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Stratigraphy and Areal Geology of Northeastern
Leavenworth County, Kansas

by

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STRATIGRAPHY AND AREAL GEOLOGY OF NORTHEASTERN
LEAVENWORTH COUNTY, KANSAS

by

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Instructor in Charge

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For the Department

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ABSTRACT

The stratigraphy and areal geology of approximately 175 square miles in northeastern Leavenworth County, Kansas is discussed in this report. This predominantly agricultural area exhibits east facing cuestas and gently rolling hills. Approximately 550 feet of Pennsylvanian rocks, ranging from the Missourian Wyandotte Limestone to the Virgilian Lecompton Limestone, and unconsolidated Pleistocene sediments are exposed. The Haskell Limestone is used to denote the top of the Stranger Formation. The regional dip is westerly at approximately 15 feet per mile. There are also nontectonic structures due to differential compaction, slump, and ice-push. The mineral resources include shale, soil, limestone, sand and gravel, and ground water. The areal geology is plotted on a 1:40,000 map.

INTRODUCTION

GEOGRAPHY OF AREA

This report deals with an area of approximately 175 square miles in northeastern Leavenworth County, Kansas (Fig. 1). The area is bounded on the east by Missouri River; on the south by T. 10 S.; on the west by R. 20 E.; and on the north by Atchison County. Graded dirt and gravel roads parallel most of the section lines.

Leavenworth County is predominantly an agricultural area. Wheat, corn, and hay are the principal crops; dairy farming is an important industry.

Leavenworth, the county seat, is the largest town in the area (pop. 1950, 20,579). Easton (pop. 287) is the only other incorporated town. Lowmont is a small unincorporated village northwest of Leavenworth. South of Leavenworth an urban area extends for 3 miles through a series of unincorporated villages to Lansing (also unincorporated).

At the city of Leavenworth the mean annual rainfall during the period 1932-1952 was 36.41 inches. The maximum temperature for this period was 110 degrees; minimum -22 degrees. The mean annual temperature was 55.1 degrees.

Northeastern Leavenworth County lies within the Kansas Drift Plain (Schoewe, 1949, p. 275). The Kansas Drift Plain is part of the

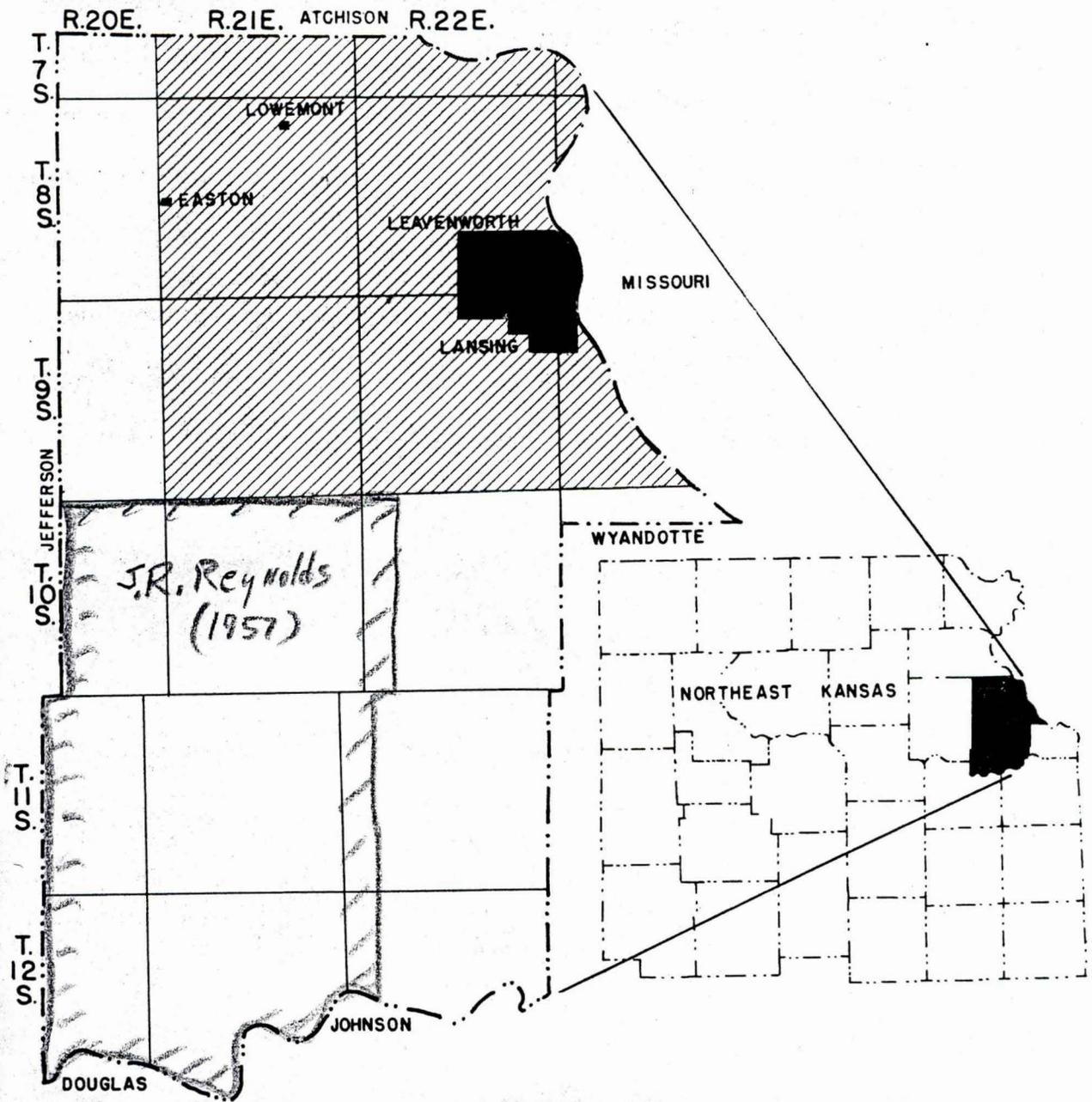


FIG.1. Index map of Leavenworth County showing location of thesis area.

Dissected Till Plain division of the Central Lowlands Province

(Fenneman, 1931, Fig. 2, p. 6-7).

The land surface slopes south to Kansas River and east to Missouri River. Altitudes range from 750 feet to 1120 feet (maximum relief, 370 feet). The most prominent topographic feature is the Oread escarpment, which rises 75 to 125 feet above the countryside to the east. Steep bluffs held up by the Oread Limestone border Stranger Creek; Missouri River is bordered by steep bluffs held up by Lansing Group rocks. The uplands have been dissected to form gently rolling hills.

Missouri River is by far the largest stream in the area. Stranger Creek, the only other large stream, is no more than 50 feet wide. No marked asymmetry was noted in any of the stream valleys except for the valleys of many of the eastward flowing tributaries of Missouri River. The asymmetry of these streams (steeper on the south side) is unexplained.

OBJECT OF STUDY

The object of this study is to prepare a detailed map of the areal geology of northeastern Leavenworth County, and to record the general characteristics of the rocks exposed in the map area. The data gathered in this study will be used by the Kansas State Geological Survey in the preparation of a report on the Geology of Leavenworth County.

METHODS OF INVESTIGATION

Field studies were made continuously during August, 1957, and during week ends and scattered week days from September, 1957, until April, 1958. The geology was plotted, in the field, on U. S. Geological Survey topographic maps (scale 1:24,000), and later transferred to a 1:40,000 base map adapted from a Kansas Highway Department map by means of a Focalmatic projector. Stratigraphic sections were measured with a steel tape and hand level. The geology of incorporated towns was not mapped.

PREVIOUS AND PRESENT WORK

The Pennsylvanian rocks of Kansas have been the subject of much study beginning with the early work of Meek and Hayden (1859). Other early workers include Swallow and Hawn (1865), Mudge (1866), Haworth (1894), Adams, Girty, and White (1903), and Haworth and Bennett (1908). Hinds and Greene (1917) published an excellent map and report that included the geology of the northeastern part of the area covered in this report.

Many of the rock units were named and described first by Moore and Newell (1932). Moore (1936, 1949) described the rocks and discussed their cyclic nature. Moore and others (1951) published the most recent classification and description of the rocks in Kansas. Jewett and Newell

(1935) reported on the geology of Wyandotte County; Reynolds (1957) reported on the geology of southeastern Leavenworth County.

Some of the rock units exposed in northeastern Leavenworth County have been studied in great detail. Patterson (1933) studied the Douglas Group; Bowsher and Jewett (1943) studied the coal in the Douglas Group. The Tonganoxie Sandstone was studied by Lins (1950). Sanders (1957) studied the sandstones of the Douglas and Pedee Groups. McManus (1956) studied the Merriam Limestone.

Current studies (1958) at the University of Kansas related to northeastern Leavenworth County include studies of the Stanton Limestone by S. Ball and the Captain Creek Limestone by W. Eastwood. Dr. L. F. Dellwig is studying ice-push features.

ACKNOWLEDGMENTS

This study was made possible by financial assistance from the Kansas State Geological Survey. Special thanks are due Dr. J. M. Jewett and Dr. W. W. Hambleton for suggesting and directing this study.

Unpublished data from the files of the Kansas Survey were made available to the author, and many of the Survey staff offered helpful suggestions. Mr. Stanton Ball gave valuable field assistance.

STRATIGRAPHY OF SURFACE ROCKS

GENERAL STATEMENT

Sedimentary rocks of Pennsylvanian age and unconsolidated sediments of Pleistocene age are exposed in northeastern Leavenworth County (Pl. 1). All rock units recognized by the Kansas State Geological Survey between the Missourian Wyandotte Limestone and the Virgilian Lecompton Limestone, except the Westphalia Limestone member of the Stranger Formation and the Amazonia Limestone member of the Lawrence Shale, can be recognized. The oldest Pennsylvanian rocks crop out in the southeastern part of the area; progressively younger rocks crop out to the north and west. Pleistocene sediments are indicated in Plate 1 only where there is an appreciable thickness over a fairly large area. Recent alluvial deposits are found in the larger stream valleys.

The Pennsylvanian rocks of Kansas are an excellent example of cyclic sedimentation. Moore (1932, 1936, 1949) has presented the most detailed discussions of cyclic sedimentation in Kansas. As defined by Moore the ideal cyclothem consists of the following units (numbered in ascending order):

- .9 Shale (and coal).
- .8 Shale, typically with molluscan fauna.
- .7 Limestone, algal, molluscan, or with mixed molluscan and molluscoid fauna.
- .6 Shale, molluscoids dominant.
- .5 Limestone, contains fusulinids, associated commonly with molluscoids.
- .4 Shale, molluscoids dominant.
- .3 Limestone, molluscan, or with mixed molluscan and

- molluscoid fauna.
- .2 Shale, typically with molluscan fauna.
 - .1c Coal.
 - .1b Underclay
 - .1a Shale, may contain plant fossils.
 - .0 Sandstone (From Moore, 1936, p. 24)

Each cyclothem represents a cycle of deposition beginning and ending with continental deposition (units .0, .1, .9). Maximum transgression of the sea is indicated by the deep water fauna of unit .5.

Moore (1936) described the cyclothem in the Pennsylvanian rocks cropping out in northeastern Kansas. In addition to defining Pennsylvanian cyclothem, Moore (1936, p. 29) recognized "cycles of cyclothem" that he called megacyclothem, and defined them for the rocks of northeastern Kansas. The ideal megacyclothem (Pl. 2) is composed of five cyclothem indicated by the letters A-E. Examination of Plate 2 will show that in none of the cyclothem are all the beds of the ideal cyclothem present. Megacyclothem of Missourian rocks are not as well developed as those in the Shawnee Group (Virgilian). In the Missourian megacyclothem the A and E cyclothem are always absent and the D cyclothem is sometimes absent. The cyclic development of the Douglas Group has not been worked out and no attempt was made to do so in this study. The cyclothem and megacyclothem defined by Moore are well developed in northeastern Leavenworth County, except for the general absence of fossils in the shale units, and can be recognized easily. Plate 2 illustrates measured sections from northeastern Leavenworth County subdivided into megacyclothem according to Moore (1949).

Considerable range in the thickness of the stratigraphic units was noted while studying the rocks of northeastern Leavenworth County. Because the area covered by this report is not large enough for a regional study, final evaluation of the reasons for the variations in thickness cannot be made. Some of the possible reasons for the thickness differences are: (1) unconformities; (2) differential compaction; (3) algal accumulations; (4) undulations in the surface of deposition; (5) tectonic movements affecting the basin of deposition. Examples of the first three possibilities are: (1) the disconformity at the base of the Virgilian Series; (2) differential compaction of the Stull Shale at the locality of measured section 1; (3) the unusually thick algal accumulation capping the Toronto Limestone at the locality illustrated in Figure 17 and in the Appendix (section 1). It is not beyond the realm of possibility to imagine enough relief on the surface of deposition to cause thickness variations of 25 feet. The effect of tectonic movements can be determined only by a regional study. However, it should be noted that the thickening and thinning of the units in northeast Leavenworth County does not have any apparent pattern.

Moore and others (1951) have described the regional stratigraphy of Kansas; therefore, the descriptions in this report deal specifically with the rocks as exposed in northeastern Leavenworth County. However, because the area studied includes or is close to the type area of many exposed units (ex. Leavenworth Limestone, Lansing Group), the descriptions herein are not materially different than those already in the literature.

Unless otherwise noted in the unit descriptions, the contacts between units

are sharp, well defined by lithologic changes, and essentially conformable. Reference to the original author of each stratigraphic unit, the definition presently recognized by the Kansas State Geological Survey, and the type locality for each unit is presented in tabular form before each unit description. The rocks will be discussed in ascending order. A generalized stratigraphic column is included in Plate 1.

PENNSYLVANIAN SYSTEM-MISSOURIAN SERIES

Defined by: Keyes, 1893, p. 85, 114-116; Moore, 1932, p. 90
Type locality: Northwestern Missouri

The upper part of the Missourian Series is exposed in northeastern Leavenworth County. Outcropping Missourian rocks are of the Zarah Subgroup of the Kansas City Group, the Lansing Group, and the Pedee Group (Fig. 2). The Missourian rocks are predominantly shale and limestone with minor amounts of sandstone. A regional disconformity, which locally cuts into the Stanton Limestone (uppermost Lansing Group), marks the top of the Missourian Series. Approximately 175 feet of Missourian rocks are exposed.

Kansas City Group-Zarah Subgroup

Defined by: Moore, 1949, p. 107
Type locality: Zarah, Johnson County, Kansas

The Zarah Subgroup includes all beds between the base of the Lane shale and the base of the Lansing Group. The subgroup is

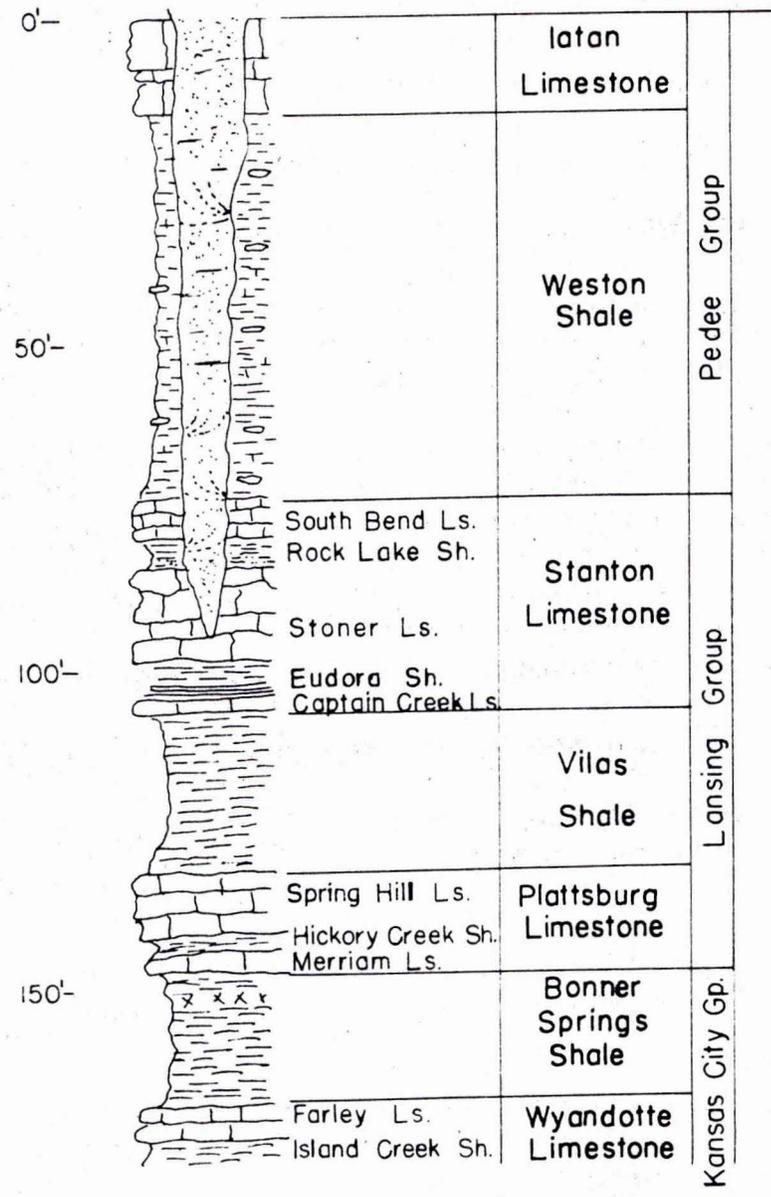


FIG. 2. Generalized stratigraphic section of Missourian rocks exposed in northeastern Leavenworth County, Kansas.

composed of (in ascending order) the Lane Shale, Wyandotte Limestone, and Bonner Springs Shale formations. The Lane Shale does not crop out in the area mapped.

Wyandotte Limestone

Defined by: Newell in Moore, 1932, p. 92

Type locality: Southern Wyandotte County, Kansas

Only the two uppermost members of the Wyandotte Limestone, the Island Creek Shale and the Farley Limestone, are exposed.

Wyandotte exposures occur only in the extreme southeastern part of the area mapped, and these exposures are poor. No locations are known within northeastern Leavenworth County where complete sections of the Island Creek can be studied. Because outcrops of the Wyandotte are so poor, no measured sections of the Island Creek or Farley Limestone are included in the Appendix.

Island Creek Shale Member

Defined by: Newell in Moore, 1932, p. 92

Type locality: Island Creek, near Walcott, Wyandotte County, Kansas

East of the Missouri Pacific Railroad near the southern boundary of T. 9 S. the interval occupied by the Island Creek Shale is just above the level of the railroad tracks. The base of the Farley is 4 to 5 feet above the fill on which the tracks are laid. The Island Creek Shale, which occupies the interval below the Farley, is mostly covered by

soil and vegetation. Digging into the cover reveals flakes of mostly bluish-gray (but with scattered green), clayey, apparently unfossiliferous shale.

Farley Limestone Member

Defined by: Hinds and Greene, 1915, p. 29

Type locality: Farley, Platte County, Missouri

The Farley Limestone is stratigraphically and topographically the lowermost limestone cropping out in the area studied. Most commonly the Farley is a massive limestone (Fig. 3) with slightly wavy indistinct bedding. However a few outcrops of thin-bedded Farley were seen. Because of the small outcrop area within northeastern Leavenworth County it was not possible to definitely determine if the bedding characteristics vary laterally or vertically. Fresh surfaces of the Farley are light gray or mottled light and dark gray; weathered surfaces are light gray or white. The massive limestone is predominantly fine-grained and the thin-bedded varieties are highly algal. All outcrops of the Farley are highly fossiliferous. Fauna found in the Farley include Dictyoclostus, Linoproductus, Juresania, Neospirifer, Myalina, Pharkidonotus, Euphimites, Ameura, and algae. The approximate thickness of the Farley Limestone is 8 feet.

Bonner Springs Shale

Defined by: Newell in Moore, 1932, p. 93

Type locality: Bonner Springs, Wyandotte County, Kansas



FIG. 3. Massive-bedded Farley Limestone. SW sec. 34, T. 9 S., R. 23 E., camera facing northwest.

The Bonner Springs Shale underlies the slope between the Farley Limestone and the Lansing Group. Although the shale is predominantly gray, black laminae and tan zones are randomly distributed throughout the lower 15 feet. A zone of red shale and calcareous nodules commonly occurs 5 to 10 feet below the top. Because the Bonner Springs is a slope former, good outcrops are rare. The best exposure in northeastern Leavenworth County is illustrated in the Appendix (section 10). The Bonner Springs Shale is 20 to 25 feet thick. Like most of the Pennsylvanian Shales in northeastern Kansas, the Bonner Springs is soft, clayey, flaky to blocky, and not particularly well-bedded.

Lansing Group

Defined by: Hinds, 1912, p. 7; Moore, 1932, p. 92
Type locality: Lansing, Leavenworth County, Kansas

Most outcrops of the Lansing Group are south of the city of Leavenworth. The Lansing Group includes (in ascending order) the Plattsburg Limestone, Vilas Shale, and Stanton Limestone formations. The limestones typically form rather prominent benches; a gentle slope is generally developed on the Vilas Shale. The Lansing Group is approximately 75 feet thick.

Plattsburg Limestone

Defined by: Broadhead, 1866, p. 317
Type locality: Clinton County, Missouri

Outcrops of the Plattsburg Limestone, the lowermost formation of the Lansing Group, are in the southeastern part of the area mapped. All three members of the Plattsburg (Merriam Limestone, Hickory Creek Shale, and Spring Hill Limestone) crop out. The Plattsburg Limestone is 15 to 25 feet thick.

Merriam Limestone Member

Defined by: Newell in Moore, 1932, p. 93
Type locality: Merriam, Johnson County, Kansas

The Merriam Limestone, the lowermost member of the Plattsburg Limestone, commonly consists of two limestone units separated by a thin

shale. The total thickness of the Merriam is 2 to 3 feet. No ledge is commonly associated with the Merriam.

The lower unit is fine-grained, massive, gray to tan limestone and 1 to 2 feet thick. Typically the lower unit is represented by a single massive bed with prominent vertical joints. Fossils found in the lower unit are: Myalina, Aviculopectin, Composita, Echinochonus, Juresania, fenestrate bryozoans, crinoid columnals, echinoid spines, and rarely, straight nautiloid cephalopods.

A thin rather nondescript shale separates the upper and lower units. This flaky gray to tan shale ranges in thickness from a featheredge to 0.5 feet.

The upper limestone is blue-gray, fine-grained, and consists of thin irregular beds. Commonly an aigal limestone, composed mostly of Osagia, caps the upper unit. Osagia is present also in lesser numbers throughout the whole upper unit. Other fossils include numerous brachiopods, crinoid columnals, fusulinids, Foraminifera, fenestrate bryozoans, and scattered molluscs.

At the Kansas State Prison Quarry (Appendix, section 9) the base of the Merriam Limestone is a discontinuous conglomerate. No other localities where the Merriam has a conglomeratic base are known in northeastern Leavenworth County. The conglomerate is composed of granule and pebble size shale and limestone fragments in a calcareous matrix. Aviculopectin, Composita, and crinoid fragments are found in the matrix of the conglomerate. The conglomerate ranges in thickness

from a featheredge to 0.9 feet.

Hickory Creek Shale Member

Defined by: Newell in Moore, 1932, p. 93

Type locality: Hickory Creek, Franklin County, Kansas

The Hickory Creek Shale is the most inconspicuous member of the Plattsburg Limestone. Throughout its outcrop area in northeastern Leavenworth County the Hickory Creek ranges in thickness from 0.5 to 1.0 feet. The black platy shale typical of the Hickory Creek in southern areas is not present in Leavenworth County. In the area studied the Hickory Creek has a reddish-brown basal unit about 1 inch thick. The reddish-brown shale is overlain by gray flaky shale that continues upward to the top of the member (Appendix, section 9). In most outcrops the shale is unfossiliferous, but there are abundant Crurithyris and echinoid spines at some of the outcrops.

Spring Hill Limestone Member

Defined by: Newell in Moore, 1932, p. 93

Type locality: Spring Hill, Johnson County, Kansas

The Spring Hill Limestone is the thickest member of the Plattsburg Limestone, and usually forms a prominent ledge (Fig. 4). Commonly the Spring Hill is about 12 feet thick, but the thickness ranges from 8 to 15 feet. The limestone is fine-grained but scattered crystalline calcite occurs in the middle part of the member at most localities. Bedding, which is always slightly wavy, may be thick or thin. In some outcrops

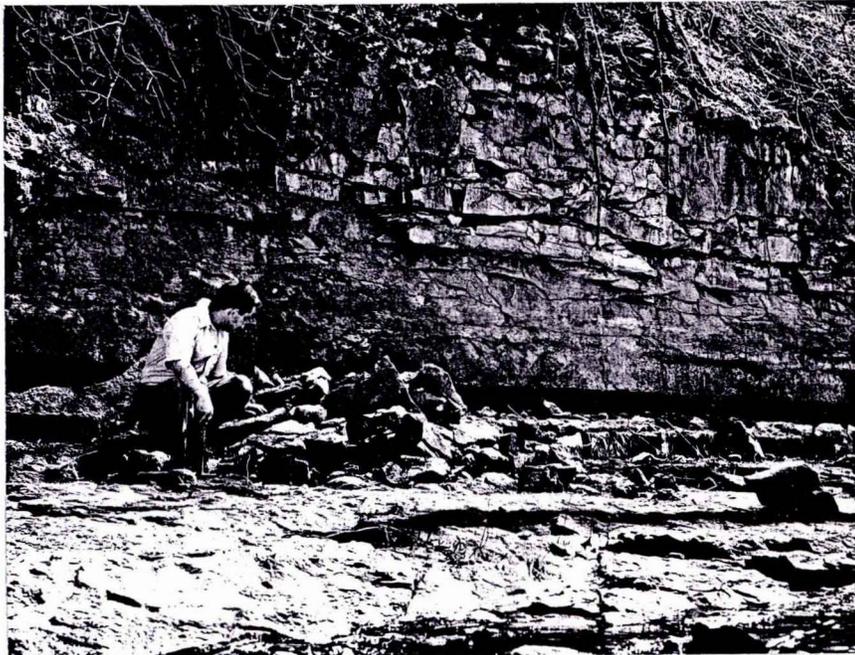


FIG. 4. Massive ledge of Spring Hill Limestone overlying thin Hickory Creek Shale. The Hickory Creek has been eroded out of the dark shadowed zone in the middle of the picture. The Merriam Limestone floors the stream. South side of stream, cen. east line, sec. 32, T. 9 S., R. 23 E.

the Spring Hill Limestone consists of a single thick limestone unit; in others there may be one or two thin (featheredge to 0.5 ft.) shale breaks. Excellent exposures of the Spring Hill are illustrated in Figure 4 and in the Appendix (sections 9, 10).

Brachiopods are abundant and found throughout the member. Algal beds ranging from a featheredge to 0.8 feet are common. Other fossils found in the Spring Hill Limestone include crinoid fragments, ramose and fenestrate bryozoans, echinoid spines, fusulinids, and planispirally coiled gastropods.

Vilas Shale

Defined by: Haworth, 1898, p. 51

Type locality: Vilas, Wilson County, Kansas

Like the underlying Plattsburg Limestone, all known outcrops of the Vilas Shale are south of the city of Leavenworth. The Vilas Shale is a gray to green, clayey to silty, flaky to blocky, unfossiliferous rock. Weathered surfaces of the Vilas are tan. The average thickness of the Vilas Shale is 21 feet, but thickness ranges from 15 to 25 feet. Because gentle slopes are usually developed on the Vilas good outcrops are hard to find. The best exposure in northeastern Leavenworth County is at the State Prison quarry (Appendix, section 9). Other fair exposures are found in T. 9 S. along some of the small tributaries of the Missouri River.

Stanton Limestone

Defined by: Swallow and Hawn, 1865, p. 6; Newell, 1935, p. 76

Type locality: Stanton, Miami County, Kansas

The Stanton Limestone is the uppermost, thickest, and most prominent formation of the Lansing Group. It has five members, which are, in ascending order, the Captain Creek Limestone, Eudora Shale, Stoner Limestone, Rock Lake Shale, and South Bend Limestone. Locally the upper members of the Stanton were removed by post-Missourian erosion.

Captain Creek Limestone Member

Defined by: Newell, 1935, p. 76

Type locality: Captain Creek, Douglas County, Kansas

Outcrops of the Captain Creek Limestone consists of one massive limestone bed or two or three massive limestone beds separated by thin (less than 0.5 ft.) shale breaks (Fig. 5; Appendix, sections 9, 10). The limestone is dense, brittle, blue or brown, and fine-grained. Abundant Composita are associated with the shale breaks. In addition to Composita, which is the most characteristic fossil of both the shales and limestones of the Captain Creek, Enteletes, Juresania, and fusulinids are present in the limestones. The maximum observed thickness of the Captain Creek Limestone is 3 feet, but 2 feet is most common. Because of its resistant nature, the Captain Creek generally forms a low bench.

Eudora Shale Member

Defined by: Condra, 1930, p. 12

Type locality: east of Eudora, Douglas County, Kansas

The Eudora Shale is composed of three shale units (Appendix, section 9). At the base of the member there are a few inches of soft, dark gray or brown shale. The middle unit is distinctive black shale. The black shale is fairly hard, platy, contains phosphatic nodules that range in size from microscopic to 1/2 inch. Conodonts, which occur in the black shale, are the only fossils found in the Eudora. The upper unit comprises 2 to 3 feet of gray flaky shale. Although the topographic expression of the Eudora Shale is a gentle slope in most places,



FIG. 5. Captain Creek Limestone showing resistant nature and massive bedding. East side Five Mile Creek, Shrine Park, sec. 11, T. 9 S., R. 22 E.

locally, for example in the stream bed east of Muncie Cemetery, sec. 7, T. 9 S., R. 23 E., the shale supports a slight ledge.

Stoner Limestone Member

Defined by: Condra, 1930, p. 11

Type locality: Stoner Farm, northwest of South Bend, Nebraska

The Stoner Limestone is the thickest member of the Stanton Limestone and usually forms a prominent ledge. The Stoner consists of many thin wavy beds of light gray to buff, fine-grained limestone. Weathered surfaces are tan or brown and weathering makes the wavy bedding more pronounced. Outcrops of the Stoner Limestone are usually easily found because almost all quarries south of Leavenworth are in the Stoner. The only readily accessible outcrop of the Stoner north of

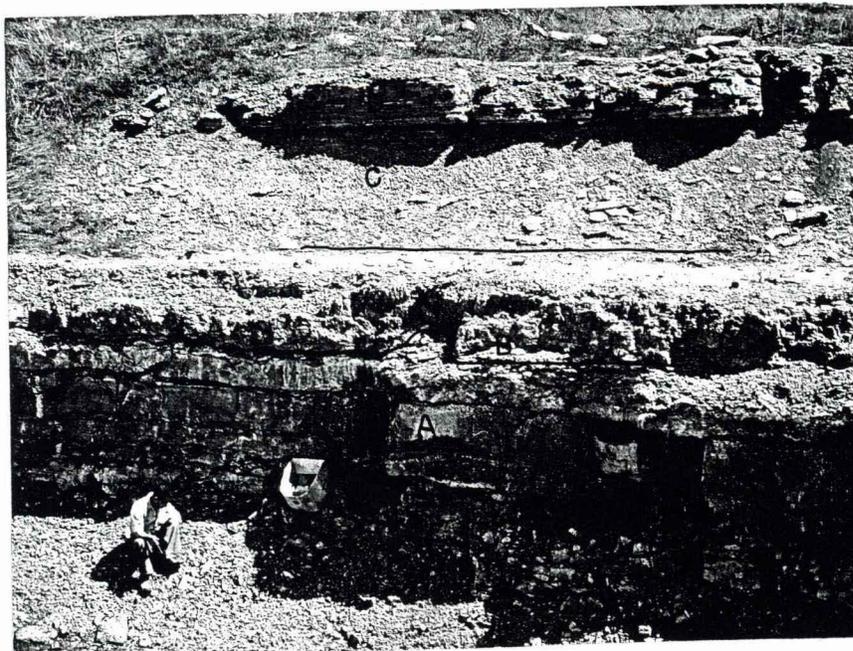


FIG. 6. Upper members of the Stanton Limestone: A, fresh Stoner Limestone; B, weathered top of Stoner Limestone; C, Rock Lake Shale; D, South Bend Limestone. Quarry, SW sec. 30, T. 9 S., R. 23 E., camera facing east.

Leavenworth is located below the Fort Bridge at Fort Leavenworth. The Stoner fauna include Composita, Marginifera, Neospirifer, Juresania, Myalina, fusulinids, horn corals, high-spired gastropods, and echinoid spines. The Stoner is 11 to 15 feet thick.

A weathered zone approximately 1 foot thick, but having an irregular lower surface, caps the Stoner Limestone (Fig. 6). The weathered zone is composed of soft yellow to tan limestone. Locally the weathered zone is replaced by limestone conglomerate that will be discussed with the Rock Lake Shale. The weathering probably took place after the deposition of the Stoner, but before the deposition of the

overlying Rock Lake Shale, and represents a slight disconformity at the end of Stoner time. A similar weathered zone was noted by Ball in Franklin County, Kansas (1957, p. 12).

Rock Lake Shale Member

Defined by: Condra, 1927, p. 59

Type locality: near South Bend, Nebraska

The Rock Lake Shale overlies the minor disconformity at the top of the Stoner Limestone. The disconformable contact between the units is sharp, easily recognized, and shows no more than 6 inches of relief. Typically the Rock Lake consists of 4 to 5 feet of gray to green arenaceous shale that becomes increasingly arenaceous in the upper beds. The lower beds are blocky; the upper beds, flaky. No marine fossils were seen in the Rock Lake but poorly preserved plant remains are common in the upper beds. Many of the upper beds have interference ripple marks that have an amplitude in the order of 1/4 inch. Thin, shaley, discontinuous lenses of limestone (max. thickness 0.8 ft.) and coal (max. thickness 0.2 ft.) are found at random levels in the Rock Lake Shale.

At some localities (Appendix, section 8) the Rock Lake consists of alternating beds of fine-grained sandstone and shale. At these localities the member is up to three times as thick as normal sections. Lenses of limestone are found also in the unusually thick sections.

A conglomerate composed of pebble and granule size discoidal limestone fragments in a silty, sandy, calcareous matrix is developed

locally at the base of the Rock Lake Shale (Appendix, sections 8, 9). Fragments of marine fossils similar to those in the underlying Stoner Limestone are found in the matrix. The maximum thickness of the conglomerate is 1 foot. The conglomerate indicates areas where post-Stoner erosion was most active.

South Bend Limestone Member

Defined by: Condra and Bengston, 1915, p. 23

Type locality: South Bend, Nebraska

The South Bend Limestone is the uppermost member of the Stanton Limestone (Fig. 6). Because the overlying Weston Shale offers little protection, South Bend outcrops are generally not complete. The South Bend is a gray-blue to gray-brown, thin-bedded, highly fossiliferous limestone. Characteristically the lower beds are arenaceous and carry pelecypods. The upper beds are more highly fossiliferous, thin-bedded, fine-grained, clean limestone. Minute shale breaks (less than 0.5 in.) separate many of the beds in the upper thin-bedded part of the South Bend. Fossils found in the South Bend Limestone include: Composita, Chonetes, Derbyia, Juresania, Linoproductus, Meekella, Neospirifer, crinoid columnals, and fusulinids. Complete sections of the South Bend are rare, but where the overlying Weston Shale is present, the South Bend Limestone is 6 to 7 feet thick.

Pedee Group

Defined by: Moore, 1932, p. 93

Type locality: Pedee Branch, near Weston, Missouri

The Pedee is the uppermost Missourian rock group. It is made up of two formations, basally the Weston Shale and uppermost the Iatan Limestone. A third formation, the Hardesty Shale (name proposed for an undiscovered but conjectured unit by Moore, 1932) may be present north of the city of Leavenworth. All complete Pedee sections are north of Leavenworth. The Iatan has been removed everywhere south of the city, and locally the Weston Shale is absent. The Pedee Group is approximately 175 feet thick.

Weston Shale

Defined by: Keyes, 1899, p. 300

Type locality: Weston, Platte County, Missouri

The Weston is a thick shale sequence lying between the top of the Stanton Limestone and the base of the Iatan Limestone. South of the city of Leavenworth the Iatan Limestone and varying amounts of the Weston Shale have been removed by post-Missourian erosion. North of the city of Leavenworth where the Iatan is present, no localities are known where the complete Weston Shale section is exposed, but in this area north of Leavenworth the interval between the top of the Stoner Limestone and the base of the Iatan Limestone is about 60 feet. South of Leavenworth there are many good partial exposures of the Weston (Fig. 7; Appendix, sections 5, 7). The shale is non-fossiliferous, clayey, blocky to platy, and bluish-gray in color. Locally discoidal ironstone concretions, 6 to 10 inches in diameter, have formed parallel to the



FIG. 7. Weston Shale with thin limestone beds. South bank of Seven Mile Creek, SE sec. 23, T. 9 S., R. 22 E.

bedding planes. Highly fossiliferous shaley limestone beds occur at some localities, but unfortunately these limestone beds do not have an areal extent great enough to be used for correlation within the Weston. The fossils found in the limestone beds are all small and include Hustedia, high-spired gastropods, and crinoid columnals.

Iatan Limestone

Defined by: Keyes, 1899, p. 300

Type locality: Iatan, Platte County, Missouri

Because of post-Missourian erosion the Iatan is present only north of the city of Leavenworth. Where present, the Iatan forms a

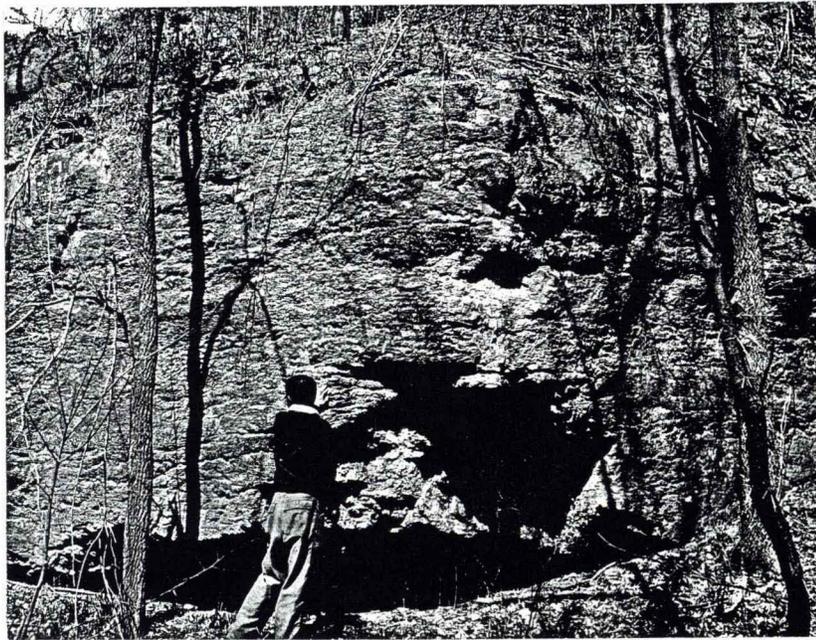


FIG. 8. Iatan Limestone showing characteristic rough weathered surface. Northwest side of creek bed, NE sec. 33, T. 7 S., R. 22 E.

prominent ledge because of its thickness and its dense, hard, massive nature. Bedding surfaces are poorly defined in both fresh and weathered outcrops. Much of the limestone appears to have been brecciated and recemented by limestone. The colors of the Iatan range from light to dark gray on fresh surfaces, and weathered surfaces have a mottled reddish-brown color. Numerous veinlets about 1/16 inch thick (max.) occur in the Iatan. These veinlets are predominantly parallel to the bedding but can be seen running in all directions. Weathered surfaces are rough owing to differential removal of calcite and limestone (Fig. 8). Other than algal beds, which are common, fossils are rare.

PENNSYLVANIAN SYSTEM-VIRGILIAN SERIES

Defined by: Moore, 1932, p. 89

Type locality: Southeastern Kansas, name derived from Virgil,
Greenwood County, Kansas

All Pennsylvanian rocks exposed in northern Leavenworth County above the Iatan Limestone belong to the Virgilian Series. Only Lower Virgilian rocks, the Douglas and Shawnee Groups, crop out in the area mapped. In northeastern Leavenworth County approximately 350 feet of Virgilian rocks are exposed.

Douglas Group

Defined by: Haworth, 1898, p. 93; Moore, 1932, p. 93

Type locality: Douglas County, Kansas

As defined by Moore (1932, p. 93) the Douglas Group includes all beds between the disconformity at the base of the Virgilian Series and the base of the Oread Limestone (Fig. 9). These boundaries are recognized easily. The boundaries of the formations and members within the Douglas Group are not generally recognized easily. Because of numerous facies changes and poor outcrops the relationship between members of the group is not always clear. In Plate 1 the whole Douglas Group is represented by a single pattern, because the limits of the formations within the Douglas can be determined only where the Haskell Limestone can be identified.

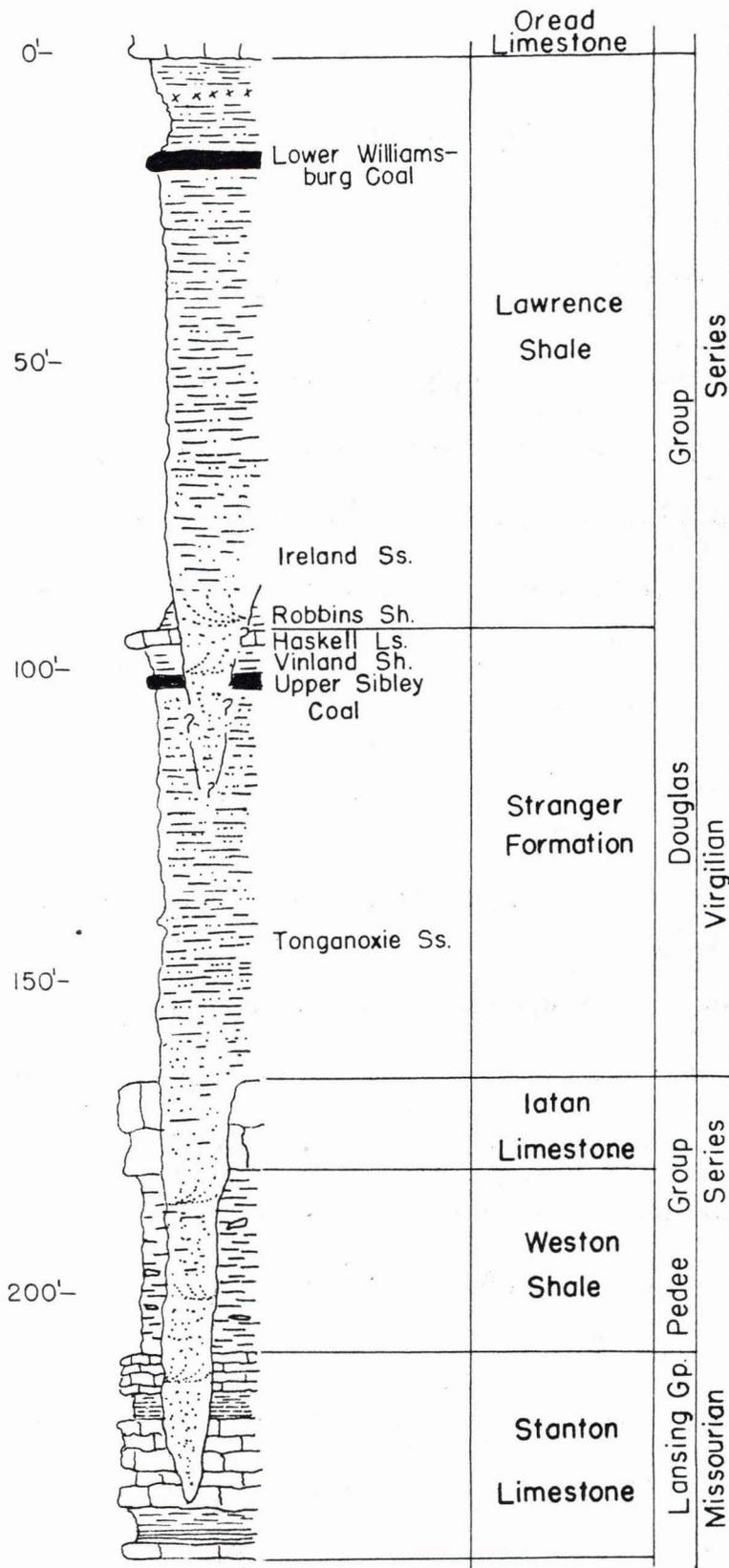


FIG. 9. Generalized stratigraphic section of Douglas Group rocks exposed in Leavenworth County.

The disconformity marking the base of the Virgilian Series is a surface of considerable relief. Rocks of the Douglas Group are in contact with rocks ranging from the Iatan Limestone down to the Stanton Limestone. The lowermost Douglas Rocks characteristically are sandstone that can be distinguished readily from the limestone and shale of the underlying Pedee and Lansing Groups (Fig. 10).

In a small area north of the city of Leavenworth the best location for the base of the Virgilian Series is debatable. In sec. 3, T. 8 S., R. 22 E. the Iatan Limestone is overlain by clay shale that contains a coal bed near the top. This shale could represent either the hypothetical Missourian unit for which the name Hardesty Shale was proposed (Moore, 1932, p. 97), or it could represent basal Virgilian deposition. If the coal bed indicates a continental environment, then the shale is probably a facies of the predominantly continental lower Douglas Group. The irregular contact (Fig. 11) between the shale and the Iatan Limestone also suggests that the shale is part of the Douglas Group.

The upper boundary of the Douglas Group is clearly marked by the Toronto Limestone member of the Oread Limestone, which is continuous throughout the area studied.

Stranger Formation

Defined by: Newell in Moore, 1932, p. 93; Moore, 1936, p. 147
Type locality: Stranger Creek, central Leavenworth County, Kansas

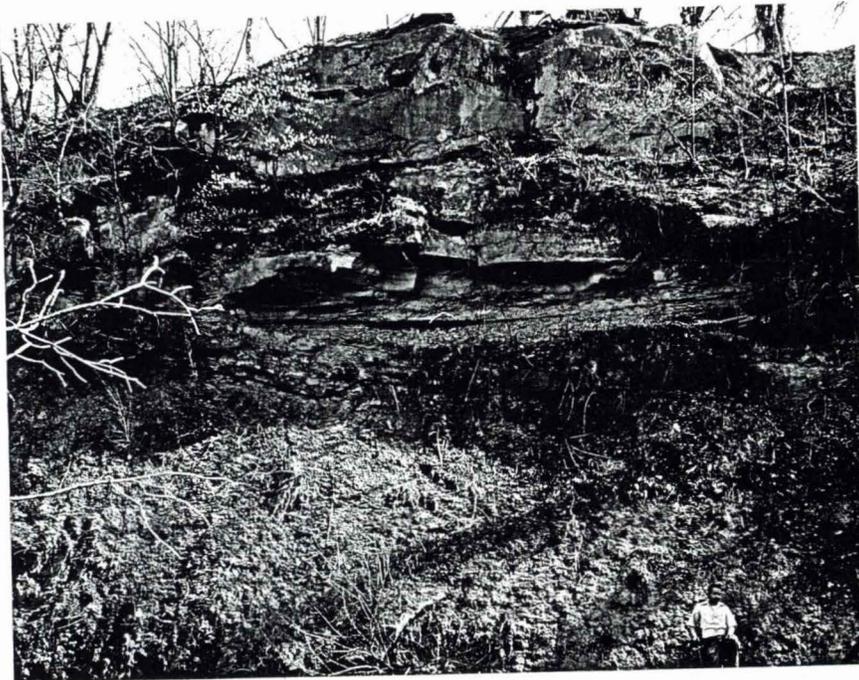


FIG. 10. Tonganoxie Sandstone overlying Weston Shale; note the irregular contact. West side of creek, near cen. east line, sec. 36, T. 9 S., R. 22 E.

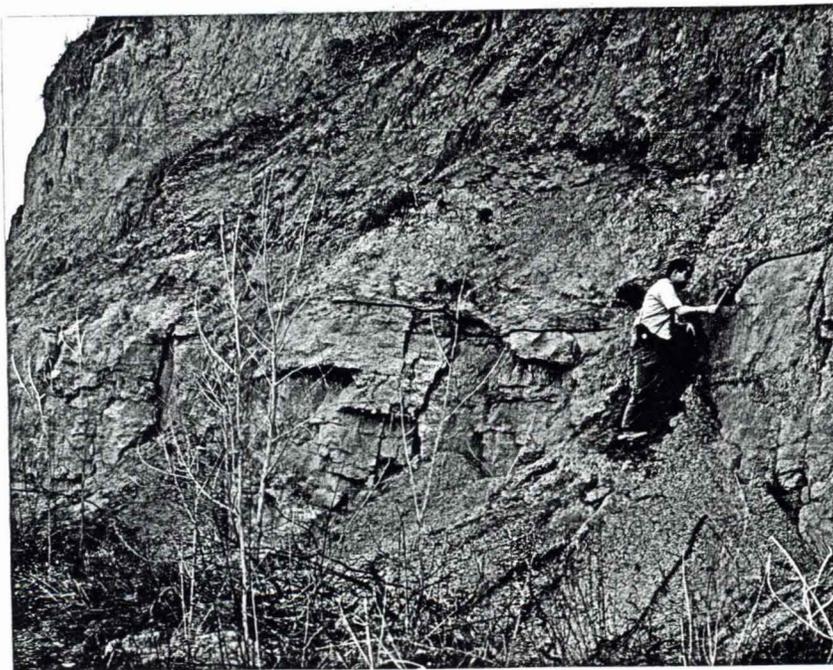


FIG. 11. Iatan Limestone and overlying shale. Note irregular contact between shale and limestone. Abandoned quarry, south side Plumb Creek, SE sec. 24, T. 6 S., R. 22 E.

$NW\frac{1}{4}SW\frac{1}{4}NE\frac{1}{4}$ sec. 3, T. 8 S., R. 22 E.

The Stranger Formation is described as a series of "non-marine and marine beds of the lower part of the Douglas Group extending upward from the base of the Virgilian rocks to a disconformity at the base of the Lawrence Formation," (Moore, 1949, p. 129). In northeastern Leavenworth County the disconformity at the base of the Lawrence Shale cannot be definitely identified. Recognizing this problem, Moore (1951, p. 72) suggested using the top of the Haskell Limestone for an alternate top of the Stranger Formation. Throughout much of the area studied the Haskell Limestone may be absent and neither definition of the Stranger Formation can be applied. However, in this report, the top of the Haskell is used to denote the top of the Stranger Formation.

As defined by the Kansas State Geological Survey (Moore and others, 1951) the Stranger Formation includes (in ascending order) the Tonganoxie Sandstone, Westphalia Limestone, Vinland Shale, Haskell Limestone, and Robbins Shale members. None of the members can be traced without interruption through northeastern Leavenworth County. Positive identification of the Westphalia Limestone has not been made in Leavenworth County. In this report the Robbins Shale is considered to be a member of the Lawrence Shale.

Tonganoxie Sandstone Member

Defined by: Moore, Elias, and Newell, 1934

Type locality: East of Tonganoxie, Leavenworth County, Kansas

After detailed study of the Tonganoxie Sandstone in Douglas and Leavenworth Counties, Lins (1950, p. 117) concluded, "The Tonganoxie Sandstone represents the filling of a large southwest-trending valley." In that study Lins (p. 119) recognized four lithologic units in the Tonganoxie Sandstone: basal conglomerate, sandstone (Fig. 12), shale, and coal. All of these units can be recognized in northeastern Leavenworth County. The basal conglomerate is not continuous. It is developed best where the disconformity at the base of the Virgillian has cut deep into the Stanton Limestone. The conglomerate consists of well-rounded discoidal limestone fragments and clay balls up to 1 inch in diameter in a sandy calcareous matrix with many fossil fragments also in the matrix. This basal conglomerate is only a few inches thick. Tan to dark reddish-brown quartz sandstone is the dominant rock type of the Tonganoxie Sandstone. The quartz grains are angular to subangular and poorly cemented by clay. Lins (p. 122) reports three types of sandstone, "(1) festooned cross-bedded siltstone and sandstone; (2) massive-bedded siltstone and sandstone; and (3) thin-bedded argillaceous siltstone, sandstone, and sandy shale." The composition of all three sandstones is similar, except for more fine material in the thin-bedded type. Because the base of the Tonganoxie Sandstone is so irregular, the thickness of the sandstone unit is variable. Locally, commonly associated with slumped zones, ironstone concretions up to 1 foot in diameter have developed in the sandstone unit. The shale unit of the Tonganoxie grades upward from the thin-bedded sandstone.

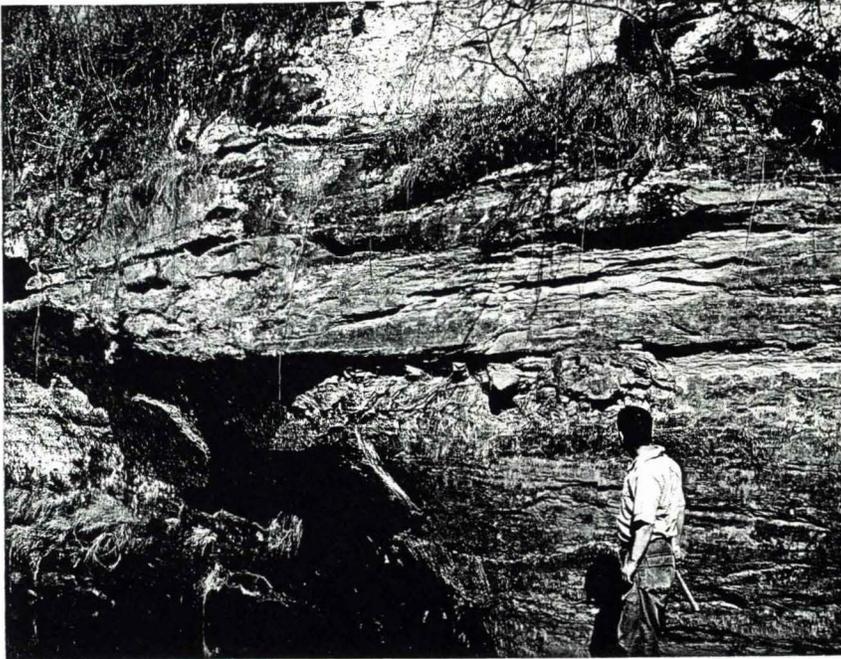


FIG. 12. Typical outcrop of massive Tonganoxie Sandstone. The mottled appearance of the sandstone is caused by moss. East side of stream, SW sec. 10, T. 9 S., R. 22 E.

The shale is commonly brown silty shale or gray clayey shale. The shale unit is 10 to 20 feet thick. The coal unit of the Tonganoxie Sandstone is the Upper Sibley Coal (Patterson, 1933, p. 12; Bowsher and Jewett, 1943, p. 43; Lins, 1950, p. 125). The Upper Sibley Coal is 1 to 1.5 feet thick. Figure 13 illustrates the relationship between the lithologic units of the Tonganoxie Sandstone.

Westphalia Limestone Member

Defined by: Moore and Newell. in Moore, 1936, p. 150
 Type locality: near Westphalia, Anderson County, Kansas

In its type area the Westphalia Limestone member is 5 feet thick and contains abundant fusulinids (Moore, 1936, p. 150; Moore and others,

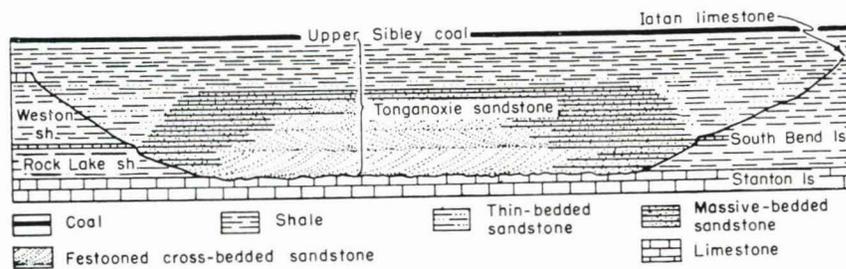


FIG. 13. Diagrammatic cross section showing the relation of Tonganoxie Sandstone to Tonganoxie Valley (from Lins, 1950, p. 124).

1951, p. 73). No limestone fitting this description crops out in northeastern Leavenworth County. A thick calcareous zone about 20 feet above the Upper Sibley Coal (Appendix, section 4) may represent the Westphalia Limestone. Lins (1950, p. 114) believes the Westphalia Limestone is represented by a thin highly fossiliferous limestone bed 3 to 4 inches above the Upper Sibley Coal. I believe that positive correlation with known Westphalia Limestone is not possible, and in northeastern Leavenworth County all beds between the Upper Sibley Coal and the Haskell Limestone should be assigned to the Vinland Shale.

Vinland Shale Member

Defined by: Patterson and Addison in Moore, 1936, p. 151; Moore and Newell in Moore, 1936, p. 151.

Type locality: Northeast of Vinland, Douglas County, Kansas

By definition the Vinland Shale includes all beds below the Haskell Limestone and above the Westphalia Limestone, or in the absence of the Westphalia Limestone, above the Upper Sibley Coal. In northeastern

Leavenworth County the top of the Upper Sibley Coal is used to denote the base of the Vinland Shale. The only good exposure of the Vinland Shale is on the south side of Plumb Creek in the center of sec. 4, T. 8 S., R. 22 E. (Appendix, section 4). At this locality the Vinland is made up of three units with a total thickness of 47 feet. The lower unit is a dark gray clay shale that grades downward into the Upper Sibley Coal.

Scattered molluscs are found in the lower unit. The middle unit is a series of alternating beds of shale and limestone. The shale is dark gray, calcareous, and slightly silty. The limestone beds are silty, shaley, and dark gray. No fossils were found in either the limestone or shale. The exact position of the limestone beds is difficult to determine, and it may be that they are not continuous even at this locality. The middle calcareous unit is 17 feet thick. The upper unit consists of 12 feet of barren, clayey, dark gray shale with a silty calcareous top.

Haskell Limestone Member

Defined by: Moore, 1932, p. 93
Type locality: Lawrence, Kansas

The Haskell Limestone is the best stratigraphic marker in the Douglas Group. Brachiopods (Marginifera, Dictyoclostus, Neospirifer), Myalina, crinoid columnals, and algae are the most common fossils in the Haskell Limestone. Fusulinids are present but rare. The upper surface of the Haskell has many irregular depressions.

North of the city of Leavenworth the Haskell Limestone has three units (Appendix, section 4). The basal unit is wavy-bedded, algal,

argillaceous, light brown limestone. In addition to algae, brachiopods are common. The lower unit is 2.3 feet thick. The middle unit is thin-bedded, dark gray limestone. Crinoid stems are profuse in the middle unit. The middle unit is 2.5 feet thick. The upper unit is distinguished from the middle unit only by much thinner beds. The upper unit is 1.5 feet thick.

In the southern part of the area studied, thin even-bedded Haskell is much less common. Locally the Haskell Limestone is made up of thin regular beds, but irregular bedding (Fig. 14; Appendix, section 3) is more common. In the south the Haskell is more algal and contains Myalina.

Lawrence Shale

Defined by: Haworth, 1894, p. 122; Newell in Moore, 1936, p. 155
Type locality: Lawrence, Kansas

The Lawrence Shale is restricted to rocks above the disconformity at the base of the Ireland Sandstone and below the Oread Limestone. The Lawrence Shale, as defined by the Kansas State Geological Survey (Moore and others, 1951), has two named members: Ireland Sandstone and Amazonia Limestone. However, in this report the Robbins Shale also is considered to be a member of the Lawrence Shale. The Amazonia Limestone does not crop out in northeastern Leavenworth County.

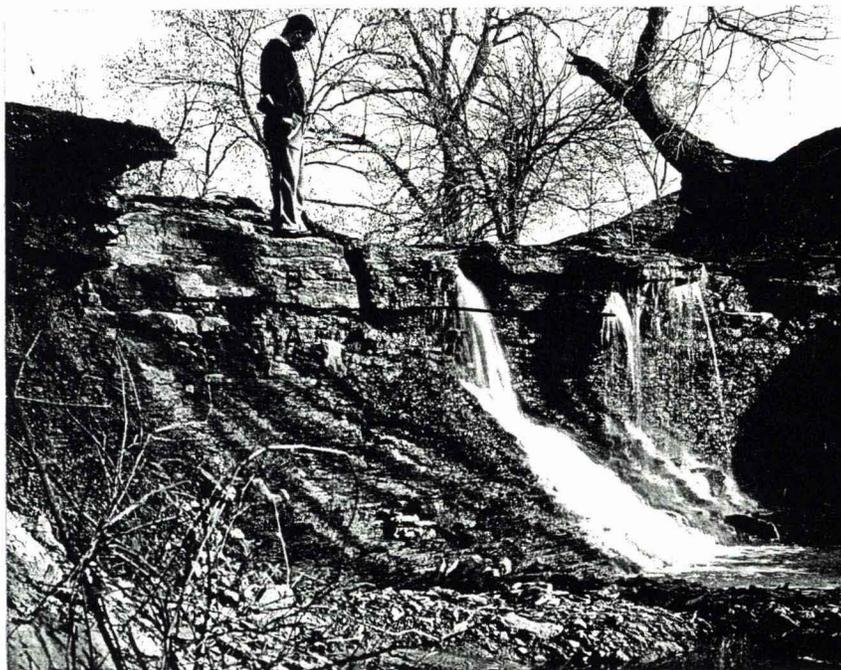


FIG. 14. Haskell Limestone capping small waterfall; A, Vinland Shale, B, Haskell Limestone. Note irregular bedding. NE sec. 36, T. 9 S., R. 21 E., camera facing north.

Robbins Shale Member

Defined by: Moore and Newell in Moore, 1936, p. 156

Type locality: Southwest of Yates Center, Woodson County, Kansas

By definition the Robbins Shale includes all beds between the Haskell Limestone and the disconformity at the base of the Lawrence Shale. This disconformity has not been positively identified in northeastern Leavenworth County. A thin discontinuous shale unit above the Haskell Limestone was correlated with the Robbins Shale by Reynolds (1957, p. 24).

Three lithologic types are present in the rocks immediately above the Haskell Limestone. Phosphatic nodules occupy the depressions in the top of the Haskell. One foot of yellowish-gray fossiliferous shale overlies the nodules. Overlying the shale is a 2 to 4 inch goethite bed that also

contains marine fossils. The goethite bed is overlain and underlain by similar shales. Reynolds used the goethite bed to mark the disconformity at the base of the Lawrence Shale. A detailed study by Miller and Swineford (1957, pp. 2012-2036) indicated that the significant break in deposition in this part of the section occurred immediately after the deposition of the Haskell Limestone.

Even though the Robbins Shale has been identified in the area studied, and even though the goethite bed may represent a slight disconformity, in this report the top of the Haskell Limestone is used to denote the top of the Stranger Formation for the following reasons: (1) the most significant break in deposition in this part of the section is at the top of the Haskell Limestone and not at the goethite bed; (2) if the most significant break is at the top of the Haskell Limestone, the "Robbins Shale" above the Haskell Limestone is more closely related to the overlying rocks and should be a member of the Lawrence Shale; (3) the Robbins Shale is too thin and discontinuous for practical mapping.

Ireland Sandstone Member

Defined by: Moore, 1932, p. 93

Type locality: Southwest of Yates Center, Woodson County, Kansas

Lithologically the Ireland Sandstone is the same as the Tonganoxie Sandstone. Lins (1950, p. 129) and Sanders (1957, p. 23) report that the Ireland and Tonganoxie Sandstones are virtually indistinguishable. Sanders (p. 24) suggests that they might be separated after detailed laboratory studies of their physical properties. In northeastern

Leavenworth County, where the Haskell Limestone can be identified, there is no typical massive or cross-bedded Ireland Sandstone. The basal 30 to 40 feet of the Lawrence Shale is a series of sandy shale beds not unlike the upper Tonganoxie shale unit described by Lins (1950, p. 124).

Lins (p. 126) illustrates a stratigraphic section in T. 9 S., R. 21 E. (within the area covered by this report) that has an abnormally thick sandstone sequence. He interpreted this to be an area where the Ireland Sandstone rests disconformably on the Tonganoxie Sandstone, and the Haskell Limestone was removed by erosion. I could not locate the section. There is not enough field evidence to indicate whether the Haskell Limestone is absent because of nondeposition or because of erosion. In fact there is not enough field evidence to prove if the Haskell is absent at all. Previously unknown outcrops of the Haskell Limestone, found during this study, suggest to me that the Haskell is probably continuous throughout the area. Outcrops in this part of the stratigraphic section are poor and well data will be required to determine the nature of the concealed rocks.

The sandy shale and small sandstone lenses of the lower Lawrence Shale grade imperceptibly into much less sandy shale of the upper Lawrence Shale. The upper Lawrence is predominantly a blue-gray clay shale without fossils. Sandy beds and minute carbonaceous layers are scattered throughout the shale. Because a gentle slope is commonly developed on the Lawrence Shale, outcrops of the Lawrence are rare.

There are two persistent horizons in the upper Lawrence Shale. A coal bed 6 to 12 inches thick occurs 30 to 50 feet below the Oread



FIG. 15. Lawrence Shale and Lower Williamsburg Coal. At this locality the surface of the coal is bleached white. South bank Cramer Creek, NE sec. 30, T. 8 S., R. 21 E.

Limestone. This coal probably is the equivalent of the Lower Williamsburg Coal (Fig. 15). The upper key horizon is a maroon zone 5 to 10 feet below the Oread Limestone.

Shawnee Group

Defined by: Haworth, 1898, p. 93; Moore, 1936, p. 159

Type locality: Shawnee County, Kansas

As presently defined, the Shawnee Group (Moore and others, 1951) includes all rocks from the base of the Oread Limestone to the top of the Topeka Limestone. Only the three lower formations (Oread Limestone, Kanwaka Shale, and Lecompton Limestone) of the Shawnee Group are exposed in the area studied (Fig. 16).

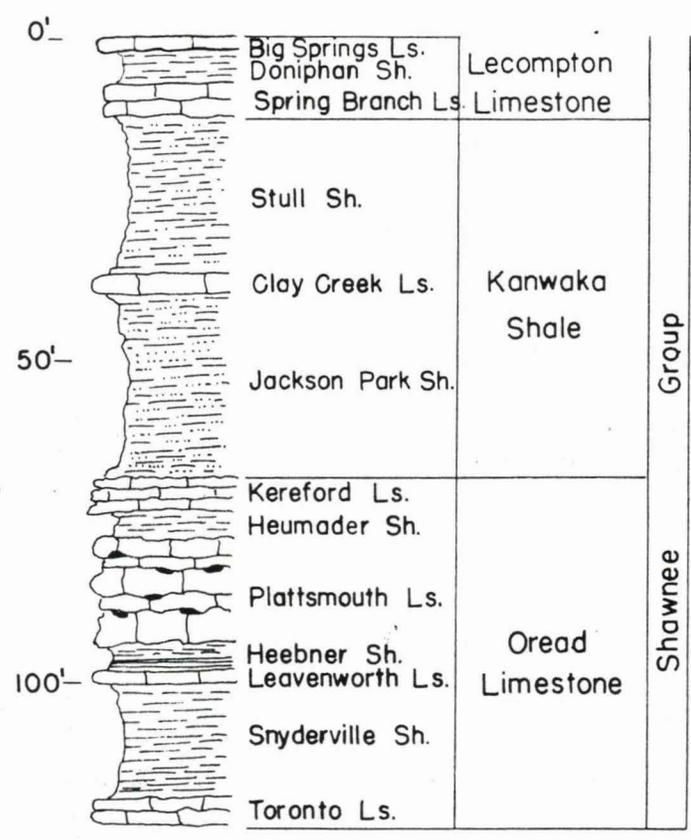


FIG. 16. Generalized stratigraphic section of Shawnee (Virgilian) Group rocks exposed in northeastern Leavenworth County.

Oread Limestone

Defined by: Haworth, 1894, p. 123; 1895, p. 461

Type locality: Mount Oread, Lawrence, Douglas County, Kansas

In northeastern Kansas the Oread Limestone forms a prominent east-facing escarpment. The members of the Oread are (in ascending order) Toronto Limestone, Snyderville Shale, Leavenworth Limestone, Heebner Shale, Plattsmouth Limestone, Heumader Shale, and Kereford Limestone. The upper and lower contacts of the Oread Limestone are essentially conformable. The average thickness of the Oread is 60 feet.

Toronto Limestone Member

Defined by: Haworth and Piatt, 1894, p. 117

Type locality: Toronto, Woodson County, Kansas

The Toronto Limestone is the basal member of the Oread Limestone. The most distinguishing characteristics of the Toronto are the rich brown color of weathered surfaces, the massive outcrops (Fig. 17), and the abundance of fusulinids. Fresh surfaces are tan to gray. Locally the upper beds are dark blue dense limestone that resembles the Leavenworth Limestone. The Toronto is fine-grained, usually abundantly fossiliferous, and has poorly defined slightly irregular bedding surfaces. Crinoid fragments, fusulinids (especially near the top), bryozoans, and brachiopods (Dictyoelostus, Composita, Neospirifer, Chonetes), are the most common fossils. Algal beds are common, particularly near the top of the member (Appendix, section 2). The thickness of the Toronto

Limestone ranges from 5 to 8 feet.

Snyderville Shale Member

Defined by: Condra, 1927, p. 38

Type locality: Snyderville Quarry, west of Nehawaka, Nebraska

Outcrops of the Snyderville Shale are rare because the typical topographic expression of the Snyderville is a gentle slope. Where exposed, the Snyderville is an essentially barren, blocky, clay shale. The color of the shale is green throughout the lower half, becomes blue-gray in the middle, and the uppermost few feet are gray or brown. No fossils were identified from the Snyderville, however, a few shell fragments were found near the top. The thickness of the Snyderville Shale ranges from 10 to 17 feet. The best exposure of the Snyderville in northeastern Leavenworth County is illustrated in Figure 17.

Leavenworth Limestone Member

Defined by: Condra, 1927, p. 38

Type locality: Leavenworth, Leavenworth County, Kansas

The Leavenworth is one massive layer, 1.5 to 2.5 feet thick, of dense, dark blue, finely crystalline limestone (Fig. 17; Appendix, sections 1, 2). Prominent vertical joints cause the upper surface to have the appearance of paving blocks (Fig. 30). Fossils, although not abundant, are found easily in the Leavenworth Limestone. Scattered fusulinids are present in all outcrops. Other fossils include gastropods, pelecypods, brachiopods, and echinoid spines.

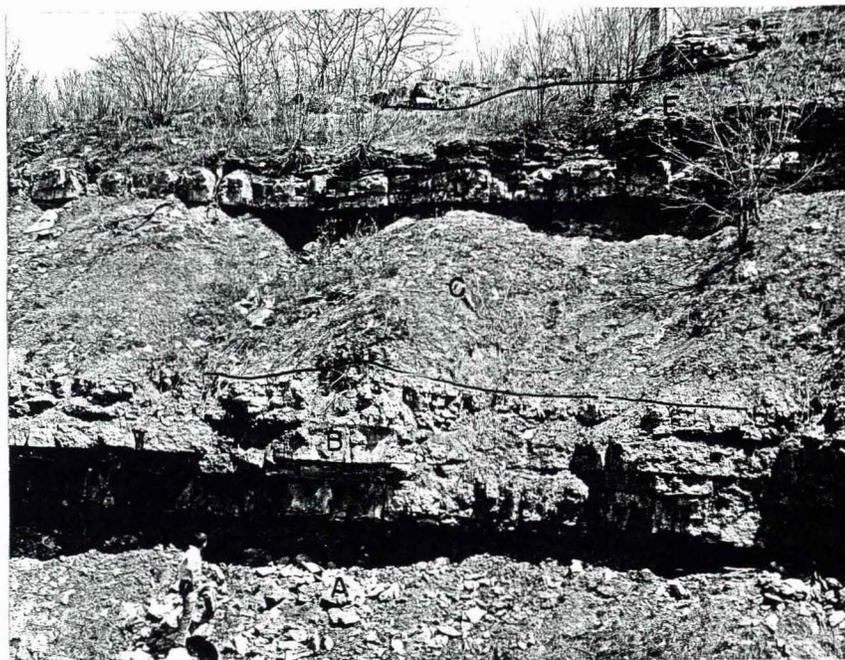


FIG. 17. Lower Oread Limestone at Leavenworth Limestone type locality. Note the massive bedding in the Toronto Limestone and the ledge formed by the Leavenworth Limestone and the Heebner Shale. A, Lawrence Shale; B, Toronto Limestone; C, Snyderville Shale; D, Leavenworth Limestone; E, Heebner Shale; F, Plattsmouth Limestone. North side road cut, Government Hill, NW sec. 22, T. 8 S., R. 22 E.

Heebner Shale Member

Defined by: Condra, 1927, p. 37

Type locality: Heebner Creek, west of Nehawka, Nebraska

The lower 2 or 3 feet of the Heebner Shale (Appendix, sections 1, 2) are black, hard, platy, easily recognized shale. Phosphatic nodules ranging in size from microscopic to 1/2 inch are common in the black shale. Gray to brown, fissile shale, which is blocky near the top, overlies the black shale. The Heebner is 4 to 5.5 feet thick. No megafossils occur in the Heebner, but there are conodonts in the black shale.

At some localities the hard platy base of the Heebner Shale and the underlying Leavenworth Limestone form a single ledge (Fig. 17).

Plattsmouth Limestone Member

Defined by: Keyes, 1899, p. 306; Condra, 1927, p. 37

Type locality: Plattsmouth, Nebraska

The Plattsmouth Limestone member is the most prominent ledge former and the thickest member of the Oread Limestone. Almost all quarries in the western and northern parts of the area studied are in the Plattsmouth Limestone. The average thickness of the Plattsmouth is 15 feet, but the thickness ranges from 10 to 20 feet. Weathered surfaces exhibit highly irregular bedding in almost white, fine-grained limestone. Fresh surfaces, such as found in active quarries, are light gray and appear more massive (Fig. 18). Black chert nodules with enclosed fusulinids are peculiar to the Plattsmouth. In addition to fusulinids, brachiopods (Hustedia, Neospirifer, Dictyoclostus, Composita, Enteletes), bryozoans, and crinoid fragments are common.

Heumader Shale Member

Defined by: Moore, 1932, p. 96

Type locality: Heumader Quarry, north of St. Joseph, Missouri

The Heumader is dark gray to green, blocky to thin-bedded, locally sandy shale. Outcrops of the Heumader are poor; the interval between the Kereford Limestone and the Plattsmouth Limestone is commonly covered. No fossils were observed in the Heumader Shale.

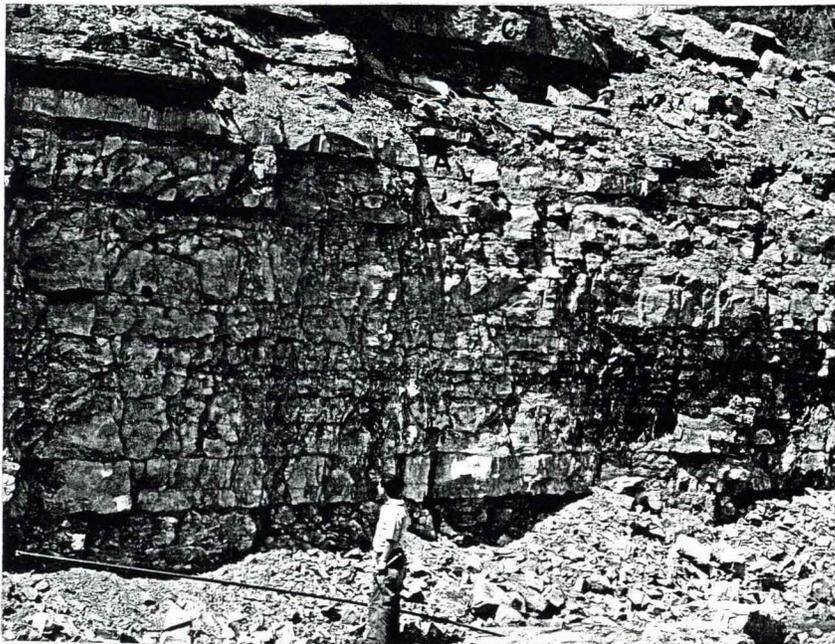


FIG. 18. Upper Oread Limestone; A, Plattsmouth Limestone; B, Heumader Shale; C, Kerford Limestone. Cen. sec. 12, T. 8 N., R. 21 E., camera facing southwest.

The thickness ranges from a featheredge to 11 feet. The best Heumader outcrops in northeastern Leavenworth County are illustrated in Figure 18 and in the Appendix (section 1).

Kerford Limestone Member

Defined by: Condra, 1927, p. 45

Type locality: Kerford Quarry, Atchison, Kansas

The Kerford is the most variable limestone exposed in northeastern Leavenworth County. Throughout much of the area the Kerford consists of 1 to 2 feet of dense blue limestone that has a light brown weathered surface. At other localities it is light gray with many shale partings. Locally there are massive algal beds. At most localities the Kerford Limestone is highly fossiliferous (Fig. 19). Common fossils

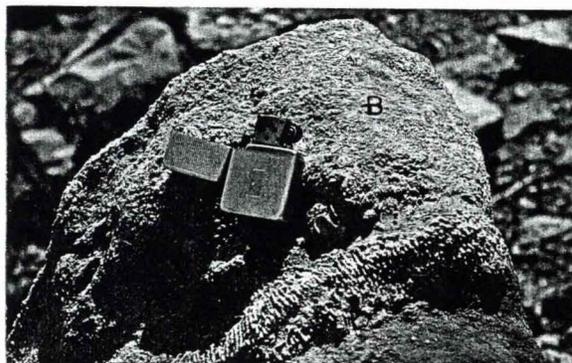


FIG. 19. Fossils from the Kereford Limestone: A, *Fistulipora*; B, unidentified bryozoans; C, bedding surface with many brachiopods. All fossils collected at the quarry illustrated in Figure 18.

include: fusulinids, large crinoid columnals, bryozoans, algae, and brachiopods. Three small specimens of Ameura were collected from Kereford outcrops in the center of sec. 32, T. 8 S., R. 21 E.

Kanwaka Shale

Defined by: Adams in Adams, Girty, and White, 1903, p. 163
Type locality: Kanwaka Township, Douglas County, Kansas

All beds between the top of the Oread Limestone and the base of the Lecompton Limestone belong to the Kanwaka Shale. The members of the Kanwaka Shale are (in ascending order) Jackson Park Shale, Clay Creek Limestone, and Stull Shale. The thickness of the Kanwaka is approximately 50 feet.

Jackson Park Shale Member

Defined by: Moore, 1932, p. 96
Type locality: Jackson Park, Atchison, Kansas

The Jackson Park Shale is bounded by the Kereford Limestone at the bottom and the Clay Creek Limestone at the top. Four units can be distinguished at the best exposure of the Jackson Park (Appendix, section 1). The lowermost unit consists of 11 feet of gray to green, platy, micaceous, highly arenaceous, ripple-marked shale. In the second unit thin-bedded gray to tan calcareous shale alternates with massive sandstone lenses up to 1.5 feet thick. The second unit is four feet thick and becomes increasingly sandy upward. The third unit is a thin (0.8 ft.), discontinuous, shaley, micaceous limestone. The limestone does not form a continuous

layer, but there are a series of calcareous lenses all at about the same horizon. Excellent cone-in-cone structure is found in some of the shaley parts of this unit. The uppermost unit is gray to tan shale with numerous sand lenses. The top unit is 14 feet thick. Plant fossils were found in float below the Jackson Park, but I do not know if they came out of the Jackson Park Shale or the overlying Stull Shale. Elsewhere in the area studied the Jackson Park Shale has similar units although the thicknesses are slightly different.

Clay Creek Limestone Member

Defined by: Moore, 1932, p. 96

Type locality: Clay Creek, west of Atchison, Kansas

This massive (Fig. 20), dense, blue limestone is an excellent horizon marker. The characteristics of the Clay Creek Limestone are constant throughout the area studied. The appearance of the Clay Creek Limestone is similar to the Leavenworth Limestone. The Clay Creek Limestone is 1.5 to 2.5 feet thick, very hard, has prominent vertical joints, and contains fusulinids. Unlike the Leavenworth Limestone, the Clay Creek Limestone has a profuse fauna. Fusulinids, brachiopods, and crinoid fragments are the most abundant fossils.

Stull Shale Member

Defined by: Moore, 1932, p. 96

Type locality: near Stull, Douglas County, Kansas

Three lithologic units can be distinguished in the Stull Shale (Appendix, section 1). The lowest unit is noncalcareous, only slightly



FIG. 20. Typical massive Clay Creek Limestone. Near Easton Cemetery, NW sec. 19, T. 8 S., R. 21 E.

sandy, gray shale. The middle unit is a thin (1 foot), massive, fine-grained, tan to brown sandstone. The upper unit of the Stull Shale consists of gray to tan slightly arenaceous shale. At some localities a thin coal bed is present 1 to 5 feet below the top of the member. No fossils were found in the Stull. The thickness of the Stull Shale ranges from 25 to 30 feet.

Lecompton Limestone

Defined by: Bennett, 1896, p. 116; Condra, 1927, p. 44
 Type locality: Lecompton, Douglas County, Kansas

The Lecompton Limestone is a series of limestone and shale members between the Kanwaka Shale and Tecumseh Shale. Only the

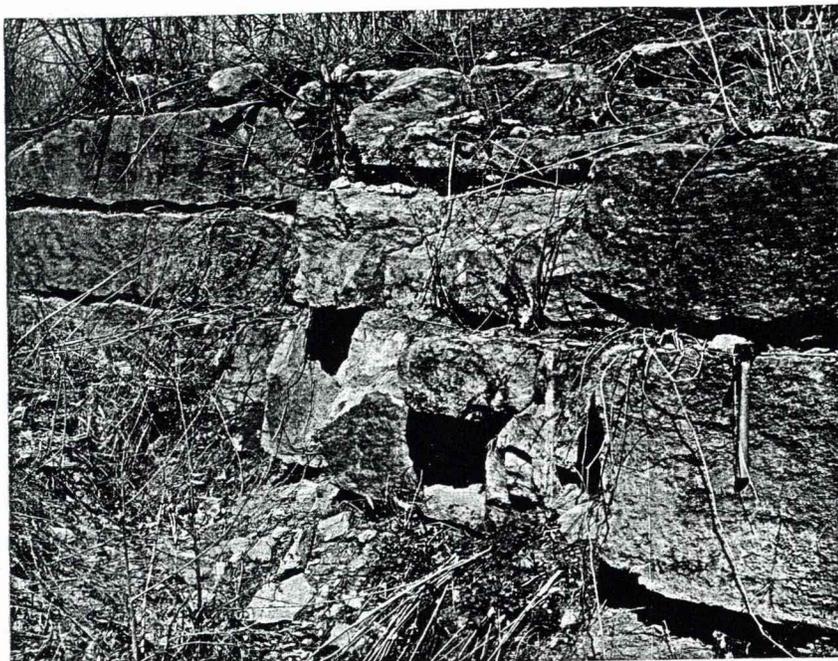


FIG. 21. Typical massive-bedded Spring Branch Limestone. North side of road, NW sec. 19, T. 6 S., R. 21 E.

three lower members of the Lecompton (in ascending order: Spring Branch Limestone, Doniphan Shale, and Big Springs Limestone) are exposed in the area studied. The best outcrops of the Lecompton are in the northwestern part of the area.

Spring Branch Limestone Member

Defined by: Condra, 1927, p. 47

Type locality: Spring Branch, Douglas County, Kansas

The Spring Branch Limestone resembles the Toronto Limestone member of the Oread Limestone. Like the Toronto, the Spring Branch is massive (Fig. 21), indistinctly and irregularly bedded, highly fossiliferous, and weathers brown. In addition to fusulinids, which are very

abundant, brachiopods, crinoid fragments, and bryozoans are profuse. In northeastern Leavenworth County the average thickness of the Spring Branch Limestone is 5 feet.

Doniphan Shale Member

Defined by: Condra, 1927, p. 47

Type locality: Northern Doniphan County, Kansas

Because no locations are known where the Doniphan is not mostly covered by glacial debris and vegetation, it can only be described very briefly. The Doniphan is gray to green, blocky, unfossiliferous shale, 7 to 10 feet thick.

Big Springs Limestone Member

Defined by: Condra, 1927, p. 47

Type locality: Big Springs, Douglas County, Kansas

Like the underlying Doniphan Shale, most outcrops of the Big Springs Limestone are partially covered by till. The Big Springs is a dense, dark gray-blue, massive bed, 2 feet thick. Abundant fusulinids are the most characteristic fossil. Like the Leavenworth Limestone and the Clay Creek Limestone, the Big Springs has prominent vertical joints. Float from the Big Springs Limestone is common in the northwestern part of the area. The float blocks have a yellowish surface color and are somewhat rounded (Fig. 22).

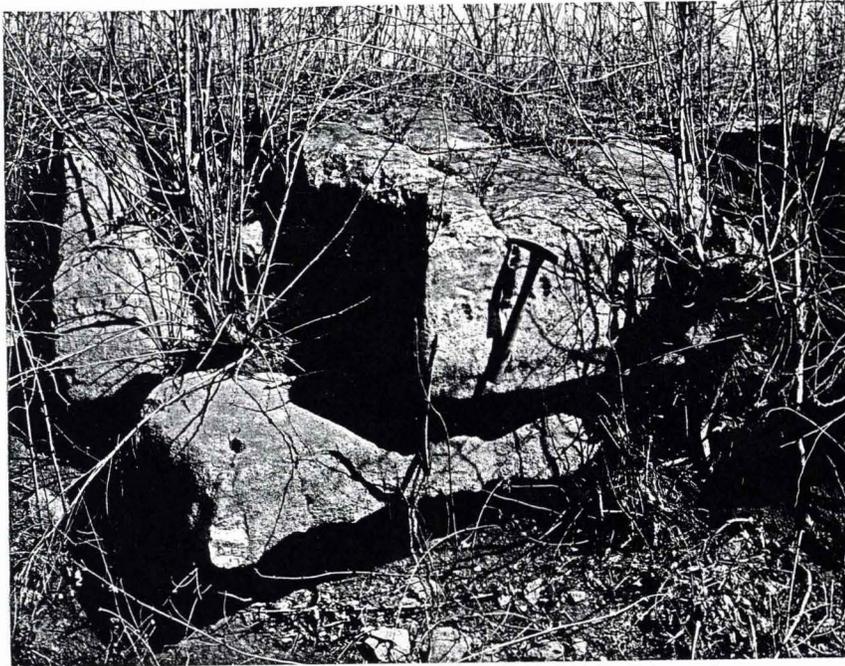


FIG. 22. Float blocks of the Big Springs Limestone. Note the massive bedding and rounded corners. North side of road, NW sec. 19, T. 8 S., R. 21 E.

QUATERNARY SYSTEM-PLEISTOCENE SERIES

The relationship between the units within the Pleistocene deposits of northeastern Kansas is complex. The Pleistocene deposits are not lithified; contain a great variety of sediments; commonly are covered by vegetation; are subject to slump; and are difficult to correlate. It is not within the scope of this study to try and unravel the Pleistocene stratigraphy of northeastern Leavenworth County. The best and most recent report covering the Pleistocene of Kansas was made by Frye and Leonard (1952).

Kansan Stage

According to Frye and Leonard (1952, p. 54, 57, Pl. 1) the oldest Pleistocene deposits in Leavenworth County are probably of Kansan age. Three Kansan formations (in ascending order: Atchison Formation, Kansan Till, and Mead Formation) are recognized in northeastern Kansas. In northeastern Leavenworth County the Atchison Formation is probably present, Kansan Till is definitely present, but the Mead Formation has never been recognized (Frye and Leonard, 1952, p. 90).

Atchison Formation

Defined by: Moore and others, 1951, p. 15
Type locality: Atchison, Kansas

The Atchison Formation consists of silt, sand, and gravel deposited by pro-glacial streams (Moore and others, 1951, p. 15). Although sediments of this type are present in northeastern Leavenworth County, they cannot be practically differentiated from the overlying Kansan Till that may have the same lithology. Therefore all Kansan deposits are indicated as Kansas Till in Plate 1.

Kansan Till

Defined by: Chamberlin, 1894
Type locality: none

Kansan Till includes, "the deposits made directly by the Kansan Glacier and some water laid sediments interstratified with the till. It does not, however, include the pro-glacial silts, sands, and gravels deposited in front of the advancing glacier (Atchison Formation) or the outwash deposits from the retreating glacier (Mead Formation)" (Frye and Leonard, 1952, p. 74). Because Kansan Till, by definition, contains stratified drift, recognition of the Kansan formations is almost impossible in areas where more than one formation is present. Therefore all Kansan sediments are described as Kansan Till in this report. The till consists of unsorted boulders, cobbles, gravel, silt, and clay. Boulders of pink quartzite may be seen in almost all parts of the area. Throughout northeastern Leavenworth County till is interbedded with stratified sand and gravel deposits. Indeed, stratified drift is more common than unstratified till.

Some of the stratified sand and gravel was probably deposited by pro-glacial streams and is part of the Atchison Formation. Sand and gravel also may have been deposited by pro-glacial streams during minor retreats of the ice-front. Some of the sand and gravel may have been derived from till reworked by pro-glacial streams during the retreat of Kansan Ice and should be classified as part of the Mead Formation. Other sand and gravel deposits resemble ice-contact stratified drift as described by Flint (1947, p. 143). In these deposits the bedding is distorted (Fig. 23) in a manner suggesting slump caused by melting of the supporting ice.

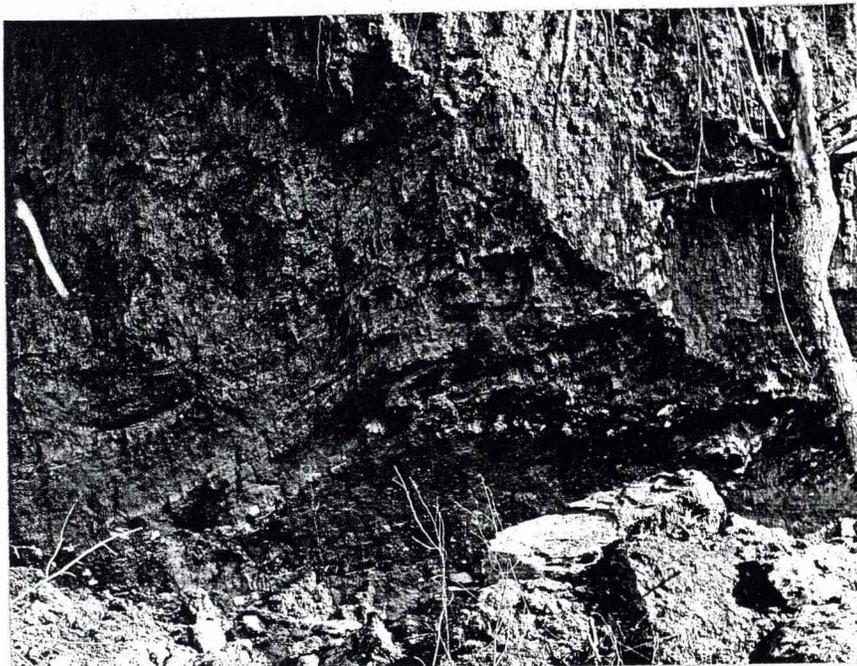


FIG. 23. Ice-contact stratified drift. Note the dip which may have been caused by melting of supporting ice. South side Little Plumb Creek, NW sec. 31, T. 7 S., R. 22 E.

A conglomerate consisting of limestone boulders and cobbles in sec. 34, T. 9 S., R. 21 E. is mapped as Kansan Till, but may correlate with the Illinoian Buck Creek Terrace described by Davis and Carlson (1952).

Later Pleistocene

Sanborn Formation

Defined by: Elias, 1931, p. 163, 179

Type locality: Cheyenne County, Kansas

The Sanborn Formation comprises deposits from the Illinoian and Wisconsinan Stages. Frye and Leonard (1952, p. 106) include the loess of northeastern Kansas in the Sanborn Formation. Elias (1931, p. 179),

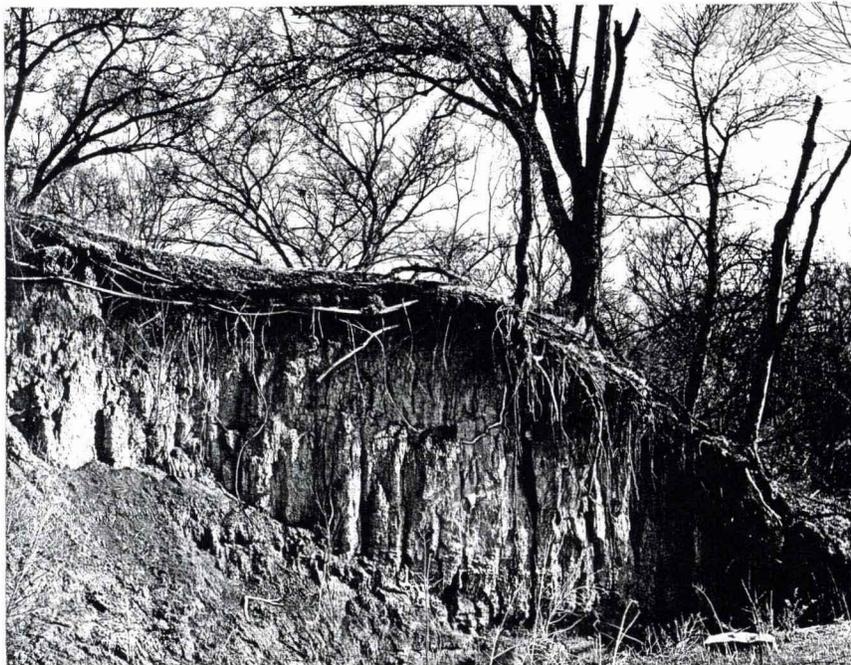


FIG. 24. Typical vertical cliff of loess. SE side Little Plumb Creek, NW sec. 31, T. 7 S., R. 22 E.

however, pointed out that the loess on valley slopes and river bottoms is for the most part not in its original site of deposition.

Loess is present throughout the area studied but is indicated in Plate 1 only on the bluffs of Missouri River where it is 20 or more feet thick. The loess is uniformly fine-grained, reddish-brown, and forms typical vertical cliffs (Fig. 24).

QUATERNARY SYSTEM-RECENT SERIES

Alluvial deposits are present in the valleys of all major streams. In the bed of Missouri River at Leavenworth the alluvium is over 50 feet thick (Hinds and Greene, 1917, p. 8). Terraces can be recognized



FIG. 25. Terraces bordering tributary to Missouri River. At this locality two surfaces are present above the present stream. Salt Creek, NW sec. 3, T. 8 S., R. 22 E., camera facing west.

in Stranger Creek Valley and in the valleys of many of the tributaries to Missouri River (Fig. 25). No attempt was made to map these terraces or to correlate them with the terraces of Kansas River described by Davis and Carlson (1952).

SUMMARY OF SUBSURFACE STRATIGRAPHY

The pre-Lansing Group rocks of northeastern Kansas are illustrated in Figures 26 and 27. Precambrian schists, phyllites, and non-granitic gneisses formed the surface of deposition for Paleozoic deposition beginning in Late Cambrian (Farquhar, 1957, Pl. 1). Approximate elevations of the Precambrian surface are: (1) southeast corner of Leavenworth County, -1500 feet; (2) southwestern corner of Leavenworth County, -1750 feet; (3) northwestern corner of Leavenworth County, -2200 feet; (4) Leavenworth-Atchison county line at Missouri River, -2000 feet.

Data concerning the thickness and character of the subsurface rocks illustrated in Figures 25 and 26 were compiled from Lee (1943). All units are named in accordance with Kansas State Geological Survey usage (Moore and others, 1951). All contacts in Figure 26 are unconformable except the gradational Bonneterre Dolomite-Lamotte Sandstone contact. The Sylvan Shale is present only in the northwestern corner of Leavenworth County (T. 7 and 8 S., R. 21 E.), elsewhere the Sylvan has been removed by erosion prior to the deposition of Devonian rocks. Although Silurian rocks have not been identified in Leavenworth County, a sandy zone next above the Sylvan Shale may be a remnant of the Lower Silurian Chimneyhill Shale that is present in Jefferson County, Kansas.

The rocks between the Sylvan Shale and the Chattanooga Shale have not been subdivided in northeastern Kansas and are collectively named

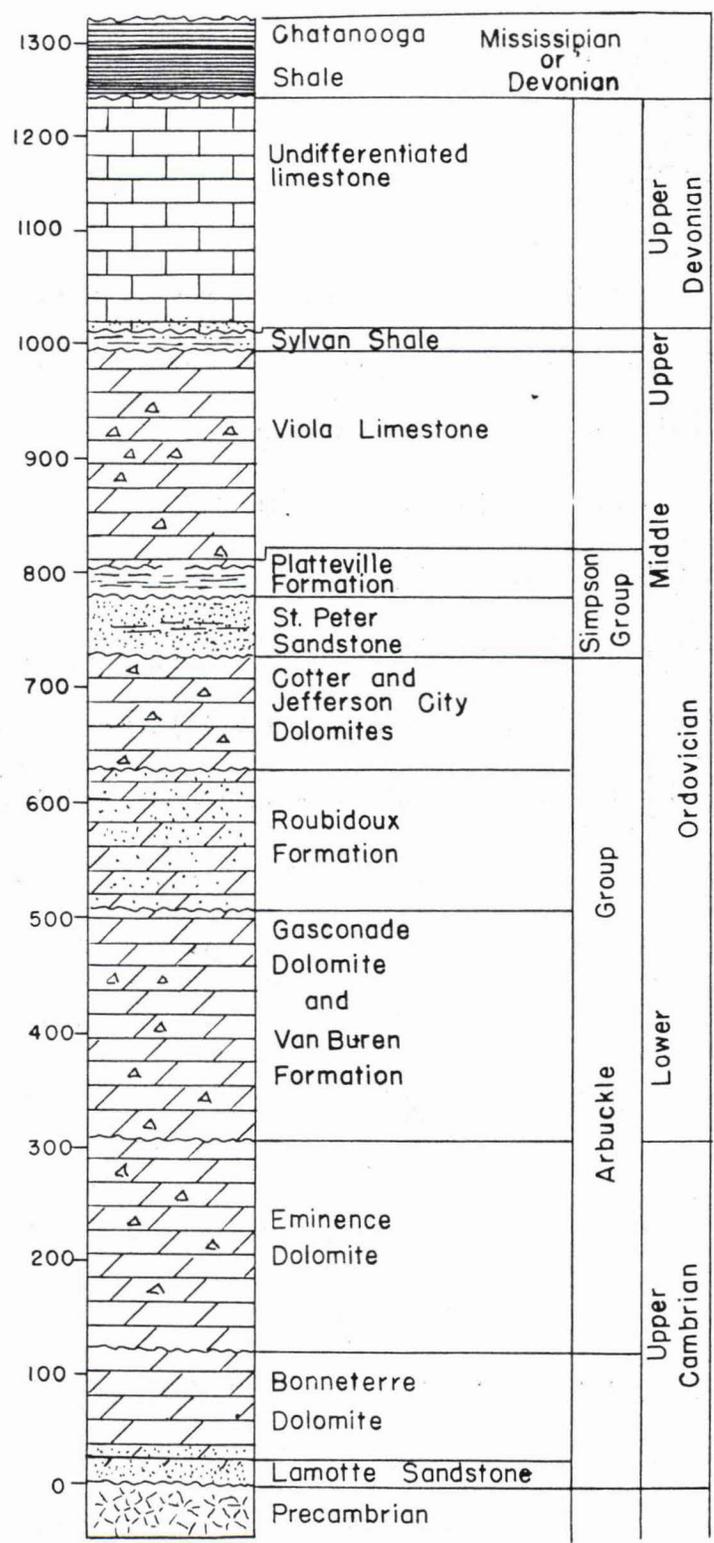


FIG. 26. Generalized stratigraphic column of pre-Mississippian (subsurface) rocks.

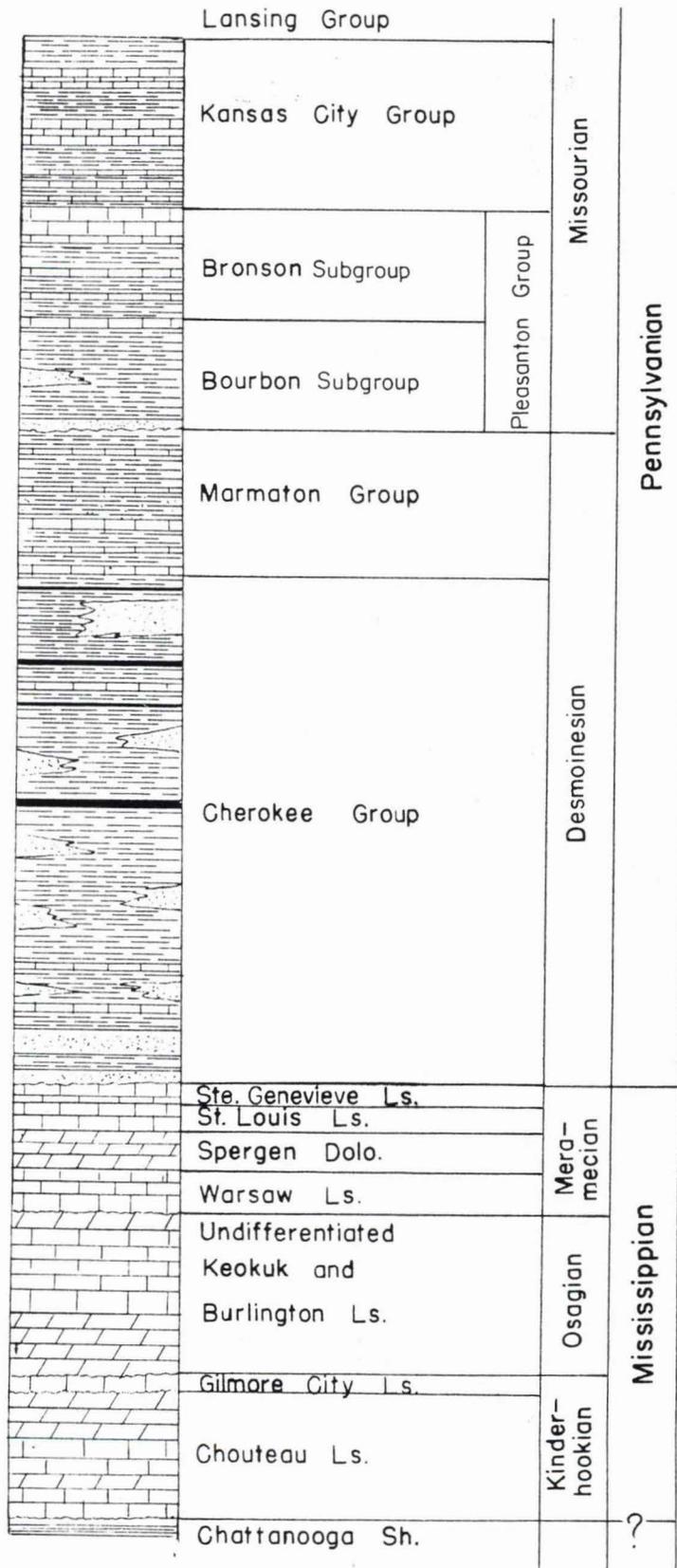


FIG. 27. Generalized stratigraphic column of post-Chattanooga (subsurface) rocks.

Hunton Limestone (Moore and others, 1951). Only the Upper Devonian is present in northeastern Kansas. The Devonian or Mississippian Chattanooga Shale and the underlying Hunton are separated by an angular unconformity.

Rocks of known Kinderhookian age unconformably overlie the Chattanooga Shale. Unconformities also separate the rocks of the Kinderhookian, Osagian, and Meramecian Series. No Chesteran rocks occur in the subsurface of northeastern Kansas. The uppermost Mississippian formations, the St. Louis and the Ste. Genevieve Limestones have a patchy distribution because of erosion before the deposition of Pennsylvanian rocks.

Subsurface Pennsylvanian rocks overlying the angular unconformity truncating the Mississippian belong to the Desmoinesian Series. The Desmoinesian is composed of a thick series of shale, sandstone with minor amounts of limestone belonging to the Cherokee Group and the overlying shales and limestones of the Marmaton Group. Missourian rocks, which disconformably overlie the Desmoinesian, include the Pleasanton and Kansas City Groups. The Missourian rocks are a series of cyclic limestones and shales with minor amounts of sandstone similar to those described in the preceding section of this report.

STRUCTURAL GEOLOGY

Leavenworth County is located in the Forest City Basin and on the Prairie Plains Monocline. The development of these structural provinces will be discussed in the following section of this report. The regional dip is to the west at approximately 15 feet per mile. Locally the rocks dip up to 60 feet per mile to the northwest. No faults appear at the surface.

Many nontectonic structures may be seen in northwestern Leavenworth County. Sedimentary structures due to differential compaction and slump are common in the Pennsylvanian rocks. Figure 28 illustrates a small fold in the Tonganoxie Sandstone. Folding and faulting caused by the weight and push of glacial ice may be seen at a quarry in the center of sec. 12, T. 8 S., R. 21 E. (Fig. 29). The origin of the prominent vertical joints in the "blue" limestones is not known. Although the joints at any one outcrop have a very definite orientation (Fig. 30), observations at several localities suggest that the joints are randomly orientated. The apparent lack of preferred orientation is interpreted to indicate a nontectonic origin for the joints.

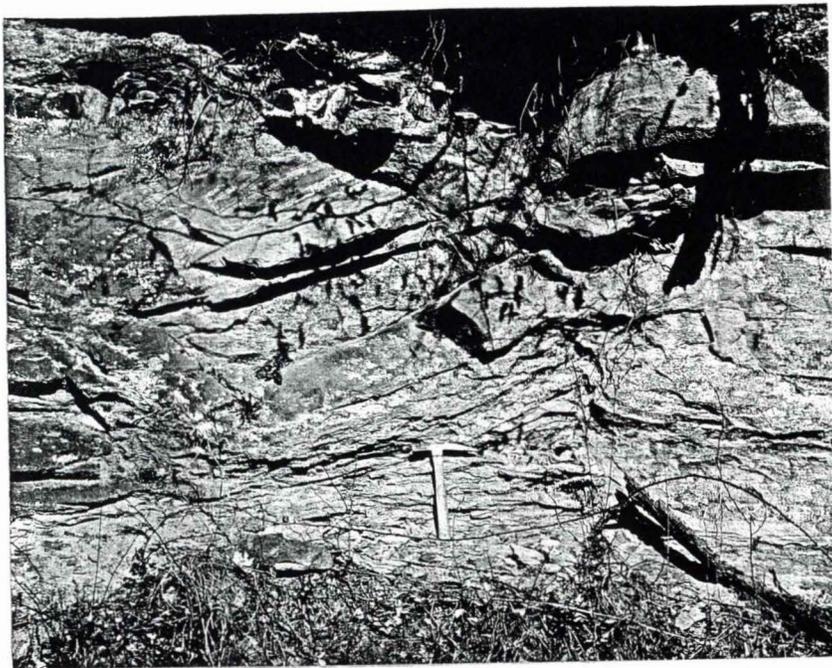


FIG. 28. Small fold due to slump in the Tonganoxie Sandstone. East bank Five Mile Creek, SW sec. 10, T. 9 S., R. 22 E.

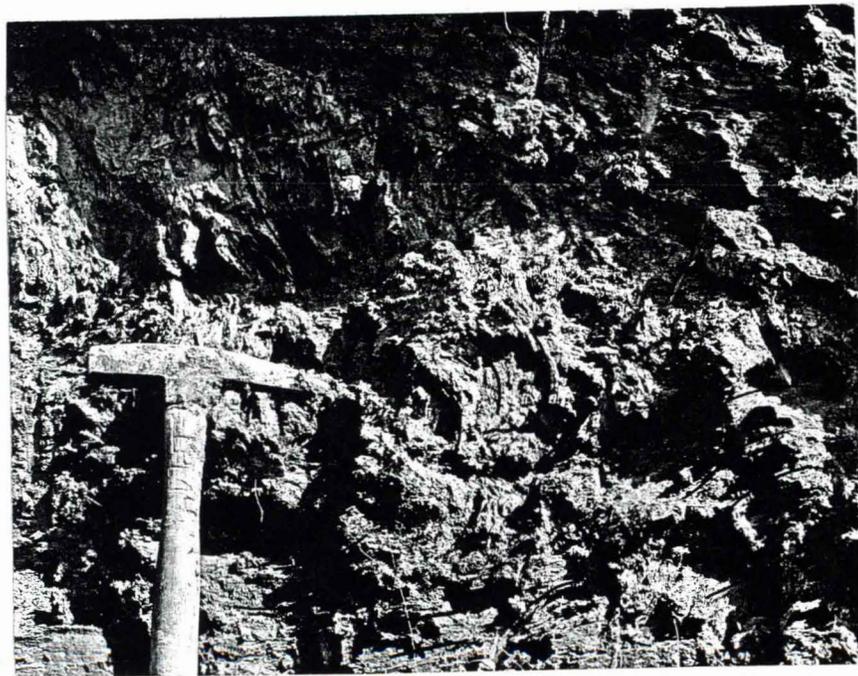


FIG. 29. Deformation caused by weight and push of glacial ice; folding and faulting indicated by ink lines. Quarry, cen. sec. 12, T. 8 S., R. 21 E., camera facing west.



FIG. 30. Joints in the Leavenworth Limestone. The angle between the joint systems is 70 deg. Quarry, SW sec. 14, T. 9 S., R. 21 E.

STRUCTURAL DEVELOPMENT OF NORTHEASTERN KANSAS

Lee (1943) presented a detailed discussion of the structural history of northeastern Kansas. Because few new data have been gathered since Lee's report, and because a discussion of geologic history must be on a regional basis, the discussion in this report can be only a brief summary of Lee's work. Most of Lee's deductions were based on the interpretation on isopach maps of intervals bounded by unconformities. He assumed that the unconformities were peneplained surfaces (essentially horizontal planes) and concluded that isopach maps would reveal "much information regarding the location and trend of structural movements . . . and, to some degree their relative importance" (Lee, 1943, p. 101). The structural features of eastern Kansas are illustrated in Figure 31.

Tectonic movements in the subsiding Ozark Basin and rising area in northeastern Nebraska controlled deposition and erosion of sediments in northeastern Kansas between the top of the Precambrian and the top of the St. Peter Sandstone. Before the deposition of the Roubidoux Formation the basin of deposition was small and subject to severe local warping. During this time northeastern Kansas was a marginal area and warping of the basin caused the rocks to be subject to erosion and beveled. Lee (1943, p. 104) reports three structural cycles during this time. The first is recorded in the Lamette Sandstone and the Bonneterre Dolomite; during the second cycle the Eminence Dolomite was deposited on the

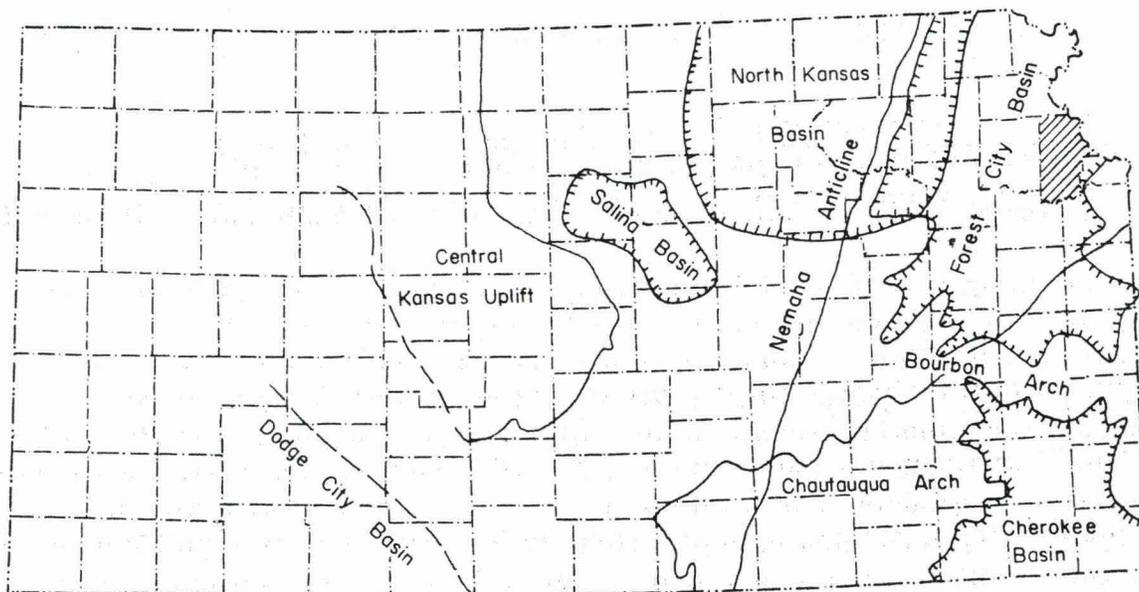


FIG. 31. Principal structural features of eastern Kansas (adapted from Lee, 1943, p. 14).

beveled edges of the Bonneterre Dolomite; the third cycle is represented by the Van Buren Formation and the Gasconde Dolomite which were deposited on the beveled Bonneterre and in turn beveled by pre-Roubidoux erosion. After deposition of the Roubidoux began the area of deposition became larger and warping in the basin was less severe as indicated by less variation in thickness and less beveling of the formations. Less marked unconformities at the top of the Roubidoux Formation and the base of the St. Peter Sandstone and minor unconformities within the formations between the Roubidoux and St. Peter are attributed to retreats and advances of the sea without local warping of the basin.

The north Kansas basin and its complementary areas, the Chautauqua arch and the Ozark uplift, dominated the structural history of northeastern Kansas from the end of St. Peter time at least until the end of Chattanooga time (Lee, 1943, p. 112). At the end of St. Peter time the St. Peter Sandstone was tilted northward reversing the earlier conditions and forming the North Kansas Basin. The Chautauqua Arch began rising sometime after the deposition of the St. Peter but before the deposition of the Sylvan Shale. Distinct movements of the North Kansas Basin during the St. Peter-Chattanooga interval are indicated by the angular unconformity between the Sylvan Shale and the overlying Silurian rocks, that were completely removed in Leavenworth County; by the angular unconformity between Silurian and Devonian rocks; by the peneplanation of the Devonian rocks; and by thickness variations of the Chattanooga Shale.

Although the first movements of the Nemaha Anticline occurred early in Mississippian time, it was not until after the deposition of the Mississippian limestones that major movement uplifted the Nemaha Anticline several hundred feet. Following this uplift all of eastern Kansas was peneplained. Renewed upward movement before the beginning of Pennsylvanian deposition caused several hundred feet of displacement on the east side of the Nemaha Anticline. The east flank of the Nemaha was deformed by faulting and a steep east-dipping monoclinial fold. Simultaneously the peneplain east of the Nemaha Anticline

was downwarped to form the Cherokee Basin, the Forest City Basin, and the Bourbon Arch.

As Pennsylvanian deposition began the Cherokee Basin, Forest City Basin, Bourbon Arch, and Nemaha Anticline were the major structural features of eastern Kansas. Because of the lack of good datum planes within the Pennsylvanian section, the Pennsylvanian structural development cannot be interpreted as well from isopach maps. However, tectonic movements during Pennsylvanian time are indicated by the disconformities in the Pennsylvanian section. The Bourbon Arch was submerged during the middle of Cherokee time (Lower Desmoinesian) and the Forest City Basin became a northern extension of the Cherokee Basin. Lower Kansas City Group rocks overlying granite on the crest of the Nemaha Anticline indicate that it was not submerged until early Missourian time.

The last major structural movement was pre-Cretaceous tilting of Kansas and adjacent states to the northwest to form the Prairie Plains Monocline. Lee (1943, p. 128) believes that at least 2000 feet of sediment overlying the Lansing Group were eroded subsequent to this tilting. Recent studies by Lee (1954) and Merriam (1956) indicate periodic movements of the Nemaha Anticline continuing until the present time.

Conclusions based on the examination of data collected in Leavenworth County can lead only to the support of Lee's theories. Because only Missourian and Virgilian rocks are exposed in Leavenworth County, Lee's theories must be tested only as they would affect these rocks. All the

evidence indicates that during this time northeastern Kansas was a low lying structurally quiet area.

The rocks exposed in Leavenworth County indicate repeated movements of the shore line back and forth across northeastern Kansas. The causes of these movements must not have been local. If the shore line migrations were caused by structural activity in northeastern Kansas, it would be indicated by the character of the sediments, shape of the sedimentary bodies, and the attitude of the sedimentary bodies. Neither the character of the sediments nor the shape and size of the sedimentary bodies suggest tectonic activity. Therefore, the sequence of beds in northeastern Kansas must be the result of eustatic changes in sea level. The cause of the changes, whatever and wherever it may have been, must have been periodic to produce the cyclic deposits of Kansas.

At least twice during the interval between Wyandotte time and Lecompton time sea level dropped low enough to cause disconformities to form in northeastern Kansas. The first occurred after the deposition of the Stoner Limestone. Following the development of the post-Stoner disconformity a series of at least partly continental beds were deposited and then normal marine sedimentation was resumed. The maximum lowering of sea level is indicated by the disconformity between the Virgilian and Missourian Series. At this time at least 100 feet of Missourian rocks were removed by erosion. Following this erosion, and possibly contemporaneous with it, the thick sequence of continental beds

in the Lower Douglas Group was deposited. Before normal cyclic sedimentation resumed the sea must have made at least one advance and retreat across northeastern Kansas to account for the marine deposits in the upper Stranger Formation and the coal beds in the Lawrence Shale.

ECONOMIC GEOLOGY

LIMESTONE

Limestone suitable for road surfacing, concrete aggregate, and similar uses is readily available in northeastern Leavenworth County. The Plattsmouth Limestone member of the Oread Limestone is the most commonly quarried limestone. The Stoner and Spring Hill Limestones are quarried in areas where erosion has removed the Plattsmouth. An abandoned quarry in the Iatan Limestone is in sec. 3, T. 8 S., R. 21 E. Runnels (1951, p. 95) reported that the Farley Limestone meets the specifications for use as a high-calcium limestone.

SHALE AND CLAY

Shale and clay are not produced at present, but studies by the Kansas State Geological Survey indicate that they do have potential economic value. Runnels and others (1952, p. 179) recorded the amounts of recoverable oil from samples of the Heebner and Eudora Shales in nearby counties. Runnels (1949, p. 39) reported that in nearby counties, phosphates can be extracted from the Eudora Shale and used for agricultural fertilizer. The Heebner Shale also is a potential source of phosphate. Plummer and Hladik (1951, pp. 55-59) reported that the Vilas Shale, the Weston Shale, the Lawrence Shale, and the Jackson Park Shale are suitable for the manufacture of light-weight concrete aggregate. The

Weston Shale was indicated to be the most suitable for this purpose. Although no commercial brick plants are presently operating in the area, bricks are manufactured from the Vilas Shale at the Lansing Prison.

COAL

Coal beds occur in the Douglas Group, which crops out in the area, and in the subsurface Desmoinesian Cherokee Shale. Although no commercial mines are operating at the present time, both the Douglas and Cherokee coals have been mined in the past. The location of three small mines that used to operate in the Douglas Group was recorded by Bowsher and Jewett (1943, p. 83). Hinds and Greene (1917, p. 11) discussed the mining operations in the Cherokee Shale. Cherokee mines operated in the Bevier Coal about 620 feet below the base of the Plattsburg Limestone. Coal mining in northeastern Leavenworth County ceased in 1948 when the Kansas State Prison Mine at Lansing shut down.

OIL AND GAS

Commercial quantities of oil or gas have never been produced in the area covered by this report. Ten dry holes have been drilled. The location and total depth of these wells was reported by Jewett (1954, pp. 255-258).

GROUND WATER

Little is known about the ground-water conditions, and it is not within the scope of this study to collect the data necessary for a comprehensive ground-water report. The Kansas State Geological Survey Ground Water Division has only six well logs from the area studied. Three of these six wells were dry holes. Two of the producing wells pump good water from sandstone within the Douglas Group; the third well is located near Missouri River and probably produces from alluvium. Observations by the writer indicate that most of the wells in the county produce from sandstone in the Douglas Group.

SAND AND GRAVEL

The only sand and gravel presently being produced comes from alluvial deposits of Missouri River. This is a virtually inexhaustible supply. Local gravel deposits in the Kansan Till might be worked, but it is doubtful if they are large enough for profitable operation.

SOIL

Because the area is predominantly agricultural, soil is the most important economic resource. Three types of soil are present: glacial and loessial soil, alluvial soil, and residual soil. All of the area has been covered by glacial and loessial deposits, and soil developed from

these deposits is by far the most common. They are commonly yellowish-brown to light brown. Locally the glacial soil is rocky. Alluvial soil is present in the flood plains of the larger streams. Borings in Missouri River bed at Leavenworth indicate at least 57 feet of alluvium (Hinds and Greene, 1917, p. 8). Residual soil is not common. In the area east of the Oread Escarpment some residual soil has developed on the rocks of the Douglas Group. The slopes in areas where Pennsylvanian limestone crops out are too steep for the accumulation of residual soil.

SUMMARY AND CONCLUSIONS

Sedimentary rocks of Pennsylvanian age and unconsolidated sediments of Quaternary age are exposed in northeastern Leavenworth County. The Pennsylvanian rocks are shale, limestone, and sandstone of the Missourian and Virgilian Series. Missourian rock units include the uppermost Kansas City Group and all of the Lansing and Pedee Groups. The Virgilian Series is represented by the entire Douglas Group and part of the Shawnee Group. Approximately 550 feet of Pennsylvanian rocks are exposed. Kansan Till and later Pleistocene deposits are present in all parts of the area. The Pleistocene sediments of northeastern Kansas have not been studied sufficiently to make precise correlations. Recent alluvial deposits are in all major stream valleys.

All units of the Missourian Series above the Island Creek Shale, and all units of the Shawnee Group below the Big Springs Limestone can be recognized and traced throughout the area. The lower and upper boundaries of the Douglas Group can be recognized but the boundaries of units within the Douglas cannot always be located.

In this report the following limits are used to define the units of the Douglas Group: Stranger Formation, all rocks between the disconformity at the base of the Virgilian Series and the top of the Haskell Limestone; Tonganoxie Sandstone member, all beds between the base of the Stranger Formation and the top of the Upper Sibley Coal; Vinland Shale, all beds

between the top of the Upper Sibley Coal and the base of the Haskell Limestone; Lawrence Shale, all beds between the top of the Haskell Limestone and the base of the Oread Limestone. According to this classification the Robbins Shale is the lowermost member of the Lawrence Shale, and includes all beds between the top of the Haskell Limestone and the overlying goethite zone. The top of the Ireland Sandstone member is not sharply defined. The Westphalia Limestone member of the Stranger Formation and the Amazonia Limestone member of the Lawrence Shale were not recognized.

The regional structure of the area is the gentle westerly dip of the Prairie Plains Monocline. Small nontectonic structures may be found. Although the mineral resources of northeastern Leavenworth County are presently not being used much, there is abundant limestone and shale that could be of great economic value.

The most outstanding unsolved geologic problems in Leavenworth County are concerned with the Douglas Group, Pleistocene stratigraphy, and ground-water conditions. An organized drilling program in northeastern Kansas would aid in the solution of all of these problems. Detailed interpretative stratigraphic studies of more Pennsylvanian units will be necessary before the environment of deposition and the paleogeography of northeastern Kansas can be fully understood. Although these suggested problems are of a regional nature, much of the data leading to their solution will come from Leavenworth County.

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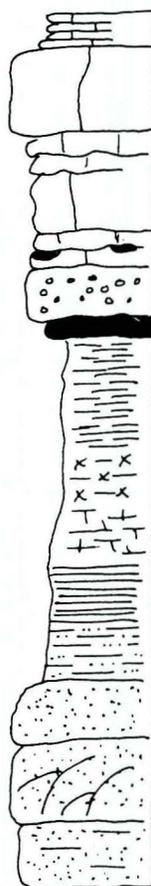
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APPENDIX

Measured sections in northeastern

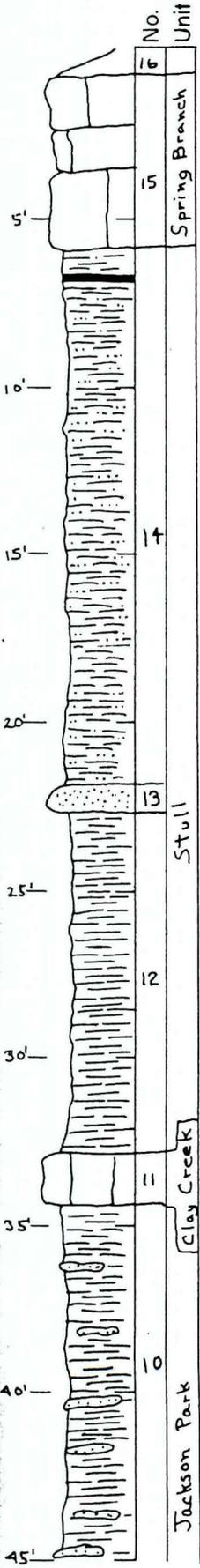
Leavenworth County, Kansas

EXPLANATION



- thin-bedded limestone
- massive-bedded limestone
- wavy-bedded limestone
- chert nodules
- conglomerate
- coal
- shale
- red shale
- calcareous shale
- black shale
- arenaceous shale
- massive sandstone
- cross-bedded sandstone
- argillaceous sandstone

MEASURED SECTION NO. 1



	X		

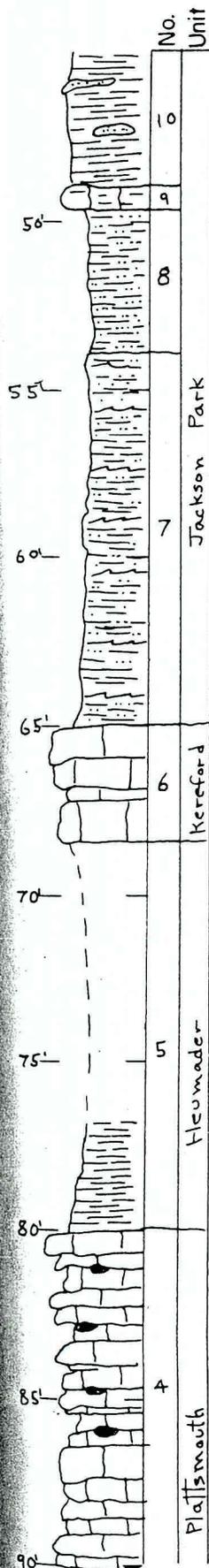
Location. sec. 19, T. 8 S., R. 21 E.
South of Easton on road to cemetery

Measured by McLaren, 1957.

No.		Feet
16	PLEISTOCENE COVER: float from Big Springs Limestone common.	
15	LIMESTONE: dark brown on weathered surface, gray on fresh surfaces; massive; highly fossiliferous, abundant brachiopods and fusulinids.	5.0
14	SHALE; gray to tan; slightly sandy; coal bed 1.5 feet below top; no marine fossils.	16.0
13	SANDSTONE: red to yellow; very fine-grained; massive; non-fossiliferous.	1.0
12	SHALE: gray; sandy in part; thin-bedded and flaky to blocky; no marine fossils.	10.0
11	LIMESTONE: fresh surfaces blue, weathered surfaces tan with red spots; one massive ledge; highly fossiliferous, fusulinids, <u>Dictyoclostus</u> , <u>Marginifera</u> , <u>Enteletes</u> , crinoids, bryozoans.	1.5
10	SHALE and SANDSTONE: gray to tan; mostly shale with many discontinuous sandstone lenses; no marine fossils.	14.0

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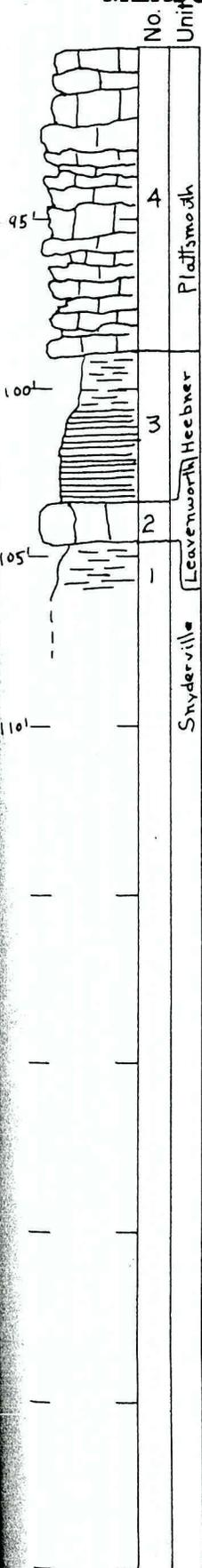
MEASURED SECTION NO. 1 (CONTINUED FROM PREVIOUS PAGE)



No.	Description	Feet
9	LIMESTONE: gray; shaley; micaceous; does not seem to be persistent unit.	0.8
8	SHALE and SANDSTONE: gray to tan to brown; calcareous; non-fossiliferous; thin-bedded massive sandstone lenses more common near top; micaceous.	4.0
7	SHALE: gray to green; platy; slightly micaceous; sandy; ripple-marked.	11.0
6	LIMESTONE: dark brown to blue; dense; massive; highly fossiliferous; brachiopods, crinoids, bryozoans, fusulinids.	3.5
5	SHALE: mostly covered; grayish-green; platy to blocky.	11.0
4	LIMESTONE: gray to dark gray, weathers tan; upper beds more massive and have darker color; black chert with enclosed fusulinids common in upper part; scattered brachiopods, crinoid stems, bryozoans.	19.0

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MEASURED SECTION NO. 1 (CONTINUED FROM PREVIOUS PAGE)

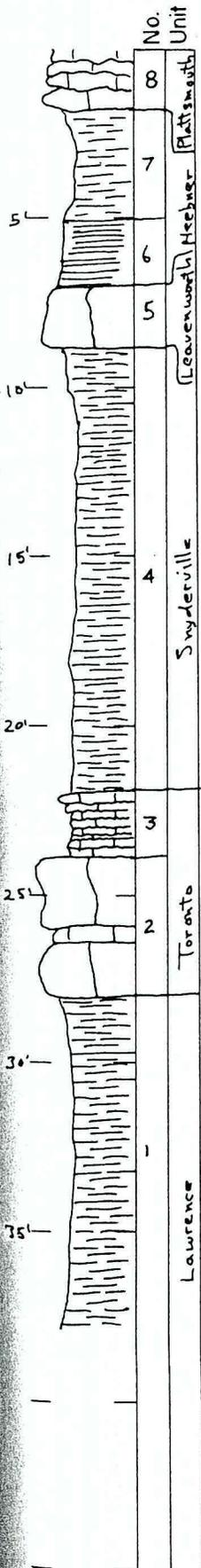
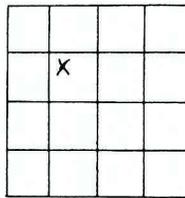


No.	Description	Feet
3	SHALE: black in lower 3 feet, upper beds gray; platy (black) to fissile and blocky (gray).	4.5
2	LIMESTONE: blue-gray; massive; fine-grained; dense; one single bed; fusulinids and brachiopods.	1.4
1	SHALE: gray to brown; blocky, base covered. exposed	3.0

MEASURED SECTION NO. 2

Location. sec. 22, T. 8 S., R. 22 E.
 Road cut on U. S. 73 at Government Hill, west
 of Leavenworth. Type locality for Leavenworth
 Limestone.

Measured by McLaren, 1958

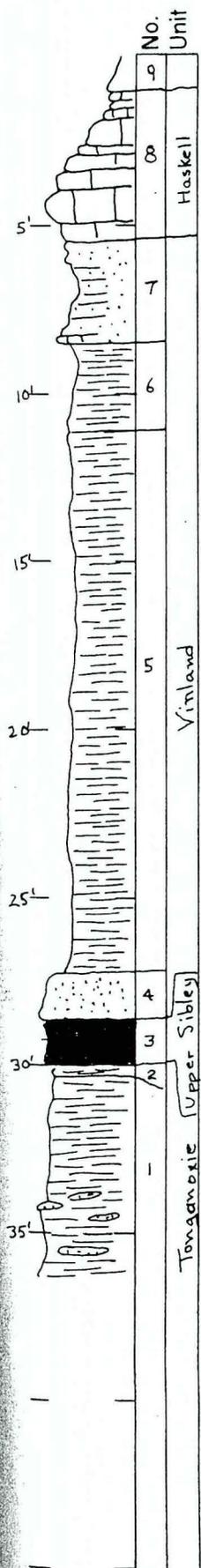
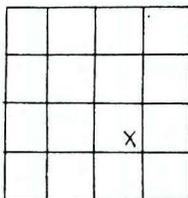


No.		Feet
8	LIMESTONE: light to dark gray on fresh and weathered surfaces; wavy-bedded; brachiopods, fusulinids, crinoid stems.	2.0
7	SHALE: yellowish-green to green; clayey; blocky; barren.	3.0
6	SHALE: black with scattered white layers; fissile; platy; hard; phosphatic nodules; ledge former; conodonts.	2.0
5	LIMESTONE: light bluish-gray; hard; dense; one massive bed; vertical joints; fusulinids and brachiopods.	1.9
4	SHALE: grayish-green to gray to tan; flaky to blocky; barren; mostly covered.	13.0
3	LIMESTONE: brown on weathered surfaces, light gray on fresh surfaces; algal; thin wavy beds, weathers vuggy; clams and snails. (This algal cap on the Toronto Limestone is not common in northeastern Leavenworth County.)	2.0
2	LIMESTONE: brown on weathered surfaces, light gray on fresh surfaces; massive; dense; abundant fusulinids, brachiopods, crinoid columnals, bryozoans.	4.6
1	SHALE: bluish-gray; flaky to blocky; scattered sandy beds; barren; base covered. exposed	10.0

MEASURED SECTION NO. 3

Location. sec. 36, T. 9 S., R. 21 E.
Northwest of Hyde, about 1 mile

Measured by Bowsher, 1942

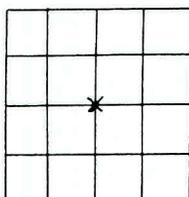
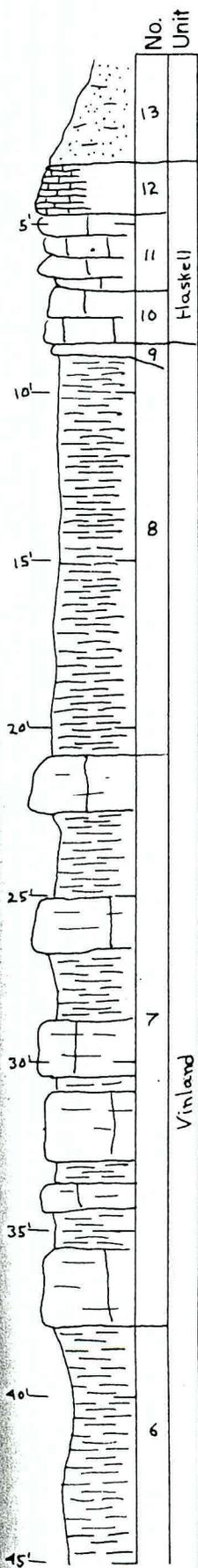


No.

Feet

- 9 SOIL.
- 8 LIMESTONE: light brown; finely crystalline; argillaceous; brachiopods and clams. 4.5
- 7 SANDSTONE: light brown; fine-grained; illitic; shaley; thin-bedded. 3.4
- 6 SHALE: light brown; silty; illitic; arenaceous dark gray concretions. 3.0
- 5 SHALE: medium dark brownish-gray; illitic. 15.4
- 4 SILTSTONE: calcareous, massive, illitic. 1.6
- 3 COAL. 1.2
- 2 SHALE and COAL: interbedded. 0.6
- 1 SHALE: dark gray; silty; illitic; interbedded with brown sandstone near base of section. 6.0

MEASURED SECTION NO. 4



Location. sec. 4, T. 8 S., R. 22 E.
Up and downstream 150 feet from bridge
over Plumb Creek.

Measured by Bowsher, 1942

No.		Feet
13	SILTSTONE: light steel gray; clayey.	3.0
12	LIMESTONE: dark steel gray; very thin-bedded; medium crystalline; crinoidal.	1.5
11	LIMESTONE: dark steel gray; thin-bedded; crinoidal.	2.8
10	LIMESTONE: light brown; argillaceous; irregular bedding; hard; <u>Marginifera</u> , <u>Dictyoclostus</u> , other fossils.	2.4
9	CLAY: brown; very calcareous.	0.5
8	SHALE: dark gray; clayey; basal 1 foot grades into light gray silty shale.	12.0
7	SHALE: dark blackish gray; calcareous; interbedded with limestone (argillaceous, dark gray, hard).	16.8
6	SHALE: dark blackish gray; clayey, blocky in upper half, base grades into coal; molluscs.	18.4

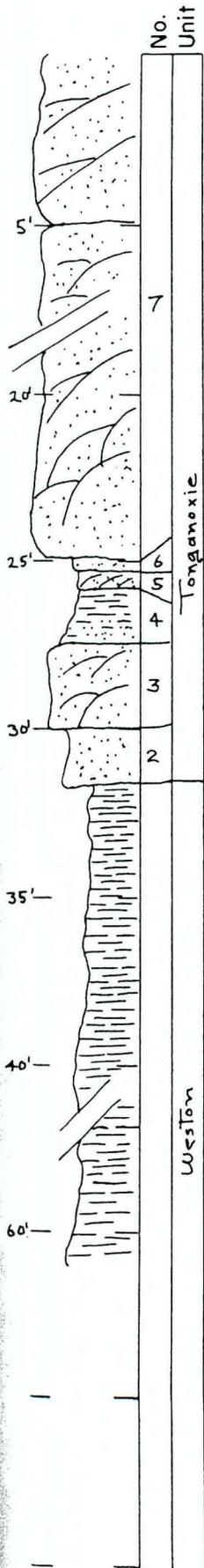
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MEASURED SECTION NO. 4 (CONTINUED FROM PREVIOUS PAGE)



No.		Feet
5	COAL.	1.5
4	SANDSTONE: light steel gray; clayey; quartzose; lignite fragments.	1.0
3	SHALE: light steel gray; silty; many lignite streaks and carbonized plant remains.	0.9
2	SANDSTONE: gray; very fine-grained; shaley and clayey; minor amounts of lignite fragments.	1.1
1	SHALE: light steel gray; silty; containing irregular sandstone bodies which are fine, steel gray, nodular, and filled with many lignite streaks and plants.	1.3

MEASURED SECTION NO. 5



			X

Location. sec. 35, T. 9 S., R. 22 E.
On south side of stream, can be seen from road

Measured by McLaren, 1958

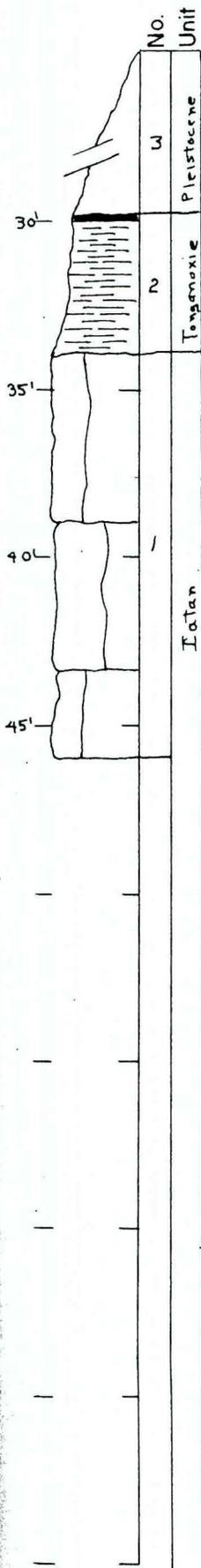
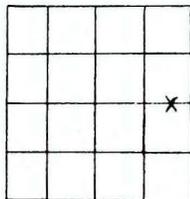
No.		Feet
7	SANDSTONE: tan to rust colored; appears massive but cross bedding seen in close inspection; fine-grained; ferruginous.	25.0
6	SANDSTONE: thin-bedded, not cross-bedded; many laminae of black carbonaceous material; fresh surfaces gray, weathers tan.	0.5
5	SANDSTONE: tan; ferruginous; fine-grained; cross-bedded.	0.5
4	SHALE: gray; laminated; platy; grades into sandstone below; nodules at the top.	1.7
3	SANDSTONE: gray to rust-colored; similar to unit 7; grades into shale above.	2.3
2	SANDSTONE: gray to rust-colored; massive; poorly cemented; fine grained; thin shale break at top.	1.9
1	SHALE: gray; blocky, clayey; barren; top 0.5 feet alternating laminae light and dark gray shale; upper contact sharp with considerable relief; base covered.	exposed 30.0

MEASURED SECTION NO. 6

93

Location. sec. 3, T. 8 S., R. 22 E.
Abandoned quarry along Mo. Pac. RR.,
walk south 1/2 mile along tracks from
section line road.

Measured by McLaren, 1958



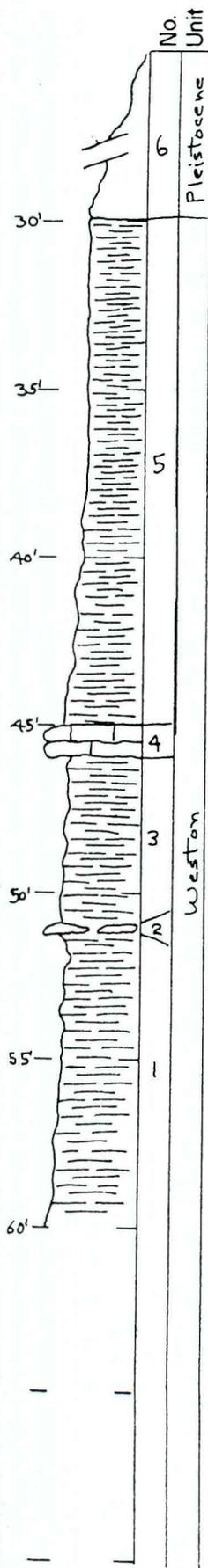
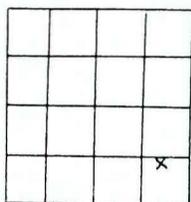
No.		Feet
3	PLEISTOCENE COVER: till overlain by loess	30.0
2	SHALE: light to dark gray; clayey; blocky; no fossils; many yellow streaks parallel to bedding; thin black layer at top (0.2 feet).	4.0
1	LIMESTONE: light to dark gray, mottled appearance, reddish in part; appears brecciated; much crystalline calcite (calcite veinlets run in all directions and give weathered surface rough texture); hard; few scattered brachiopods and crinoid stems, algal; base covered.	12.0

(outcrops 1 mile north indicate this limestone is at least 14 feet thick)

MEASURED SECTION NO. 7

Location. sec. 23, T. 9 S., R. 22 E.
 South side Seven Mile Creek, walk 1/8 mile
 west along stream from section line road.

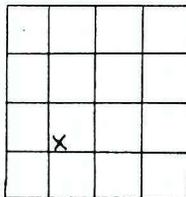
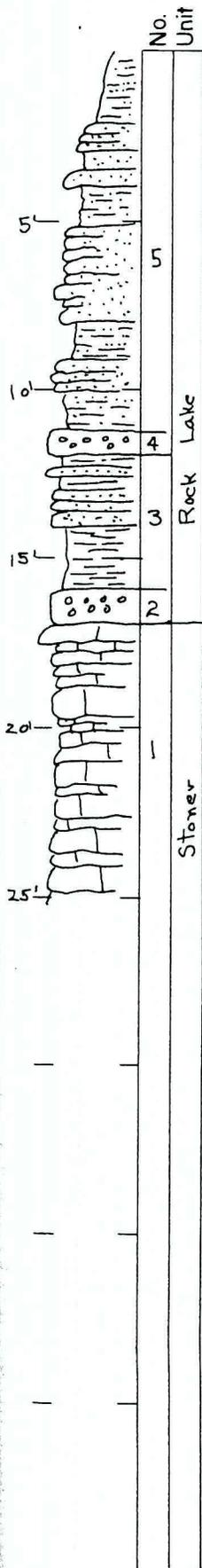
Measured by McLaren, 1958



No.		Feet
6	COVER: locally the Tonganoxie Sandstone exposed.	30.0
5	SHALE: dark gray; medium hard; platy, very slick when wet; many limonite streaks, barren.	15.0
4	LIMESTONE: tan, weathers reddish-brown; shale parting in middle; earthy; <i>Hustedia</i> , crinoid stems, high-spired gastropods.	1.2
3	SHALE: same as unit 5	5.0
2	MUDSTONE: dark gray, yellow on weathered surfaces; flagstone-like nodules; conchoidal fractures; ferruginous; dense.	0.2
1	SHALE: same as unit 5, base covered. exposed	9.7

(top of Stanton Limestone approximately 10 feet below base of section)

MEASURED SECTION NO. 8

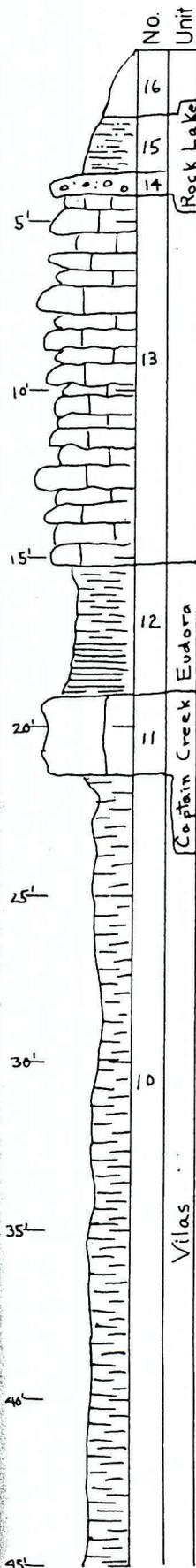


Location. sec. 18, T. 9 S., R. 23 E.
 Quarry section north of K-5 and 1 mile
 north of State Prison quarry. This quarry
 recently re-opened.

Measured by Ball, 1957

No.		Feet
5	Alternating silty gray-tan and blue-gray shale and even-bedded micaceous sandstone beds; sparse plant remains in sandstone; discontinuous arenaceous limestone beds are random levels in quarry walls.	9.0
4	CONGLOMERATE: limonite and limestone pebbles in lime matrix; not continuous in quarry wall.	1.0
3	Alternating olive drab to blue-gray silty, clayey shale and fine-grained sandstone or siltstone beds; variable thickness.	4.0
2	CONGLOMERATE: gray to brown; ironstone and limestone pebbles, brachiopod, clam, crinoid, and fusulinid fragments in a lime matrix.	1.0
1	LIMESTONE: gray to buff; thin irregular beds; fine-grained; compact; <u>Composita</u> , <u>Marginifera</u> , <u>Neospirifer</u> , <u>Punctospirifer</u> , <u>Juresania</u> , fusulinids, high-spired gastropods, crinoid fragments; thickness variable because of hummocky top surface that has 2 to 3 feet of relief within the quarry walls; base covered.	8.0

MEASURED SECTION NO. 9



			X

Location. sec. 20, T. 9 S., R. 23 E.
Kansas State Prison Quarry

Measured by Ball, 1957

No.		Feet
16	PLEISTOCENE COVER.	
15	SHALE: gray to tan; flaky; silty.	3.0
14	CONGLOMERATE: limestone and limonite fragments in a limy matrix.	1.0
13	LIMESTONE: gray-blue to tan; thin irregular beds; fine-grained; abundant crinoid fragments, <u>Composita</u> , <u>Dictyoclostus</u> , <u>Hustedia</u> .	11.0
12	SHALE: gray in lower 0.4 feet, black and fissile in next 1.4 feet, gray and platy to flaky upward in upper 2.0 feet; <u>Ozarkodina</u> .	4.0
11	LIMESTONE: blue to brown on fresh surface, weathers brown; single thick even bed; extremely fine-grained; brittle; <u>Composita</u> , <u>Enteletes</u> , <u>Juresania</u> , fusulinids.	2.5
10	SHALE: gray to tan; flaky to blocky; silty and clayey; seemingly barren.	25.0

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MEASURED SECTION NO. 9 (CONTINUED FROM PREVIOUS PAGE)

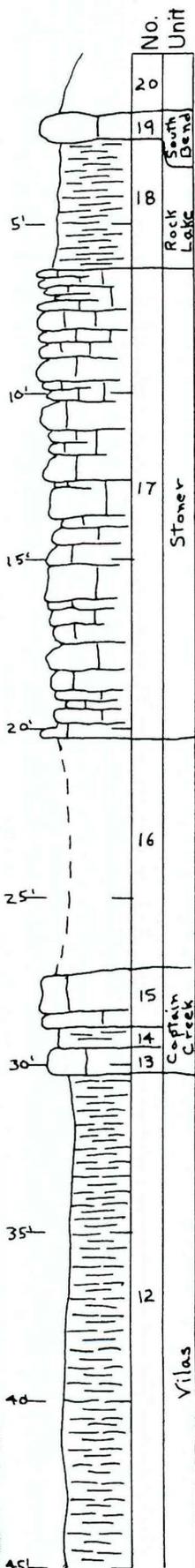
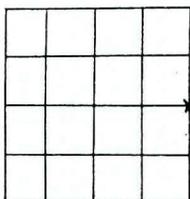
No.	Unit	Feet
10		
9	Spring Hill	11.0
8		0.6
7	Hickory Creek	1.0
6		0.2
5	Merriman	2.0
4		0.9
3	Banner Springs	2.8
2		1.2
1		3.0

No.	Description	Feet
9	LIMESTONE: gray to brown; thin to thick and slightly irregularly-bedded; fine-grained; compact; <u>Bellerophon</u> , <u>Composita</u> , <u>Enteleles</u> , <u>Linoproductus</u> , <u>Neospirifer</u> , crinoids, echinoids, fusulinids, fenestrate and ramose bryozoans; crystalline calcite.	11.0
8	SHALE: gray-blue; flaky; seemingly barren; lower inch of unit red-brown.	0.6
7	LIMESTONE: gray to brown; slightly irregular bedding; <u>Osagia</u> , foraminifera, brachiopods, crinoids in lower 0.4 feet; upper 0.6 feet a codular, shaley limestone with crinoids.	1.0
6	SHALE: gray to tan; flaky.	0.2
5	LIMESTONE: gray-blue on fresh surface, weathers tan; single even bed; fine-grained; compact; <u>Composita</u> , <u>Myalina</u> middle and lower parts.	2.0
4	CONGLOMERATE: brown; clay and limestone fragments in a limy matrix; <u>Aviculopecten</u> , <u>Composita</u> , crinoids; thickness variable.	0.9
3	SHALE: gray to tan; blocky; contains ferruginous limestone nodules.	2.8
2	LIMESTONE: gray to tan; thin-bedded; shaley; barren.	1.2
1	SHALE: gray-blue; blocky; calcareous; lower contact covered. exposed	3.0

MEASURED SECTION NO. 10

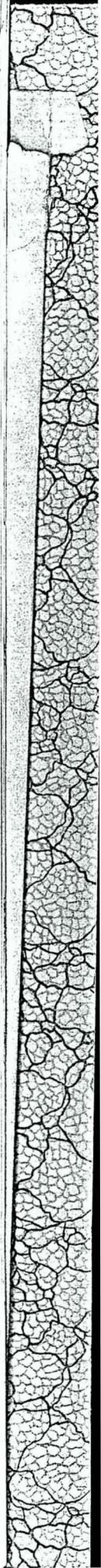
Location. sec. 29, T. 9 S., R. 23 E.
 Along drainage ditch east from highway K-5

Measured by Ball, 1957

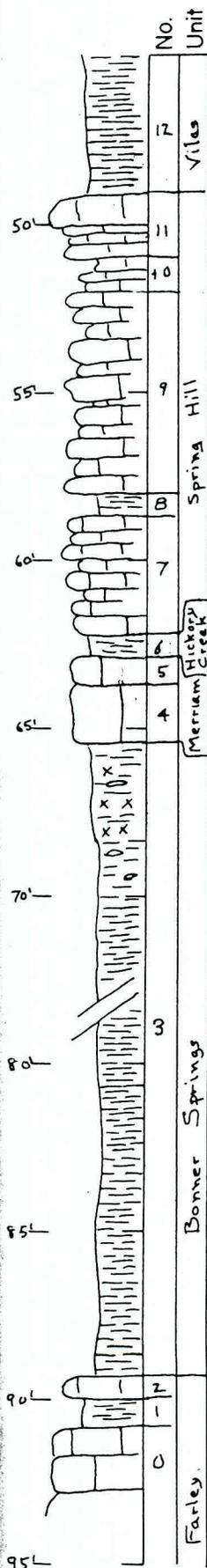


No.	Description	Feet
20	PLEISTOCENE COVER.	
19	LIMESTONE: gray-blue on fresh surface, weathers buff; brittle; <u>Composita</u> , <u>Meekella</u> , fusulinids, crinoids.	0.7
18	SHALE: gray-green; blocky; clayey, sterile.	4.0
17	LIMESTONE: gray-white on fresh surface, weathers buff; highly weathered in upper part; partly covered; brachiopods, crinoids, fenestrate bryozoans.	14.0
16	COVERED INTERVAL.	7.0
15	LIMESTONE: gray on fresh surface, weathers buff; fine-grained; <u>Dictyoclostus</u> , <u>Echinoconchus</u> , <u>Marginifera</u> , crinoids, echinoids, fenestrate bryozoans.	1.8
14	SHALE: yellow; blocky.	0.3
13	LIMESTONE: blue on fresh surface, weathers buff; extremely even, could be used for dimension stone; profuse <u>Composita</u> .	1.0
12	SHALE: gray to tan in lower part, yellow-green in uppermost part; blocky, clayey; seemingly barren.	19.0

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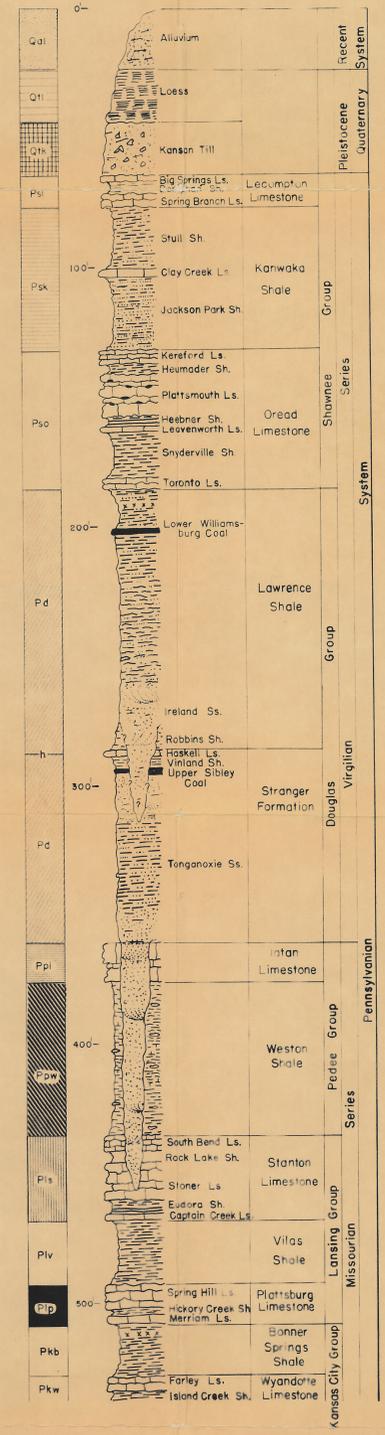


MEASURED SECTION NO. 10 (CONTINUED FROM PREVIOUS PAGE)



No.	Unit	Feet
11	LIMESTONE: gray on fresh surface, weathers buff; thin irregular beds; <u>Composita</u> crust caps unit.	1.7
10	SHALE and LIMESTONE: two thin shales and a brachiopod-bearing limestone blue-gray in color.	0.6
9	LIMESTONE: blue-gray to tan; thin irregular beds; detrital <u>Osagia</u> , foraminifers, brachiopods, crinoids, echinoids, ramose and fenestrate bryozoans; abundant crystalline calcite.	6.0
88	SHALE: brown; seemingly sterile	0.4
7	LIMESTONE: light gray-blue on fresh surface, weathers buff; thin, irregular beds, fine-grained; <u>Dictyoclostus</u> , <u>Marginifera</u> , crinoids, echinoids, ramose and fenestrate bryozoans.	3.5
6	SHALE: gray-blue on fresh surface, weathers tan; flaky; abundant <u>Crurithyris</u> , echinoids.	0.5
5	LIMESTONE; gray to tan; even-bedded; compact; <u>Osagia</u> , fusulinids, echinoid spines.	0.5
4	LIMESTONE: gray to tan; even-bedded, fine-grained; compact; <u>Echinoconchus</u> , <u>Juresania</u> , <u>Marginifera</u> , fenestrate bryozoans.	1.6
3	SHALE: gray to tan; locally black; platy to blocky; clayey; blocky and red in upper portion with calcareous nodules.	24.0
2	LIMESTONE: gray on both fresh and weathered surfaces; single even bed; highly detrital; abundant <u>Osagia</u> , sparse <u>Myalina</u> , <u>Marginifera</u> , <u>Neospirifer</u> .	0.6
1	SHALE: gray; poorly bedded; clayey, very profuse <u>Myalina</u> .	1.0
0	LIMESTONE: gray to tan on fresh and weathered surfaces; even-bedded; highly detrital; <u>Osagia</u> -oolith banding; abundant <u>Myalina</u> , <u>Aviculopecten</u> , <u>Septopora</u> , <u>Linoproductus</u> , high-spired gastropods; lower contact covered.	exposed 2.6

Generalized stratigraphic column of outcropping rocks



Explanation

Stratigraphic symbols

- Wavy-bedded limestone
- Chert nodules
- Black shale
- Massive limestone
- Red shale
- Sandstone
- Shale
- Calcareous shale
- Concretions
- Sandy or silty shale
- Coal
- Cross-bedded sandstone

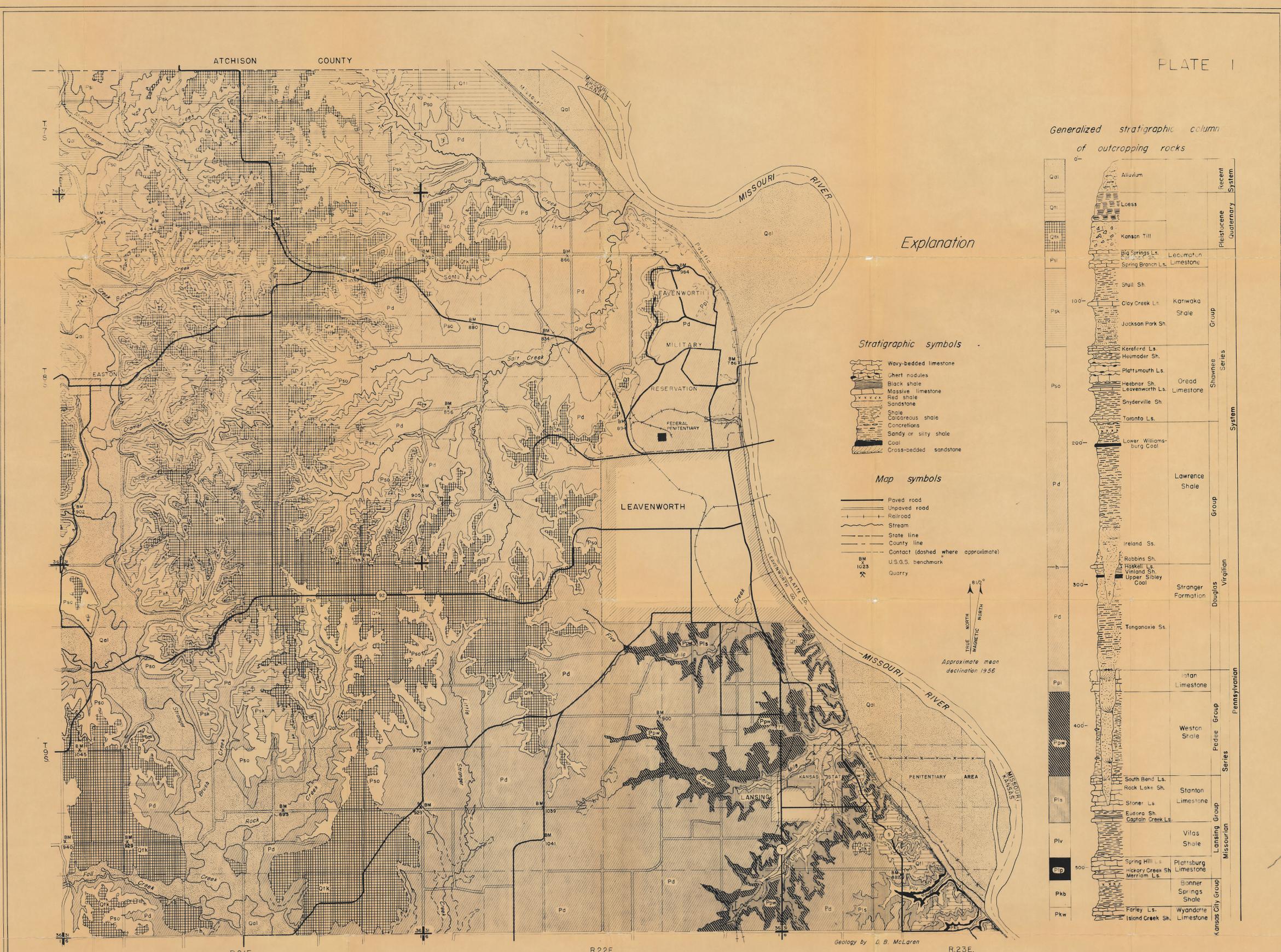
Map symbols

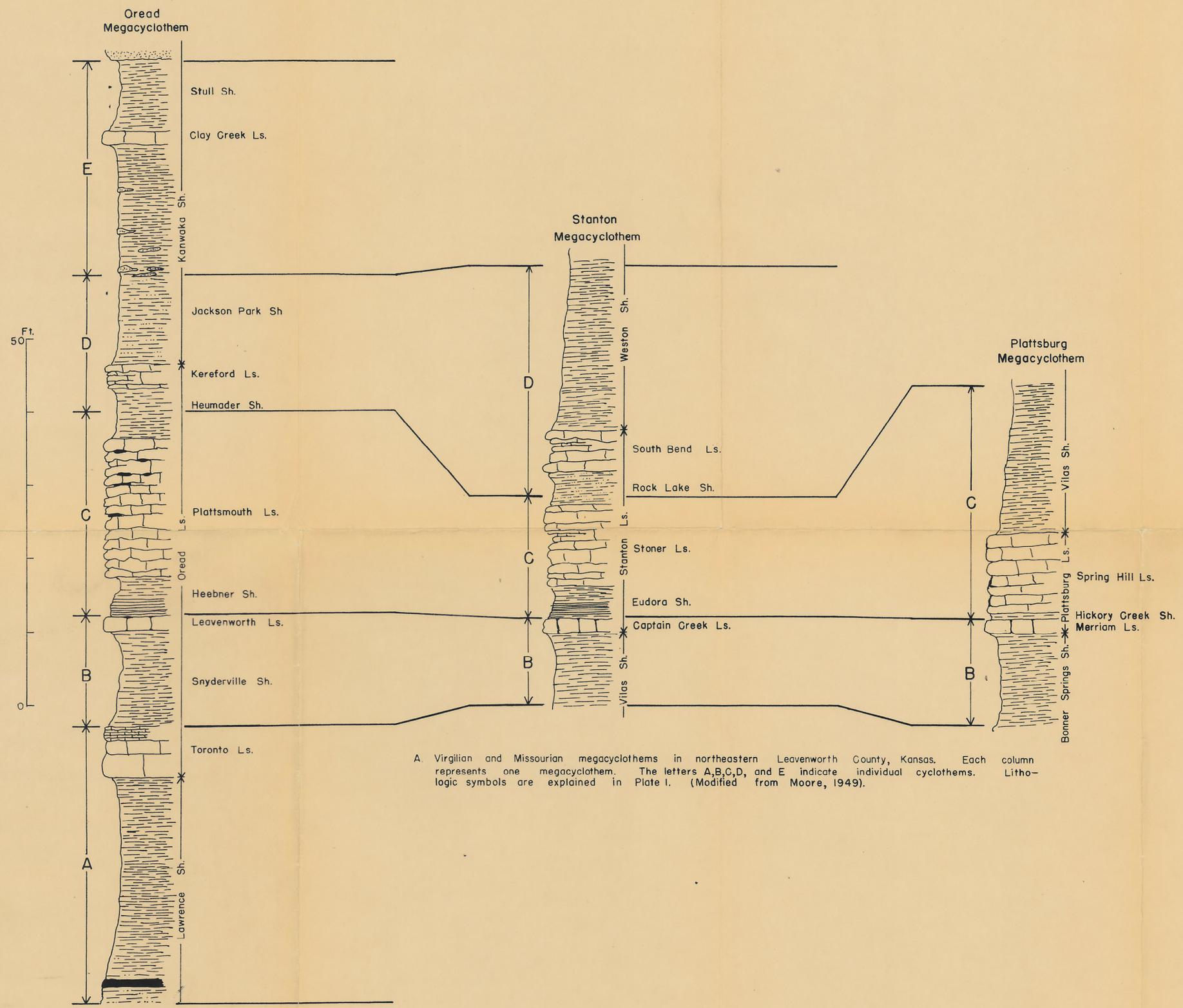
- Paved road
- Unpaved road
- Railroad
- Stream
- State line
- County line
- Contact (dashed where approximate)
- U.S.G.S. benchmark
- Quarry

Approximate mean declination 1956

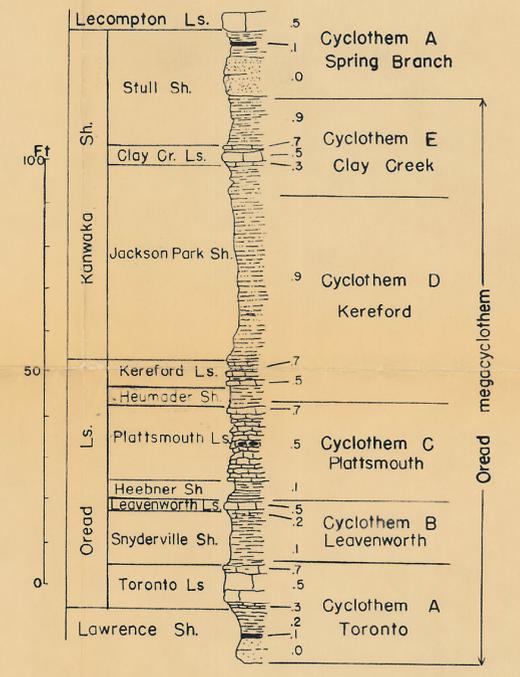


GEOLOGIC MAP OF NORTHEASTERN LEAVENWORTH COUNTY, KANSAS





A. Virgilian and Missourian megacyclothems in northeastern Leavenworth County, Kansas. Each column represents one megacyclothem. The letters A, B, C, D, and E indicate individual cyclothems. Lithologic symbols are explained in Plate I. (Modified from Moore, 1949).



B. Typical Shawnee Group megacyclothem. The numbers .1—.9 indicate members of an ideal cyclothem. (Modified from Moore, 1936).