIG. 21. Explanation of lithology.



NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 31, T. 10 S., R. 21 E. along east-west country road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; grayish-orange, weathers very pale orange, thin-bedded, contains brachiopods, crinoid stems, bryozoans, fusulinids............6.0

Heebner shale member

2. Shale; light olive brown, calcareous, fossils in upper portion...............4.3
3. Shale; black, platy to fissile............2.3

Leavenworth limestone member

4. Limestone; grayish-orange, weathers olive-gray, finely crystalline, compacted, massive, flat even top. Fossils include small fusulinids and brachiopods.......1.9

Snyderville shale member

5. Shale; light olive-gray, clayey, calcareous in upper portion..............12.4

Toronto limestone member

6. Limestone; dark yellowish-orange, thin-bedded, nodular, contains crinoids, brachiopods, fusulinids, algae.................5.4
7. Limestone; moderate yellowish-brown, fresh dark yellowish-orange, massive, weathers deeply and is rough and pitted. Abundant crinoid collumns, fusulinids, brachiopods, some algae.3.5

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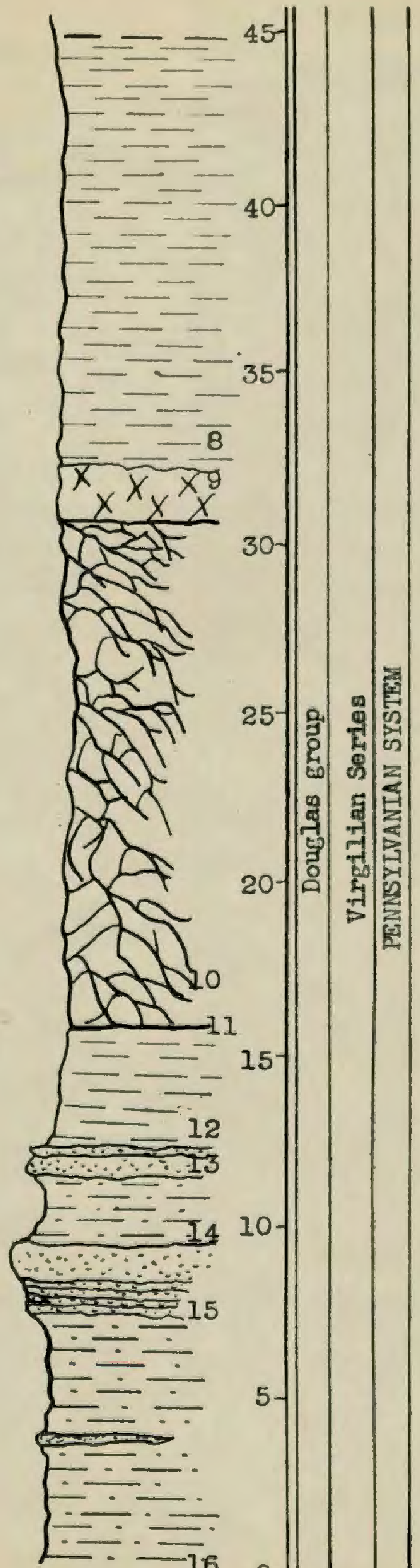

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LAWRENCE SHALE

8. Shale; dark greenish-gray, clayey, calcareous in upper portion..............21.6
9. Shale; maroon, blocky, clayey........1.7

10. Shale; olive-gray, blocky, clayey.......15.2

11. Carbonaceous seam.....0.2

12. Shale; olive-gray, clayey................3.6

13. Limestone; yellowish-gray, sandy, unfossiliferous...............1.0

14. Shale; olive-gray, sandy to silty........2.0

15. Sandstone; yellowish-gray, medium-grained, micaceous.............2.0

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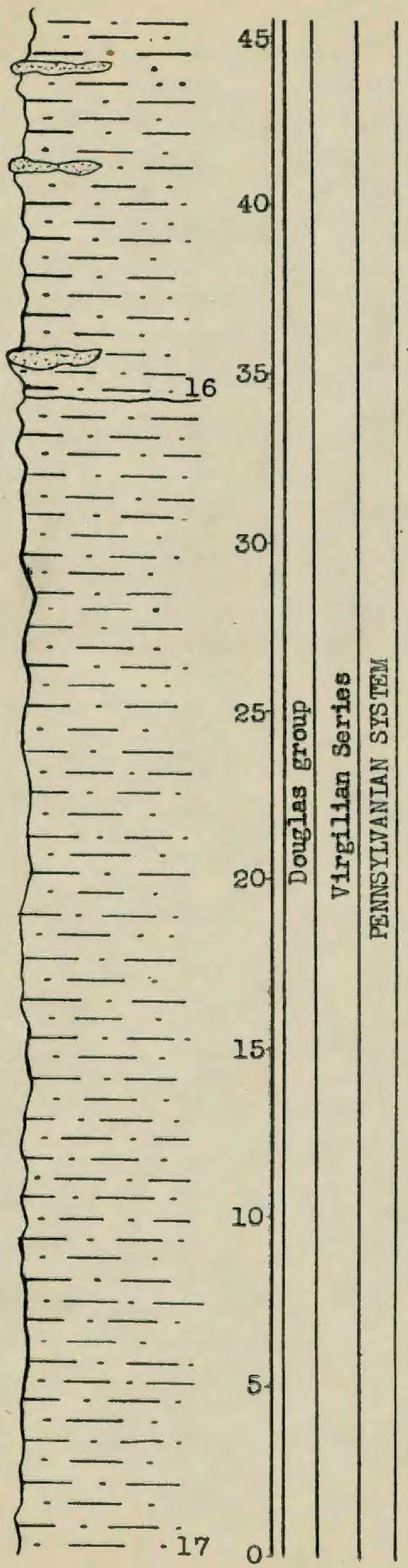

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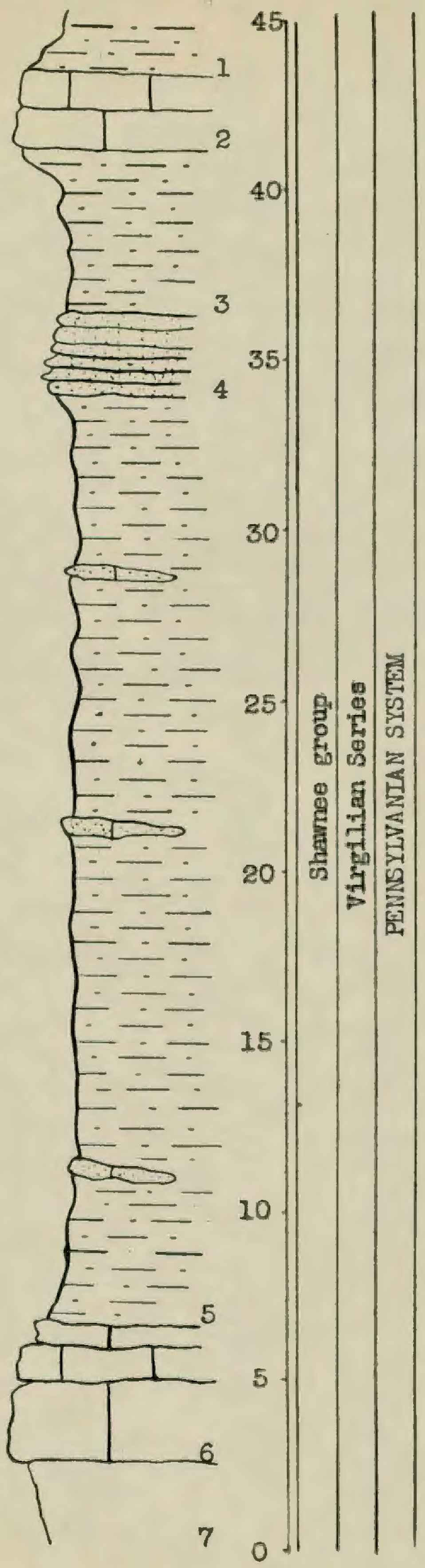
LAWRENCE SHALE (continued)

16. Shale; medium light-gray, sandy to silty, brown sandstone lenses..............18.5

17. Shale; light olive-gray, silty with limonite stains.....33.5



North line sec. 15, T. 11 S., R. 20 E., on the north side of east-west section road.

KANWAKA SHALE

Stull shale member

1. Shale; light brown, clayey...............2.0

Clay Creek limestone member

2. Limestone; yellowish-orange, massive, abundant fusulinids, few brachiopods and crinoid remains......2.2

Jackson Park shale member

3. Shale; light olive-gray, clayey.........5.0
4. Sandstone; yellowish-brown, thin-bedded...2.5

5. Shale; light olive-brown, sandy to silty, sand limestone stringers.....27.2

OREAD LIMESTONE

Kereford limestone member

6. Limestone, brownish-gray, weathers dusky yellow, prolific fusulinids, fauna, brachiopods, Dielasma, Composita, Neosprifer, Derbyia..4.0

Heumader shale member

7. Covered interval.....6.0

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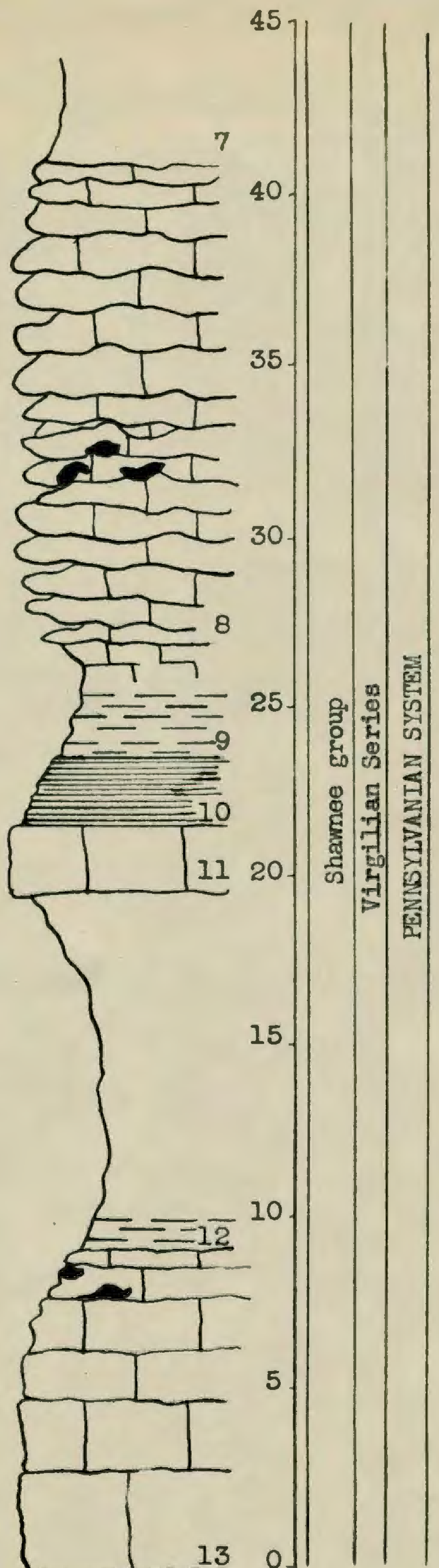


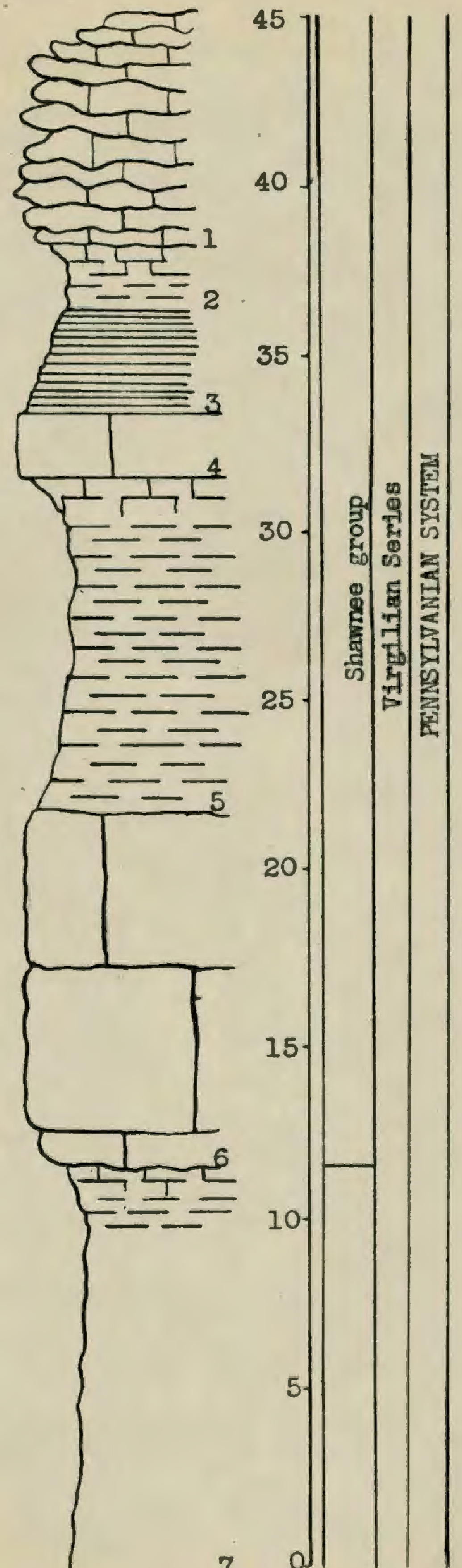
OREAD LIMESTONE (continued)
Plattsmouth limestone member
8. Limestone; yellowish-gray, wavy-bedded, chert nodules, Bellerophans, corals, clams, bryozoans, brachiopods, fusulinids..........14.0

Heebner shale member
9. Shale; light olive-brown, calcareous, clayey...............3.4
10. Shale; grayish-black, platy to fissile, phosphatic nodules..............2.2

Leavenworth limestone member
11. Limestone; olive-gray, weathers dusky yellow, jointed, rectangular, fusulinids, brachiopods..........1.8

Snyderville shale member
12. Covered interval....10.6

Toronto limestone member
13. Limestone; yellowish-orange, massive, chert nodules, fusulinids, brachiopods, crinoid collumns............10.5



Center sec. 3, T. 12 S., R. 20 E., north side of road; on east-west country road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; pale orange, weathers yellowish-orange, wavy-bedded, calcite stringers, crinoid remains, brachiopods Composita, Hustedia, corals...............6.8

Heebner shale member

2. Shale; light olive-brown, calcareous....2.0
3. Shale; black, platy, phosphatic nodules...2.9

Leavenworth limestone member

4. Limestone; pale yellowish-brown, weathers light olive-gray, brachiopods, fusulinids...........1.8

Snyderville shale member

5. Shale; light olive-gray, clayey to silty...............10.7

Toronto limestone member

6. Limestone; moderate yellowish-brown, massive beds, weathering deeply, abundant crinoid remains, few fusulinids, brachiopods.10.3

LAWRENCE SHALE

7. Shale; olive-gray, calcareous, interval partly covered......13.2

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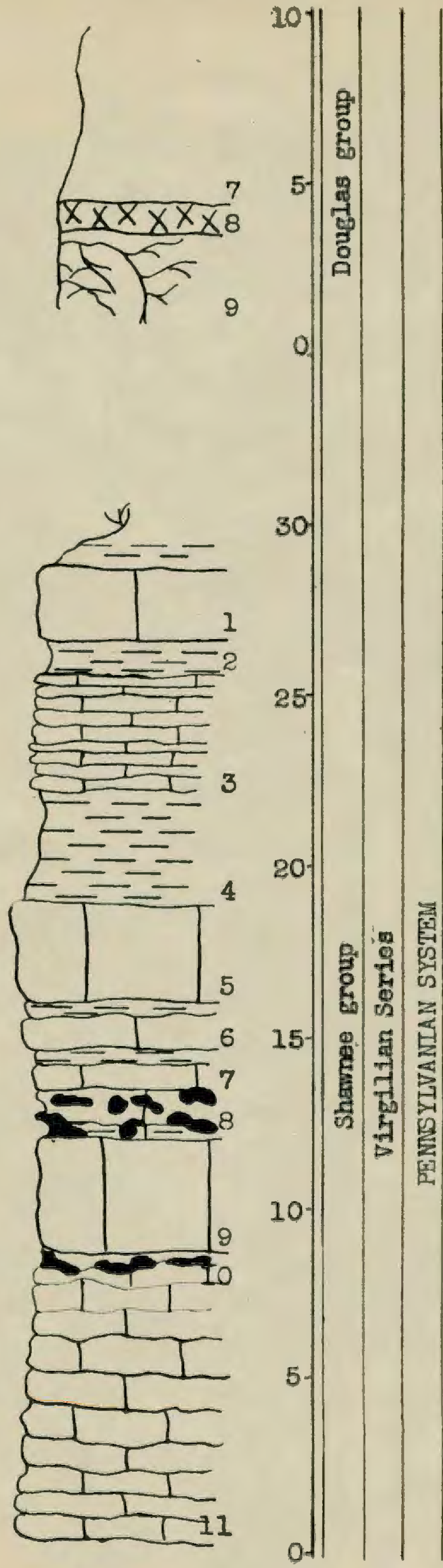

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LAWRENCE SHALE (continued)

8. Shale; dusky red, clayey, blocky.......0.7
9. Shale; grayish-green, blocky, clayey.......2.1

Detailed Section

OREAD LIMESTONE

Kereford limestone member

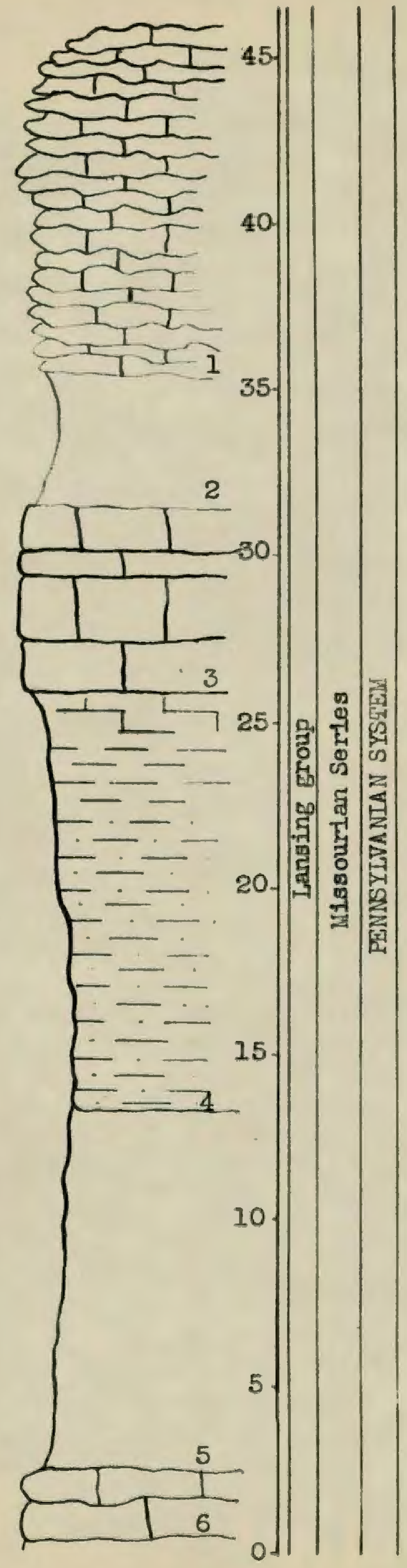
1. Limestone; pale brown, weathers dark yellowish-orange, massive, abundant fossils, crinoids, fusulinids, bryozoan, brachiopods..2.3
2. Shale; brown, calcareous, fossiliferous........0.9
3. Limestone; pale yellowish-brown, thin-bedded, brachiopods, shell fragments......3.5

Heumader shale member

4. Shale; medium light gray, calcareous, clayey, fossiliferous...............3.0

Plattsmouth limestone member

5. Limestone; light gray, massive, abundant small fusulinids, crinoid remains, brachiopods Composita, Dictyoclostus, Marginifera..........3.0
6. Limestone; light gray, fossiliferous........1.3
7. Limestone; light gray, fossiliferous........0.7
8. Chert zone; blue-gray, coquinoid shale partings, abundant fusulinids..1.0
9. Limestone; medium gray, crinoid stems, fusulinids, brachiopods Hustedia, Dictyoclostus 3.0
10. Chert zone; blue-gray, fusulinids...........0.4
11. Limestone; light gray weathers blue-gray, thin-bedded, abundant fossils. 7.5



SW$\frac{1}{4}$, NE$\frac{1}{4}$ sec. 11, T.11 S., R. 21 E., along country road near bridge across Stranger Creek.

STANTON LIMESTONE

Stoner limestone member

1. Limestone; very pale orange, weathers pale yellowish-orange, thin wavy-bedded, brachiopods, crinoid remains, fusulinids..........10.8

Eudora shale member

2. Covered interval.....4.0

Captain Creek limestone member

3. Limestone; grayish-orange, weathers pale yellowish-brown, massive, fine-grained, rectangular jointed, contains abundant brachiopods _Composita_, _Hustedia_, and _Enteletes_, fusulinids, fenestrate bryozoans.5.5

VILAS SHALE

4. Shale; olive-gray, clayey to silty, limonite stains on bedding planes......13.5

5. Covered interval....10.8

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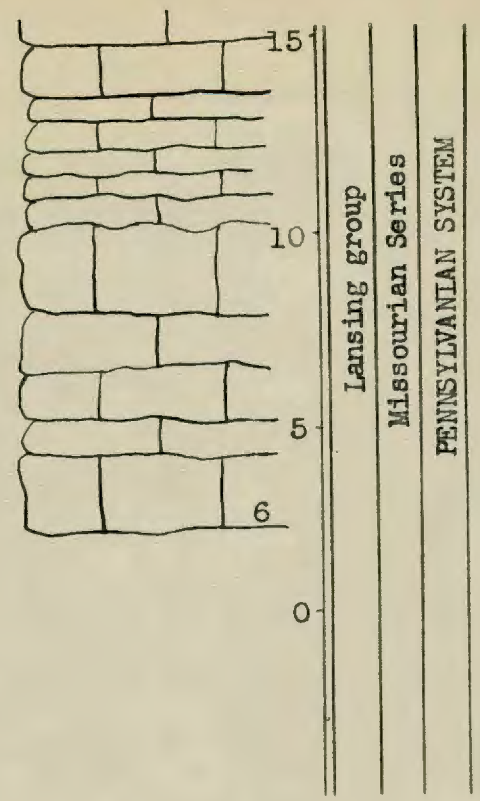

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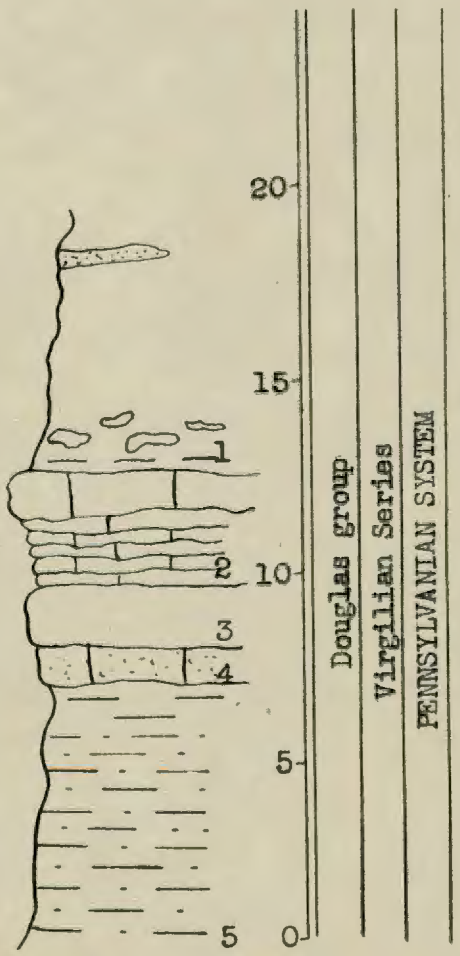
PLATTSBURG LIMESTONE

Spring Hill limestone member

6. Limestone; light gray, fine-grained, ollitic at base, becoming sandy near top, massive- to thin-bedded, calcite stringers, abundant <u>Composita</u>, echinoid spines, bryozoans, fusulinids..........14.9



NE¼; NE¼ sec. 16, T. 10 S., R. 21 E., on a creek bank on west side of Jarbalo Mound.

STRANGER FORMATION

Robbins shale member

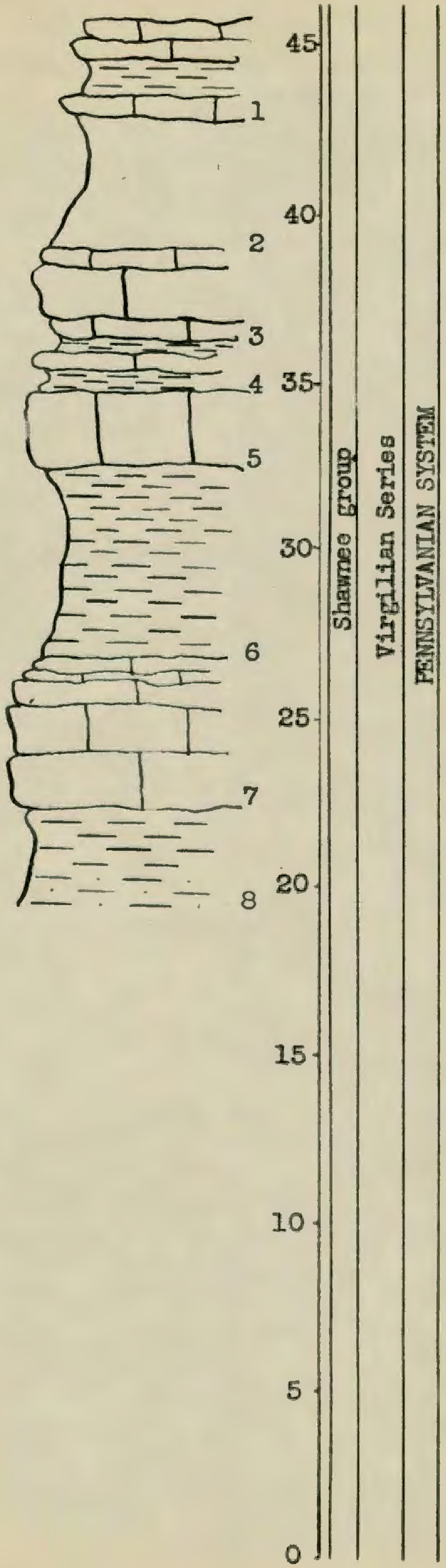
1. Shale; olive-brown, clayey to silty near top, base contains zones of limonite concreations, and is calcareous........5.6

Haskell limestone member

2. Limestone; light olive-gray, weathers very pale orange, massive near top, punky in lower part, abundant <u>Myalina</u> clams, brachiopods <u>Neosprifer</u>, <u>Marginifera</u>, algae......3.3
3. Limestone; brown, sandy, no fossils...........1.4
4. Limestone; dusky yellow, sandy, punky, contains abundant <u>Myalina</u> clams........1.0

Vinland shale member

5. Shale; olive-gray, sandy to silty, Myalina clams in upper portion........7.7



NW$\frac{1}{4}$ sec. 10, T. 10 S., R. 20 E., in a creek north of east-west country road.

LECOMPTON LIMESTONE

Beil limestone member

1. Limestone; pale yellowish-gray, thin-bedded, abundant fossils, corals, bryozoans, brachiopods, echinoid spine, fusulinids....2.8
2. Covered interval.....4.0

Big Springs limestone member

3. Limestone; light olive-gray, weathers pale yellowish-orange, abundant fusulinids..0.5

Doniphan shale member

4. Shale; brown, clayey, calcareous, thin limestone bed near center.1.5
5. Limestone; pale olive-brown, lithographic, calcite stringers, no fossils..............2.2
6. Shale; olive-brown, limonite stains, clayey...............6.8

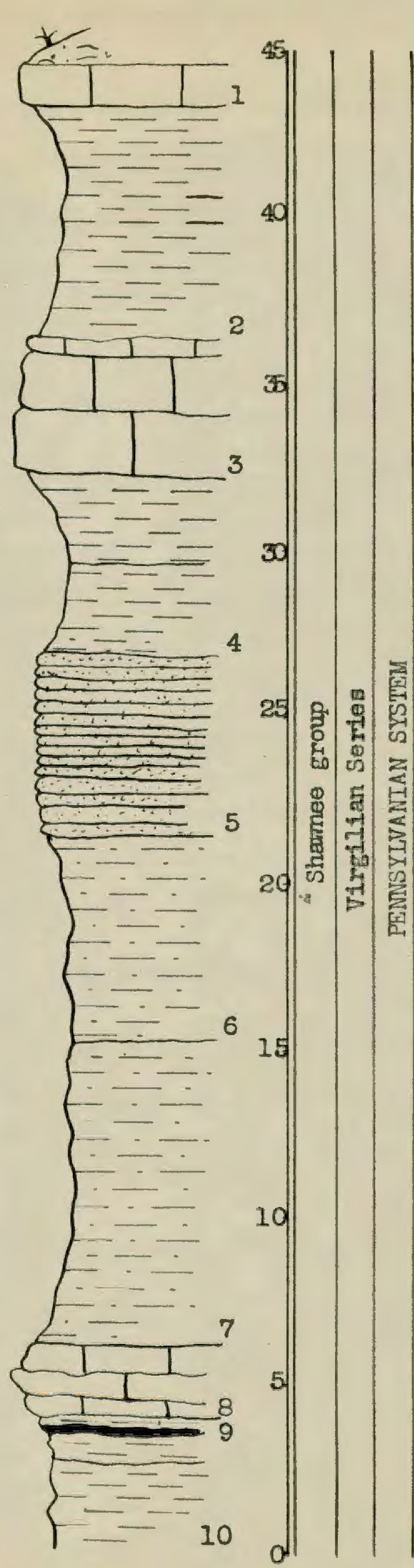
Spring Branch limestone member

7. Limestone; moderate brown, massive, weathers deeply, abundant fossils.....4.3

KANWAKA SHALE

Stull shale

8. Shale; light gray, clayey to silty, plant fossils........3.0



SE$\frac{1}{4}$ sec. 3, T. 10 S., R. 20 E., along east-west section road and in a small creek on north side of land.

LECOMPTON LIMESTONE

Big Springs limestone member

1. Limestone; light olive-gray, fine-grained, compacted, rectangular jointed, sparsely fossiliferous........1.3

Doniphan shale member

2. Shale; olive-gray, clayey to fissile....6.9

Spring Branch limestone member

3. Limestone; dark yellowish-orange, weathers moderate yellowish-brown, abundant fusulinids, crinoid collumns, bryozoans, clams, Myalina, brachiopods, Dictyoclostus, Neosprifer, echinoid spines and plates....4.1

KANWAKA SHALE

Stull shale member

4. Shale; greenish-gray, clayey to silty, carbonaceous seam 2.6 feet below base of Spring Branch, contains abundant leaf and plant fossils..............5.4
5. Sandstone; light brown, thin-bedded...5.4
6. Shale; light gray, sandy...............6.2
7. Shale; olive-brown, sandy, limonite stains...............9.0

Clay Creek limestone member

8. Limestone; pale yellowish-brown, abundant fusulinids..2.2

Jackson Park shale member

9. Coal.................0.3

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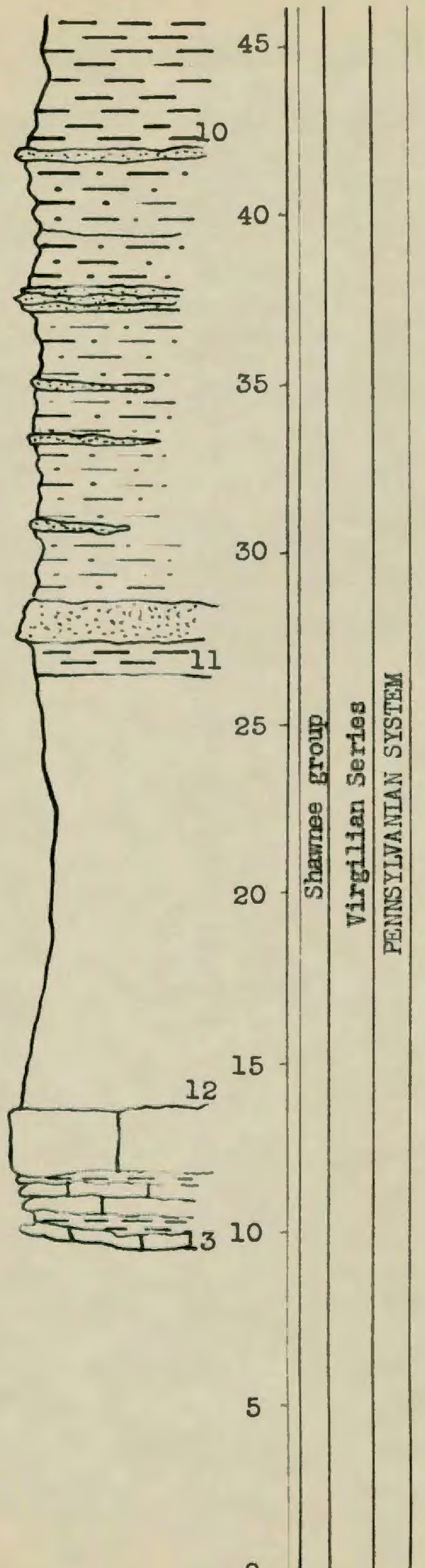

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KANWAKA SHALE (continued)

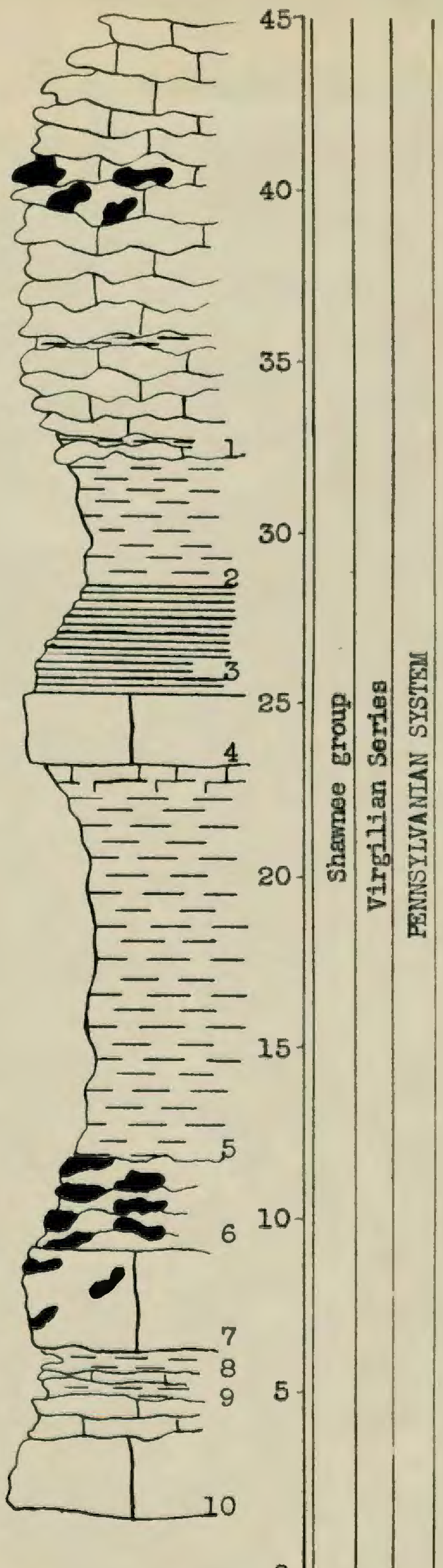
10. Shale; medium gray, limonite stains, carbonaceous seams, plant fossils........5.9

11. Shale; medium gray, sandy, containing thin brown sandstone lenses, limonite stains..............13.1

12. Covered interval....12.6

OREAD LIMESTONE
Kereford limestone member

13. Limestone; pale yellowish-orange, massive- and thin-bedded, abundant fusulinids, snails, bryozoans, Dielasma, Composita, Neospifer............4.0



NE$\frac{1}{4}$ sec. 14, T. 11 S., R. 20 E., along east-west country road.

OREAD LIMESTONE

Plattsmouth limestone member

1. Limestone; yellowish-gray, weathers pale orange, abundant fusulinids, brachiopods, crinoid columnals...12.8

Heebner shale member

2. Shale; light olive-brown, calcareous, fossiliferous........4.1
3. Shale; black, thin, platy, phosphatic nodules..............2.8

Leavenworth limestone member

4. Limestone; light olive-gray, fresh pale yellowish-brown, fusulinids, brachiopods..........1.9

Snyderville shale member

5. Shale; light olive-gray, clayey........11.4

Toronto limestone member

6. Limestone; grayish-orange, containing light gray chert nodules..............3.0
7. Limestone; dark yellowish-orange, abundant crinoid stems, sandy near top.......3.0
8. Shale; brown, sandy..0.5
9. Shale; grayish-brown, calcareous...........0.5

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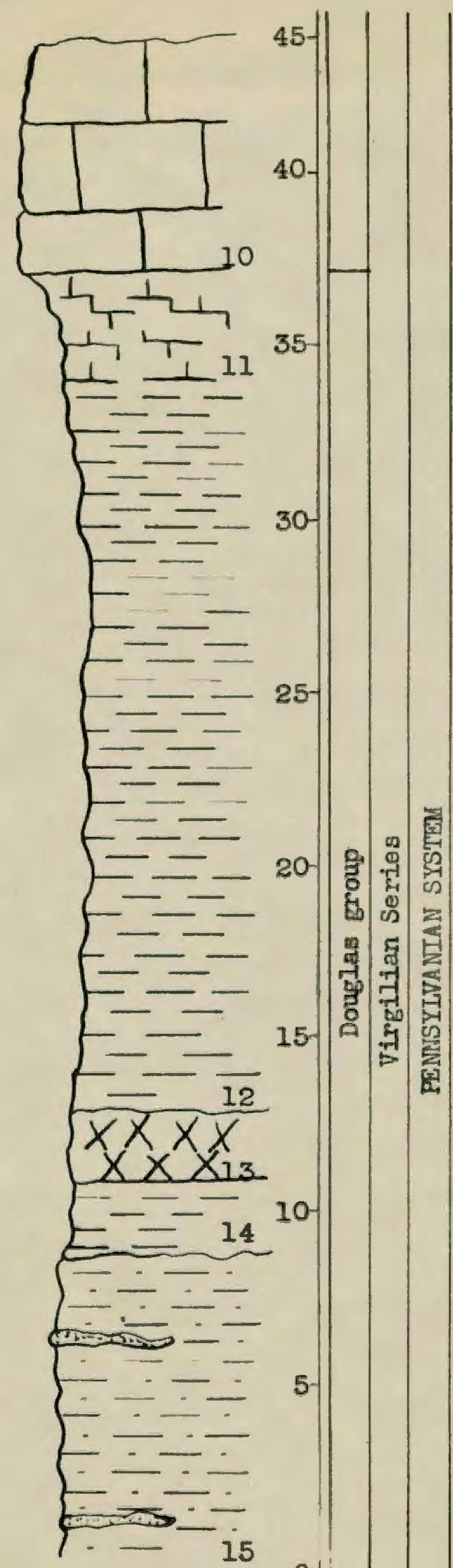

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OREAD LIMESTONE (continued)

10. Limestone; moderate yellowish-brown, massive, weathers deeply, abundant crinoids, brachiopods, few fusulinids.......7.6

LAWRENCE SHALE

11. Shale; olive-gray, calcareous...........3.0

12. Shale; pale olive-gray, clayey to silty...............21.9
13. Shale; dusky red, clayey, blocky.......2.0
14. Shale; olive-green, clayey...............2.0

15. Shale; brown, sandy, thin sandstone lenses..............28.3

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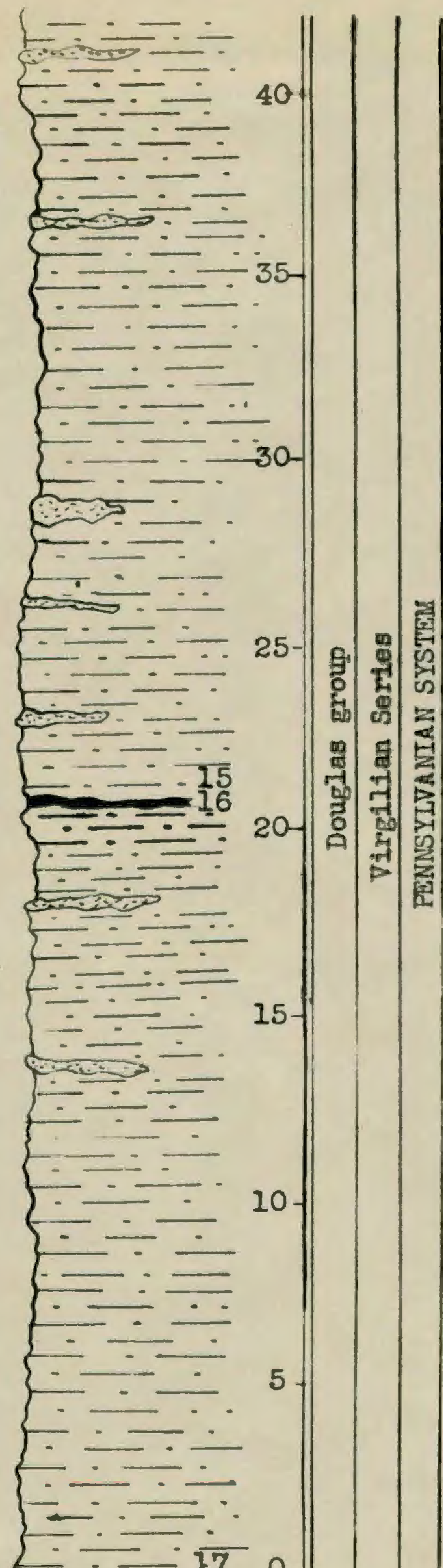
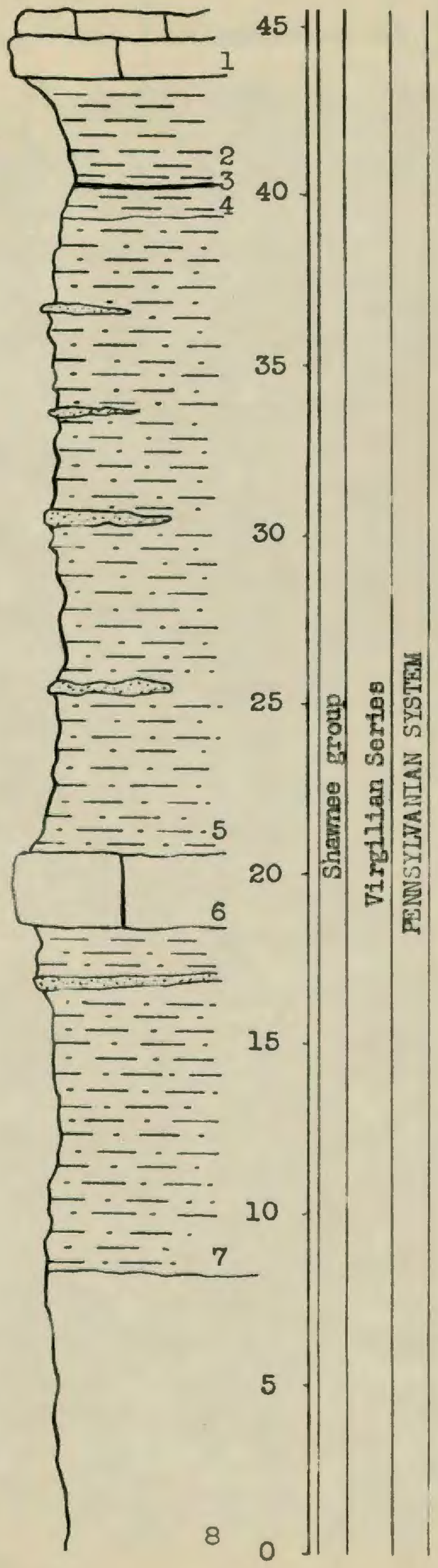


LAWRENCE SHALE (continued)

16. Coal..................0.3

17. Shale; light brown, sandy, with thin sandstone lenses.....21.0



West line of NW$\frac{1}{4}$ sec. 27, T. 10 S., R. 20 E., along north-south country road.

LECOMPTON LIMESTONE

Spring Branch limestone member

1. Limestone; pale yellowish-orange, weathers grayish-orange, fusulinids, crinoid collumns, brachipods Dictyoclostus, Chonetes, shell fragments.............2.2
2. Shale; light gray, clayey, limonite stains................3.2
3. Carbonaceous seams....0.1
4. Shale; gray, clayey to silty..............0.9

KANWAKA SHALE

Stull shale member

5. Shale; light olive-brown, sandy, limonite stains, thin sandstone lenses...............18.7

Clay Creek limestone member

6. Limestone; pale yellowish-brown, weathers grayish-orange, abundant fusulinids, few snails................2.3

Jackson Park shale member

7. Shale; olive-gray, limonite stains, sandy to silty.......10.0

8. Covered interval.....21.6

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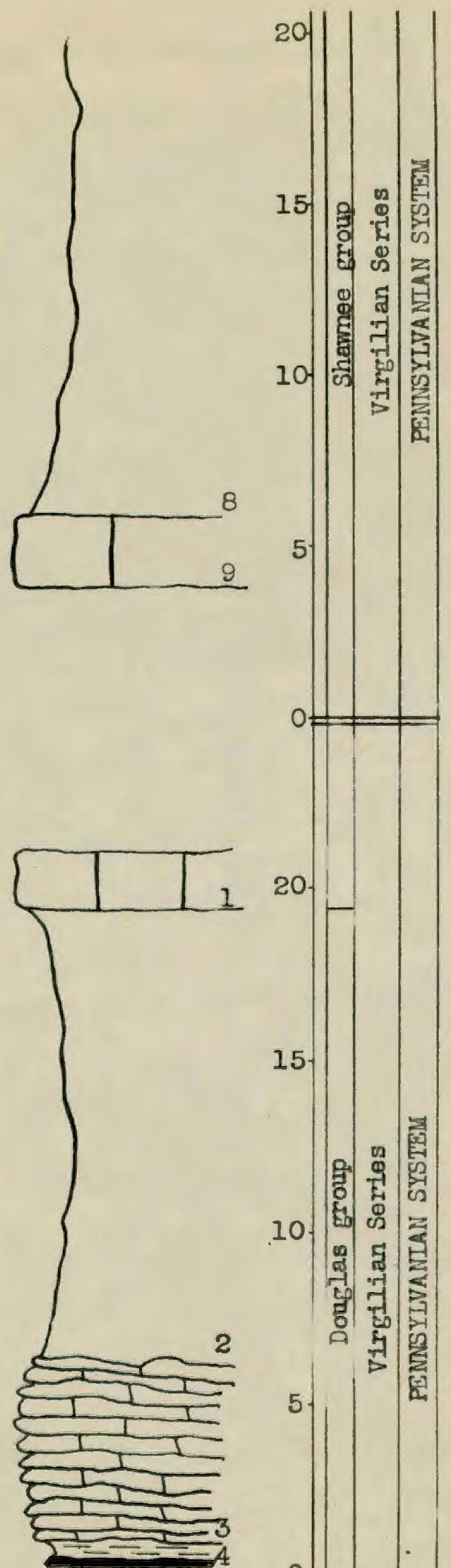

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KANWAKA SHALE (continued)
8. Covered interval....21.6

OREAD LIMESTONE
Kereford limestone member
9. Limestone; massive, fusulinids, snails, fenestrate bryozoan, brachiopods, Neospirifer, Dielasma, Composita............2.0

North line NW¼ sec. 10, T.11 S., R. 20 E., on west bank of Nine Mile Creek.

OREAD LIMESTONE
Toronto limestone member
1. Limestone; moderate yellowish-brown, massive, abundant crinoid collumnals, few fusulinids and brachiopods..........2.0

LAWRENCE SHALE
2. Covered interval....40.0

Amazonia limestone member(?)
3. Limestone; medium light gray, weathers grayish-orange, thin and wavy-bedded, thin shale partings, coquinoid, carbonaceous material, gastropods, bryozoan, snails, abundant Dictyoclostus, Marginifera..........5.2
4. Coal.................0.5