Geology of Wabaunsee County Kansas

GEOLOGICAL SURVEY BULLETIN 1068

Prepared in cooperation with State Highway Commission of Kansas as part of a program of the U. S. Department of the Interior for development of the Missouri River basin

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By MELVILLE R. MUDGE *and* ROBERT H. BURTON

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CONTENTS

	Page
Abstract	1
Introduction	2
Acknowledgments	5
Physical features	6
Transportation routes	6
Climate	7
Outline of geologic history	9
Geology	10
Pennsylvanian system	16
Wabaunsee group	16
Auburn shale	17
Emporia limestone	17
Reading limestone member	17
Harveyville shale member	18
Elmont limestone member	19
Willard shale	20
Zeandale limestone	21
Tarkio limestone member	21
Wamego shale member	23
Maple Hill limestone member	24
Pillsbury shale	25
Stotler limestone	26
Dover limestone member	27
Dry shale member	28
Grandhaven limestone member	29
Root shale	30
Friedrich shale member	31
Jim Creek limestone member	32
French Creek shale member	32
Wood Siding formation	33
Nebraska City limestone member	34
Plumb shale member	34
Grayhorse limestone member	37
Pony Creek shale member	38
Brownville limestone member	39
Permian system	41
Admire group	41
Onaga shale	41
Towle shale member	42
Aspinwall limestone member	43
Hawxby shale member	46
Falls City limestone	47
Janesville shale	47
West Branch shale member	48
Five Point limestone member	49
Hamlin shale member	51

Permian system—Continued Page
Council Grove group 52
Foraker limestone 53
Americus limestone member 53
Hughes Creek shale member 56
Long Creek limestone member 57
Johnson shale 58
Red Eagle limestone 58
Glenrock limestone member 59
Bennett shale member 59
Howe limestone member 61
Roca shale 62
Grenola limestone 63
Sallyards limestone member 63
Legion shale member 64
Burr limestone member 65
Salem Point shale member 66
Neva limestone member 66
Eskridge shale 69
Beattie limestone 71
Cottonwood limestone member 71
Florena shale member 75
Morrill limestone member 76
Stearns shale 76
Bader limestone 77
Eiss limestone member 78
Hooser shale member 79
Middleburg limestone member 80
Easly Creek shale 81
Crouse limestone 82
Blue Rapids shale 84
Funston limestone 84
Speiser shale 87
Chase group 88
Wreford limestone 88
Threemile limestone member 88
Havensville shale member 91
Schroyer limestone member 92
Matfield shale 93
Wymore shale member 93
Kinney limestone member 93
Blue Springs shale member 94
Barneston limestone 95
Florence limestone member 95
Oketo shale member 96
Fort Riley limestone member 97
Doyle shale 98
Holmesville shale member 99
Quaternary system 99
Older gravels 100
Glacial till 101
Glacial ice-contact deposits 103
Grand Island formation 104
Sappa formation 105
Sanborn formation 106

	Page
Quaternary system—Continued	
Terrace deposits	110
Travertine	111
Alluvium	111
Economic geology	113
Summary of construction material resources	113
Geologic sources	113
Aggregate for concrete	113
Chert gravel	115
Limestone gravel	115
Mineral filler	116
Riprap	117
Structural stone	118
Road metal	119
Calcareous binder	120
Subgrade and embankment material	121
Coal	122
Petroleum	123
Agriculture lime	124
Stratigraphic sections	125
Literature cited	204
Index	209

ILLUSTRATIONS

PLATE 1. Map showing outcrops in Wabaunsee County, Kans., of limestones useful in engineering construction ---------- Plate Volume
2. Geologic map of Wabaunsee County, Kans ---------- Plate Volume
3. Structure section along U. S. Highway 40, Wabaunsee County, Kans ---------- Plate Volume
4. Correlation diagram of the Aspinwall limestone member of the Onaga shale to the French Creek shale member of the Root shale ---------- Plate Volume
5. Aerial photograph showing typical outcrop patterns of many of the Permian limestones ---------- Facing 42
6. *A*, Basal conglomerate of the channel of the Towle shale member of the Onaga shale in the NE¼SE¼ sec. 4, T. 13 S., R. 13 E., Wabaunsee County, Kans.; *B*, Americus limestone member of the Foraker limestone in a road cut in SW¼SE¼ sec. 12, T. 12 S., R. 11 E., Wabaunsee County, Kans ---------- Facing 43
7. Correlated sections of the Foraker limestone down to the Hawxby shale member of the Onaga shale in Wabaunsee County, Kans ---------- Plate Volume
8. State and county road network of Wabaunsee County, Kansas showing road metal and its source as of June, 1949 - Plate Volume
9. Correlated sections of the Roca shale down to the base of the Johnson shale in Wabaunsee County, Kans ---------- Plate Volume

Page

PLATE 10. Correlation diagram of the Grenola limestone in Wabaunsee County, Kans ---- Plate Volume

11. Correlation diagram of the Beattie limestone and Eskridge shale in Wabaunsee County, Kans ---- Plate Volume

12. *A*, Cottonwood limestone member of Beattie limestone exposed in road cut in the center of sec. 12, T. 12 S., R. 10 E., Wabaunsee County, Kans.; *B*, Typical outcrop of the Cottonwood limestone member of the Beattie limestone in the NW¼NE¼ sec. 9, T. 14 S., R. 11 E., Wabaunsee County, Kans ---- Facing 78

13. Correlation diagram of the Crouse limestone down to the base of the Bader limestone in Wabaunsee County, Kans ---- Plate Volume

14. Correlation diagram of the Funston limestone and Speiser shale in Wabaunsee County, Kans ---- Plate Volume

15. *A*, Oolite beds in Funston biostrome in a streambank in the NE¼NW¼ sec. 24, T. 13 S., R. 9 E., Wabaunsee County, Kans.; *B*, *Somphospongia*? sp., in beds of limestone that flank the biostrome in the Funston limestone in the SE¼NE¼ sec. 9, T. 12 S., R. 9 E., Wabaunsee County, Kans ---- Following 78

16. Correlated sections of the Wreford limestone, Wabaunsee County, Kans ---- Plate Volume

17. A biostrome in the Threemile limestone member of the Wreford limestone exposed in a streambank in the SW¼SE¼ sec. 26, T. 13 S., R. 9 E., Wabaunsee County, Kans ---- Following 78

18. Pre-Kansan drainage and topography of Wabaunsee and southern Pottawatomie Counties, Wabaunsee County drainage and topography during the maximum advance of the Kansan ice sheet, and present drainage and topography of Wabaunsee and southern Pottawatomie Counties, Kans ---- Plate Volume

19. *A*, Glacial boulders and till in the SW¼ sec. 1, T. 11 S., R. 10 E., Wabaunsee County, Kans.; *B*, Yarmouth silt and clay impregnated with calcium carbonate and overlain by loess of Loveland silt member of the Sanborn formation in a streambank in the SW¼ sec. 22, T. 14 S., R. 12 E., Wabaunsee County, Kans ---- Facing 79

FIGURE 1. Index map of Kansas showing areas covered by this report and by other construction-materials investigations ---- 4

2. Chart showing temperature and precipitation ranges at Eskridge, Kans ---- 8

3. Subdivision of the Aspinwall limestone member of the Onaga shale in Wabaunsee County, Kans ---- 44

TABLES

TABLE 1. Summary of tests on construction materials of Wabaunsee County, Kans ---- Plate Volume

2. Outcropping stratigraphic units in Wabaunsee County, Kans ---- 12

GEOLOGY OF WABAUNSEE COUNTY, KANSAS

By MELVILLE R. MUDGE and ROBERT H. BURTON

ABSTRACT

Wabaunsee County is in east-central Kansas. The northern part of the county is mostly a till plain with smooth rounded hills; the eastern part is a relatively broad flat lowland with well-incised streams with shallow valleys, which is bordered on the west by the Flint Hills escarpment. The central and western parts of the county comprise an upland that is part of the Flint Hills. The county is thoroughly drained by streams that have cut deep valleys that form a dendritic pattern.

The county is underlain by the Forest City structural basin, except the western part which contains the Nemaha and Alma anticlines. The oldest rocks exposed are of the upper part of the Pennsylvanian system. They generally consist of thin dark-colored fossiliferous limestone beds separated by relatively thick nonfossiliferous gray to olive-drab shale beds. Most of these shale beds contain sandy shale, sandstone, and beds of coal. Two of the shales, the Plumb and Pony Creek shale members of the Wood Siding formation, contain deep ancient stream channels.

The lowermost 100 feet of the Permian rocks are similar in lithology to the Pennsylvanian rocks. The Indian Cave sandstone bed of the Towle shale, a channel deposit, is exposed in two places in the county. The rest of the exposed Permian strata consist of thick light-colored limestone beds separated by thick brightly variegated and gray shale beds. Many of the gray shale beds are very fossiliferous. Biostromes were traced for a considerable distance in three of the Permian limestone beds.

Many exposures of the Permian and Pennsylvanian rocks were measured and studied in detail. Most of the units persist across the county, but they vary considerably in thickness and in character. The fauna of each unit was recorded and some of the fossils were very important in the identification of certain limestones. Faunal changes were noted laterally in some of the beds of limestone and shale.

Sediments of Quaternary age are widespread, and chert gravels of pre-Kansan age are along many of the larger streams. In the northern part of the county the chert gravel deposits mark the position of Mill Creek before the advance of the Kansan ice sheet. The deposits indicate that this creek formerly extended northeastward from Alma to St. Marys.

At its maximum advance the Kansan glacier diverted the Kansas River southeastward through a series of cross-axial diversion channels and into Wakarusa Creek. As the ice retreated, the present course of the Kansas River and Mill Creek were established. Deposits of upper Kansan, Illinoian, and Wisconsin glacial stages also are in the county.

Limestone and gravel have been extensively used in the county as aggregate for concrete, and for road metal, ballast, and for various bituminous mixes; Permian limestone has been widely used also as structural stone. The limestone units quarried most are the Fort Riley, Threemile,

Funston, Cottonwood, Neva, Red Eagle, Americus, Five Point, and Aspinwall units of the Permian system and Tarkio unit of the Pennsylvanian system.

The samples of limestones tested and accepted for concrete aggregate by the Kansas State Highway Commission were from the Funston, Threemile, part of the Neva, Cottonwood units, and from the biostrome in the Bennett shale member of the Red Eagle limestone. The limestone units acceptable as riprap and wash check are the Cottonwood, Eiss, Funston, Five Point, Fort Riley, Red Eagle, Neva and Tarkio. The limestone units used in the county as structural stone are the Fort Riley, Crouse, Cottonwood, Neva, Five Point, Aspinwall, and Grayhorse.

Other information that may be of value to engineering, pertains to the use of shales and to the location of some seeps and springs. Many of the Permian and Pennsylvanian shales have been used as fill material along major highways. Small seeps and springs are at various horizons throughout the stratigraphic column. These are numerous within or at the base of Quaternary sediments, and in the Fort Riley, Florence, Threemile, Cottonwood, and Neva units. A few springs and seeps also occur in other beds of limestone and in beds of shale.

In Wabaunsee County, the Kansas River Valley contains the largest potential reserves of sand and gravel acceptable for general engineering use. In the northern part of the county, chert gravels of pre-Kansan age have been used extensively for road metal on secondary routes. Other chert gravels, terrace deposits, and ordinary stream gravels along most of the major streams and their tributaries constitute a limited potential reserve of gravel for road metal.

INTRODUCTION

The investigation of the geology of Wabaunsee County, Kans., was made in cooperation with the State Highway Commission and is part of an inventory of construction materials in the northern part of Kansas. The study of this county is also a contribution to the geologic mapping and mineral resource investigations of the Missouri River basin.

This investigation included detailed stratigraphic studies and geologic mapping of the Upper Pennsylvanian and the Permian rocks cropping out in the county, and included reconnaissance type studies of the Pleistocene deposits mantling much of the area. These studies were integrated with a survey of the materials used in building dams, highways, railways, airports, and other engineering structures.

The available laboratory test data have been included as an aid in the evaluation of materials. The information given in table 1 is based on standard testing procedures of the State Highway Commission of Kansas (1937 and 1945) and the American Association of State Highway Officials (1947). It is expected that prospects shown on plate 2 will be proved by augering, drilling, or test pitting and that the materials will be subjected to laboratory testing before production for specific uses is attempted.

Although many prospect pits and quarries were plotted (pl. 2) no attempt was made to complete a survey of all possible sources of materials. In relating the construction materials available in Wabaunsee County to the geologic formations mapped on plate 2, and described in the text, the use of this report and map should aid the fieldman in his search for the materials needed in a construction project.

The statements made here, that pertain to the use of material in fills, does not necessarily conform with the standards of the State Highway Commission of Kansas, but is, as near as can be determined, similar to the requirements of the American Association of State Highway Officials (1947, p. 37–38) for subgrade and embankment uses. In many cases most any material is used in fills, except the upper 12 to 18 inches, regardless of physical properties.

A preliminary report on the geologic construction-material resources in Wabaunsee County was placed on open file in April 1951. Almost all of the data in that report is given here.

Wabaunsee County is in the third tier of Kansas counties south of the Nebraska border and in the fourth tier west of Missouri (fig. 1). The county is bounded on the north by Pottawatomie and Shawnee Counties, on the west by Riley, Geary, and Morris Counties, on the south by Morris and Lyon Counties, and on the east by Osage and Shawnee Counties. The county encompasses about 800 square miles and lies about 15 miles west of Topeka and about 85 miles west of Kansas City.

A field party composed of personnel from the two cooperating agencies undertook an investigation of the geology of Wabaunsee County, Kans., in the summer and fall of 1948 and completed it in the spring of 1951.

The base map used in the field was compiled from aerial photographs (scaled 8 inches equal 1 mile) provided by the Production and Marketing Administration of the U. S. Department of Agriculture. The geologic mapping was done on the photographs. Some of the mapped units are single lithologic units, but most are composed of two lithologic units, generally a limestone and the shale overlying it.

An effort was made to accumulate all available data pertaining to construction materials in the county; these are presented in table 1. Some of the tests recorded in this summary were made from samples collected in the county by members of the materials division of the State Highway Commission of Kansas; the rest were collected by the authors. All of the tests were made at Manhattan, Kans., in the materials-testing laboratory of the State Highway Commission.

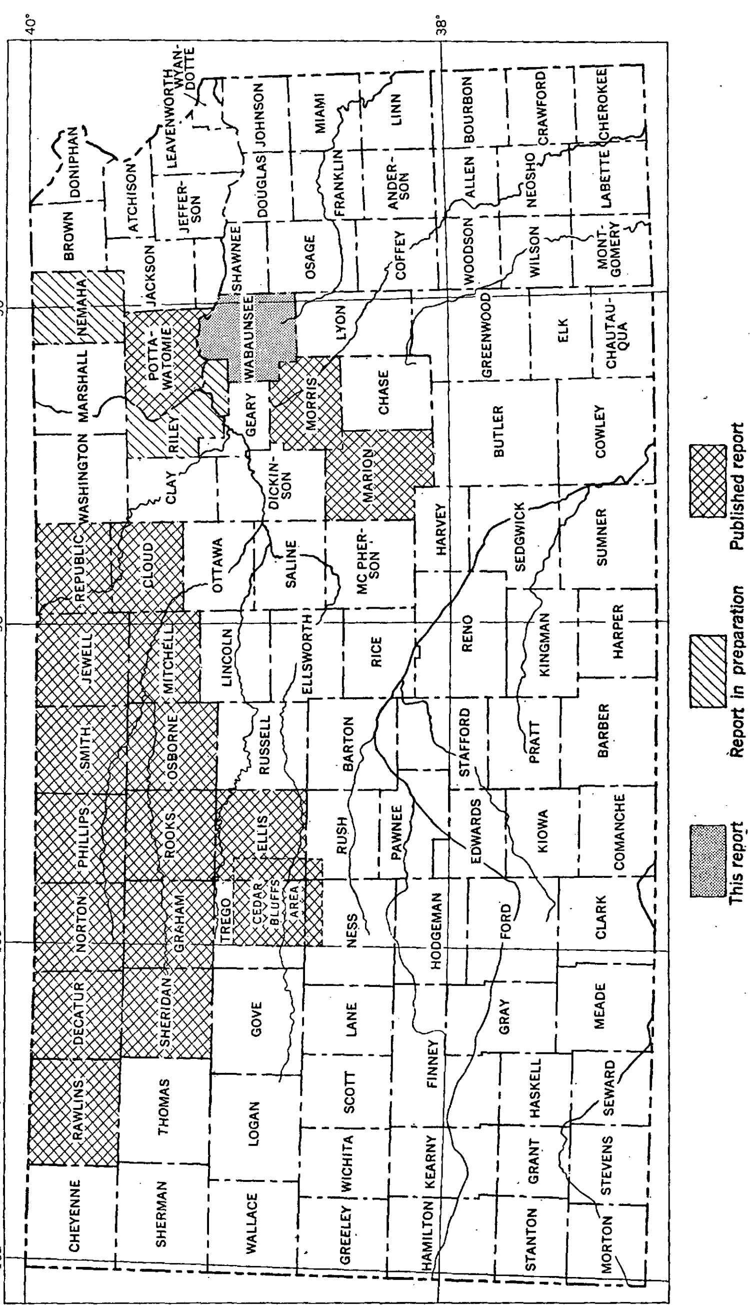

FIGURE 1.—Index map of Kansas showing areas covered by this report and by other construction-materials investigations.

Much of the information on engineering geology in this paper is based on field observations, personal interviews with county and local engineers, and from notes provided by the Geologic section of the State Highway Commission of Kansas.

The locations of pits and quarries are shown on plate 2. The symbols indicate whether the pit or quarry is being operated, has been operated, or is a prospect, the type of construction material available at each site, and the estimated quantity of material (in units of 10,000 cubic yards) that can be removed with no more than moderate overburden (unconsolidated sediments less than 6 feet thick). Most of these sources of construction materials are listed in table 1 and are numbered within each classification of materials as follows: the numbering starts in the northeast township and continues west along the same tier to the west boundary of the county; it is continued in the next tier south starting again with the east township and proceeding to the west boundary of the county, and so on. Within a township the sources are numbered in the same sequence as are the sections of the township.

The areal distribution of the local stratigraphic units is shown on a geologic map of the county (pl. 2), and each mapped unit is indicated by an identifying symbol. Concentrations of glacial boulders are shown as black dots, the number of dots indicating, in a general way, the abundance of boulders in an area.

ACKNOWLEDGMENTS

Those persons who contributed information and data used in this report include: R. D. Finney, engineer of materials and W. E. Gibson, engineer of tests, both of the State Highway Commission of Kansas, who supervised the testing of materials and interpreted much of the information obtained from these tests; S. E. Horner, (deceased), chief geologist, geologic section of the State Highway Commission of Kansas, contributed geologic information about construction materials along state highways in the county, furnished the cross section shown on plate 3, and suggested methods of conducting a materials survey; Dr. J. C. Frye, executive director, and Dr. J. M. Jewett, geologist, both of the State Geological Survey of Kansas at Lawrence, Kans., contributed materially to the geological information given here; and Carl H. Diepenbrock, engineer of Wabaunsee County, assisted in the materials survey. The residents of Wabaunsee County were most hospitable, courteous, and cooperative.

This report, in manuscript form, was reviewed by J. D. McNeal, chief geologist of the State Highway Commission of Kansas. J. Harlan Johnson of the Colorado School of Mines examined and identified the algal remains *Spongiostroma* listed in this report. Wendel Becraft, chairman of the Kansas State Production and Marketing Committee furnished most of the data on lime for agricultural use.

PHYSICAL FEATURES

Wabaunsee County is in the Great Plains province (Fenneman, 1931) and is near the western boundary of the Central Lowlands (Frye and Swineford, 1949, p. 71). The county is included in the subdivision of the Central Lowlands known as the Osage plains, and the Flint Hills upland extends through the western part. The eastern boundary of this upland is marked by the prominent Flint Hills escarpment which forms a bluff about 125 feet above the relatively flat lowland. The Flint Hills are composed of alternating beds of shale and flinty limestones. Many of the limestones form conspicuous benches on the hillside above the streams that have dissected them. The shales, which are less resistant to erosion than the limestones, form the steep slopes between the benches (pl. 18).

The eastern part of the county is a relatively broad flat lowland with well-incised streams. This lowland is formed on the easily dissected lower Permian and Upper Pennsylvanian rocks.

Wabaunsee County is thoroughly drained by an intricate dendritic stream system. The principal stream is the Kansas River which flows eastward along the northern boundary (pl. 2). This river continues to shift its course by cutting laterally into older terrace deposits. North of Maple Hill and near St. Marys, the Kansas River cut a new channel across a large meander in the early 1900's, thus isolating an area of about 4 square miles, north of the present course. (See pl. 2.) About 8 miles north of Paxico, from the year 1937 to 1948, the river cut laterally three-fourths of a mile into the south bank. The northern and western parts of the county are drained by Mill Creek and its many tributaries. The southern part of the county is drained by the Marais des Cygnes River and Dragoon, Rock, and Soldier Creeks. The east-central area is drained by Mission Creek.

Even though an intricate drainage pattern has developed over the county, erosion is moderate. This is probably due to the extensive practice of soil conservation methods and to the fact that more than 50 percent of the county is uncultivated land. Contour farming and construction of stock ponds have been extensive.

TRANSPORTATION ROUTES

Wabaunsee County is served by two railroads, the Chicago, Rock Island, and Pacific, and by a branch line of the Atchison, Topeka, and Santa Fe.

The only transcontinental (U. S.) highway in Wabaunsee County is U. S. 40. There are six state highways (pl. 2) that connect most of the small cities and serve as direct links to the larger cities.

In areas of scant relief, most roads follow section lines. Where the topographic relief is great, however, the roads have been located in stream valleys and, in some cases, in the interstream areas. In the central and western parts of the county, where dissection has been greatest, roads are relatively few, but numerous trails permit access to the area. Most of the state highways are surfaced with bituminous material. All county roads are surfaced with local material. Township roads are either surfaced or are maintained as earth roads. There are no airports in Wabaunsee County.

CLIMATE

Wabaunsee County is in an area of continental-type climate in which the summers are relatively long and hot, and the winters short and fairly cold. The mean annual temperature is 55°F. and ranges from a mean of 29°F. in January to a mean of 79°F. in July. There are 85 cloudy days, 100 partly cloudy days, and 180 clear days in a year. The average date of the last killing frost in the spring is April 14; the ground is covered with snow 25 days of the year (Flora, 1948).

Figure 2 indicates, for the 10-year period (1937–1946), the number of days each month in which the maximum daily temperature fell within the ranges of temperature that is generally important in engineering construction. Days in which the maximum temperature does not exceed 32°F. occur only in the five months from November to March with the maximum incidence of such days (7.5) in January. July, which is the warmest month of the year, has an average of 19.1 days on which the maximum temperature exceeds 90°F. The chart also shows the average difference between the daily maximum and minimum temperatures for each month. The greatest difference in daily temperatures, 26°F., is in July; the least difference, 19°F., is in December and January.

Precipitation ranges at Eskridge, Kans., also given in figure 2, are presented to show the effect of precipitation on engineering construction. During the 10-year period of 1937–1946 (Climatological Data, Kansas section, 1937–1946) there averaged, for example, 17.9 days in June without measurable precipitation, 5 days in which the precipitation ranged from a trace to 0.1 inch, 5.3 days in which 0.11 to 1 inch of rain fell, and 1.8 days in which the precipitation was more than 1 inch. Persistent rains generally

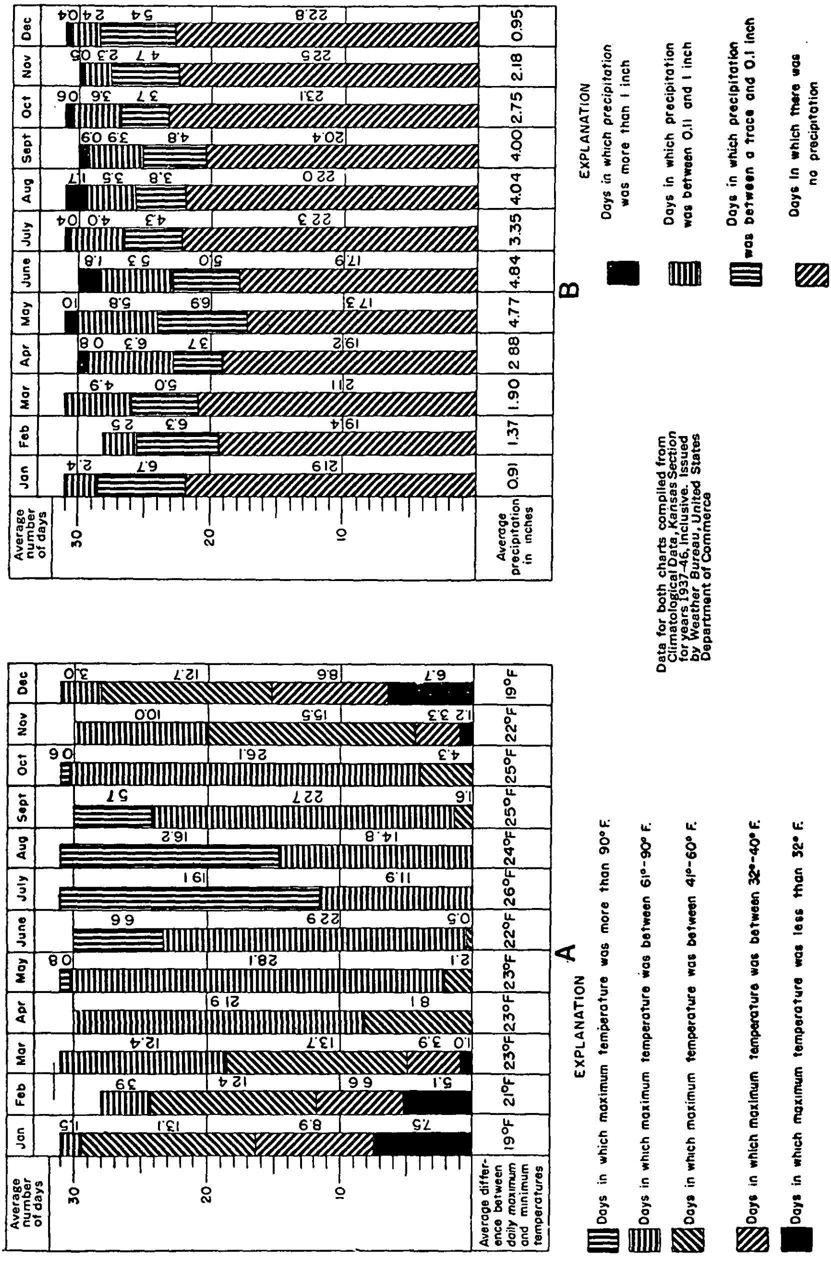

FIGURE 2.—Chart showing temperature and precipitation ranges at Eskridge, Kans. for the 10-year period (1937 to 1946).

fell in the late spring and early autumn. Other rainfall is generally in the form of showers. The normal annual precipitation is 33.94 inches.

OUTLINE OF GEOLOGIC HISTORY

The early Paleozoic history of the area encompassed by Wabaunsee County is fairly well known. A basement complex of Precambrian rocks underlies the area. Cambrian sediments were deposited on a Precambrian surface of low relief. Almost all of the Cambrian sediments were eroded before being inundated by Ordovician seas and alternating periods of emergence and submergence continued throughout the Ordovician. The seas of the Silurian, Devonian, and Mississippian periods covered the area with intervals of emergence separating each of the three inundations. The North Kansas basin was formed before Mississippian time (Lee, 1943, p. 15).

The Nemaha Range was rejuvenated at the close of the Mississippian period and all of the rocks deposited over it were eroded. The Forest City basin and the Nemaha and Alma anticlines were developed after this time. The relief of the Precambrian surface in Wabaunsee County was a maximum of 2,500 feet and the eroded Mississippian surface before inundation by the Pennsylvanian seas was more than 1,000 feet.

The Pennsylvanian and Permian seas inundated the area and sediment completely covered the Nemaha Range. The sediments of these two systems indicate cyclic sedimentation without a major disconformity between systems. The seas of these periods were shallow, and toward late Pennsylvanian time the area was one of very low relief. Many periods of subsidence and emergence occurred in the area, as indicated by stream channels and beds of coal overlain by marine sediments. At the close of the Paleozoic the seas withdrew from this area and did not re-enter until Cretaceous time.

Wabaunsee County was probably inundated throughout Cretaceous time, marking the final period of submergence for this area. The Cretaceous deposits were completely eroded prior to Tertiary or early Quaternary time, as no deposits of gravel in the county contain any fragments of Cretaceous sandstone. The nearest outcrop of Cretaceous sedimentary rocks is about 40 miles west of the county.

Tertiary sediments were deposited along the course of some of the streams that existed in the area. These streams are ancestral to many of the present day streams. Periods of aggradation continued throughout the early part of the Pleistocene, but in this area no evidence was found to indicate a boundary between the Tertiary and the Quaternary.

The northern part of the county was occupied by glacial ice during part of the Kansan glacial stage. The advance of this ice sheet had a profound effect on the eastward-flowing streams. The Kansas River, which was dammed at St. George in Pottawatomie County, was diverted through a series of diversion channels which were cross-axial to Mill, Mission, and Wakarusa Creeks; and small ponds or lakes were formed in the valleys of all streams that were dammed by the ice. As the ice sheet retreated from the area, Mill Creek and the Kansas River occupied the channels that are their approximate courses today (Mudge, 1955, p. 279–280).

During the Illinoian and Wisconsin glacial stages degradation and aggredation continued. Loess and gravels were deposited during the glacial stages, and soils were formed during the interglacial stages.

GEOLOGY

The rocks underlying the area, but not outcropping, range from Precambrian to Late Pennsylvanian in age. Smith and Anders (1951, p. 13–52) thoroughly describe the subsurface rocks at and adjacent to the Davis Ranch Pool in Wabaunsee County. Moore and others (1951, p. 122) state: "Rocks of pre-Cambrian age underlie all of Kansas. They include granite, porphyry, gneiss, schist, quartzite, slate, and marble, according to reports of deep wells. Granite or gneiss probably is most widespread."

The western part of Wabaunsee County is underlain by part of the buried Precambrian mountain range that Moore and Haynes (1917, p. 168) named the Nemaha Mountains after the valley of that name in Nemaha County where these rocks approach the surface. On the east, the ridge is flanked by gently dipping rocks of Cambrian, Ordovician, Silurian, Devonian, and Mississippi ages; rocks of the same ages are even more gently dipping on the west side (Smith and Anders, 1951, fig. 2) of the ridge.

It was not the purpose of this study to make an investigation of structure in Wabaunsee County, therefore, this subject will be mentioned only briefly in the following sentences. The principal structures, which are the North Kansas basin, Forest City basin, and Nemaha and Alma anticlines, have been discussed by Lee (1943), Lee, Leatherock, and Botinelly (1948), Smith and Anders (1951, p. 13–52), and by Jewett (1951, p. 105–172). The North Kansas basin was developed before Mississippian time, but, the Forest City basin and Nemaha and Alma anticlines were developed mainly after Mississippian time (Lee, 1943, p. 15).

Moore and Haynes (1917, p. 169) discuss this deformation and propose the occurrence of: ***"a rather pronounced though local deformation in central Kansas in Late Mississippian or Early Pennsylvanian time, followed by rapid erosion which removed all of the sediments covering at least the top of the granite." This has been firmly established as pointed out by Lee (1943, p. 118–119).

Small normal faults in the northwest part of the country are shown on plate 2.

There are many small structures in the county that can be interpreted from the outcrop pattern on plate 2. These include the plunging anticlines west of Alma and northeast of Eskridge, and a small basin northeast of Alta Vista. Some of the other structures are shown on a structure section taken along Kansas Highway 10 (pl. 3).

The presentation of data in this report is based on the chronologic sequence in which the formations were deposited. Names of the formations and members, type locality, areal distribution, description, thickness, general paleontology, and engineering geology are included. Measured sections of each of the formations are in the section of this report entitled Stratigraphic sections. They were selected to illustrate the formation as it crops out in the county and to show some of its facies changes. This group of measured sections represents about 40 percent of those that were studied in detail.

The following discussion includes briefly an outline of geologic history and detailed descriptions of the outcropping rocks in Wabaunsee County that are shown on plate 2 and table 2.

The Paleozoic rocks cropping out in Wabaunsee County average about 575 feet in thickness. They are relatively flat lying, have a general dip to the northwest, and belong to the Permian system and the upper part of the Pennsylvanian system (table 2). The Upper Pennsylvanian and lower Permian rocks are similar in lithology in that they contain thick beds of gray to tan-gray nonfossiliferous shale and thin medium-hard limestone beds. The beds of shale are clayey to silty, locally sandy with channels of varying depths, and contain thin lenses of sandstone and coal. The ancient stream channels in Kansas are in almost all beds of shale in the Upper Pennsylvanian and lower 100 feet of the Permian rocks. The disconformity at the base of the channel deposit of the Towle shale member of the Onaga shale as assigned by Moore and Moss (1933, p. 100) is one of the local channels. The occurrence of these channels in each of the shale units made it impractical to select one as the disconformity between systems (Mudge, 1956, p. 677). The placement of the boundary between the Pennsylvanian and Permian systems was not changed. In Wabaunsee County the rest of the lower Permian

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TABLE 2.—*Outcropping stratigraphic units in Wabaunsee County, Kansas*

System	Group	Formation	Member	Thickness (feet)	Description
QUATERNARY		Alluvium		0-100	Tan-brown to gray-brown silt and clay with sand and gravel in lower part.
		Travertine		3-12	Gray to light-gray deposit of dense, porous calcium carbonate. Contains leaf and wood fragments.
		Terrace deposits		0-60	Gray-brown to red-brown silt and clay; tends to stand in vertical banks; lenses of chert and limestone gravel in lower part.
		Sanborn formation		0-15	Gray-brown to red-brown loess. Some deposits of chert and limestone gravel; colluvium of local rock.
		Sappa formation		3	Clayey gravel and clay with fossil soil; dark gray grading down into gray brown; calcium carbonate abundant. Fossiliferous.
		Grand Island formation.		3-6	Northern outcrop area consists of glacial outwash sand and gravel; southern outcrop area consists of limestone and chert gravels.
		Glacial ice-contact deposits.		0-30±	Various sizes of material ranging from fine sand to boulders; variety of igneous and metamorphic rocks; some limestone and chert fragments; large inclusions of glacial till.
		Glacial till		0-50	Nonstratified light-gray to gray-brown clay with some silt, sand, and erratics; erratics range in size from sand to boulders 5 feet or more in diameter.
		Older gravel		0-15	Thick beds of chert gravel and red-brown clay overlain in northern area by glacial till. Chert semiangular; size varies from sand to cobbles.
PERMIAN	Chase	Doyle shale	Holmesville shale	8+	Silty calcareous tan-gray to gray shale.
		Barneston limestone.	Fort Riley limestone.	25+	Massive to shaly, beds vary from hard to soft dolomitic limestones, shale partings near base and in center. Lower limestone forms conspicuous "rimrock" outcrop.
			Oketo shale	0-8	Silty, calcareous, tan gray to gray, locally blue gray. Shale sparsely fossiliferous to nonfossiliferous.
			Florence limestone	35-38	Massive beds of hard, gray to light-gray limestone containing numerous chert nodules and lenses. Locally beds of shale in upper and lower parts.
		Matfield shale	Blue Springs shale	20-30	Predominantly silty and calcareous shale; tan-gray, green, maroon and purple zones in upper part, tan gray in lower part.
			Kinney limestone	1.0-15	Two beds of moderately hard light-gray to tan limestone separated by a gray and locally fossiliferous shale; lower limestone contains microfossils in upper part.
			Wymore shale	16-25	Silty and clayey, calcareous shale beds with tan-gray beds in upper part and gray-green, tan, and maroon shale in lower part.
		Wreford limestone	Schroyer limestone	8.5-19	Massive, fossiliferous, light-gray limestone containing numerous chert lenses and nodules. Beds of shale in upper and middle parts.
			Havensville shale	6-18+	Shale, clayey in lower part and silty in upper part, gray green to gray; thin limestone lenses in middle and upper parts.
			Threemile limestone.	13-36	Massive hard light-gray chert limestone with persistent bed of shale in lower part. Biostrome in southern part of county.

TABLE 2.—*Outcropping stratigraphic units in Wabaunsee County, Kansas*—Con.

System	Group	Formation	Member	Thickness (feet)	Description
PERMIAN	Council Grove	Speiser shale		6-30	Silty and clayey shale, usually varicolored, tan gray predominant in upper part, maroon and gray green in lower part; persistent bed of limestone in upper part.
		Funston limestone		8.8-26+	Generally three thin beds of moderately hard massive limestone separated by gray beds of shale. Western area contains biostrome that is mostly oolitic limestone.
		Blue Rapids shale		15-22	Predominantly silty and calcareous shale; gray brown with some gray-green and maroon zones; locally, a bed of hard, massive sandy limestone is present.
		Crouse limestone		11-23	Two or more hard limestone beds separated by a thick tan-gray shale; uppermost limestone weathers platy; lower limestone is hard and massive.
		Easly Creek shale		10-18	Predominantly silty and calcareous shale, gray green in lower part with green, and maroon zones composing remainder. Thin lenses of limestone locally in upper and lower parts.
		Bader limestone	Middleburg limestone	5.6-8.6	Two massive fossiliferous limestones separated by a silty calcareous gray shale.
			Hooser shale	5.5-15.2	Predominantly silty and calcareous shale, gray to gray green with maroon beds and limestone lenses.
			Eiss limestone	6.4-15.0	Two limestones separated by a gray silty calcareous fossiliferous shale. The upper limestone is massive and porous. Lower limestone is soft, shaly, tan gray and fossiliferous.
		Stearns shale		10.2-18.3	Predominantly silty and calcareous shale, tan gray to gray green; thin, clayey limestone lens near middle.
		Beattie limestone	Morrill limestone	3.3-7.5	Two or more thin limestone beds separated by shale partings; limestone is tan gray to gray brown and weathers porous to cavernous.
			Florena shale	6.9-10.7	Silty calcareous tan-gray and fossiliferous shale; locally a gray-green zone in upper part; generally lower part very fossiliferous.
			Cottonwood limestone	4.1-8.8	Hard massive gray fossiliferous limestone with some chert nodules and lenses; fusulinids very abundant in upper part. Forms prominent hillside bench.
		Eskridge shale		32.6-38.0	Silty to clayey predominantly calcareous gray green, olive drab, maroon, and purple shale beds, thin beds of limestone in upper and middle parts. In southern area, upper part contains thin coal bed.
		Grenola limestone	Neva limestone	13.8-16.7	Massive beds of limestone separated by two or more calcareous tan gray shale beds; limestone in middle part, soft, porous to cavernous; shale and lime stone beds are fossiliferous.
			Salem Point shale	4.2-9.7	Silty, calcareous, gray, green to olive drab shales; numerous calcareous plates on weathered surface.

TABLE 2.—*Outcropping stratigraphic units in Wabaunsee County, Kansas*—Con.

System	Group	Formation	Member	Thickness (feet)	Description
PERMIAN	Council Grove	Grenola limestone	Burr limestone	2.7–9.6	Soft massive gray-brown fossiliferous beds of limestone separated by thin, calcareous shale beds. Ostracodes abundant in upper part of upper bed.
			Legion shale	1.4–8.7	Silty to clayey gray calcareous shale; locally fossiliferous.
			Sallyards limestone.	0.4–2.0	Moderately hard gray fossiliferous limestone; weathers blocky to shaly.
		Roca shale		25±	Silty to clayey calcareous shale; gray, gray green with some maroon and purple zones in middle part. Locally contains one or more lenses of limestone.
		Red Eagle limestone.	Howe limestone	2–5±	Soft massive tan to gray-orange limestone. Ostracodes abundant in thin zones in upper part.
			Bennett shale	6.–28±	Clayey to silty gray brown to dark gray thin bedded shale beds. Usually fossiliferous. South outcrop area contains biostrome in middle and upper parts.
			Glenrock limestone	0–2.1	Hard massive fossiliferous limestone, absent in vicinity of Alma.
		Johnson shale		25±	Predominantly silty and calcareous tan to gray shale with some thin gray-green zones in lower part; calcareous lenses in upper part.
		Foraker limestone	Long Creek limestone	2.5–8.0	Soft massive dolomitic gray to gray-orange limestone with secondary celestite common. Locally, pelecypods are present in lower part.
			Hughes Creek shale	.32–40	Silty calcareous gray to tan-gray very fossiliferous shale containing two clayey limestone beds in the upper part and one or more clayey limestone beds in the middle part.
			Americus limestone	2.8	Three hard, gray beds of limestone grading northward into two beds, thin bed of shale lenses out northward. Distinctive algae in lower bed.
	Admire	Janesville shale	Hamlin shale	35–45	Mainly silty, calcareous shales; gray, gray green and maroon in upper part; gray and gray-green in lower part; contains lenses of sandstone, sandy shale, conglomerate and limestone.
			Five Point limestone	4–8	Two or more hard gray limestone beds separated by one or more calcareous beds of shale; uppermost limestone platy or massive and is locally coquinoid.
			West Branch shale	27±	Silty to sandy, tan-gray, gray-brown and gray-green shale with a thick lens of clayey limestone in upper part. Persistent thin coal bed near top. Locally small channels filled with sandstone in middle part.
		Falls City limestone		12–17	Two or more beds of hard locally dense gray to gray-brown fossiliferous beds of limestone with interbedded shale.
		Onaga shale	Hawxby shale	6–17	Predominately clayey and calcareous gray to gray-green shale with thin soft tan lenses of limestone in middle part.
			Aspinwall limestone	8±	Generally three beds of limestone separated by gray shale, which are locally maroon and gray-green. Lower limestone very persistent and contains iron specks in thin zones. Middle limestone conglomeratic.

TABLE 2.—*Outcropping stratigraphic units in Wabaunsee County, Kansas*—Con.

System	Group	Formation	Member	Thickness (feet)	Description
PERMIAN	Admire	Onaga shale	Towle shale	6–95±	Generally clayey noncalcareous gray to blue-gray shale, with some thin limestone and variegated shale beds. Locally channels filled with sandstone and sandy shale cut into underlying formations of Pennsylvanian age.
PENNSYLVANIAN	Wabaunsee	Wood Siding formation	Brownville limestone	1.8–4.5	Massive moderately hard gray-brown fossiliferous limestone; local shale lens in middle part.
			Pony Creek shale	6–70+	Clayey gray and gray-brown shale; local maroon beds and limestone lenses. Channels filled with sandstone, sandy shale, conglomerate, clayey and silty shale beds; cuts into underlying units.
			Grayhorse limestone	0.2–2.8	Hard massive gray-brown to tan-brown conglomeratic limestone; fossiliferous.
			Plumb shale	7.8–100+	Silty to clayey gray-green to gray shale; local maroon zones. Channels filled with sandstone, sandy shale, conglomerate, coal lentils, clayey and silty shales; cut into underlying formations.
			Nebraska City limestone	0.6–2.5	Very fossilferous gray moderately hard limestone that weathers into irregular blocks and chips. Locally is a shaly limestone and very calcareous shale.
		Root shale	French Creek shale	21.3–26.0	Clayey noncalcareous gray to blue-gray shale; micaceous in upper part; persistent bed of coal in upper part.
			Jim Creek limestone	0.6–1.0	Hard dark-gray fossiliferous shaly-limestone.
			Friedrich shale	13±	Clayey olive-drab to gray shale in upper and lower parts, maroon in middle part.
		Stotler limestone	Grandhaven limestone	0.9–3.2	Hard dense massive brown fossiliferous limestone.
			Dry shale	3.4–23.0	Tan-gray to gray-brown calcareous shale. Locally a thin lens of sandstone is in upper part.
			Dover limestone	1.9–5.9	Two limestone beds, locally separated by a shale bed; limestone beds are massive to nodular, gray brown to light gray, and contains fusulinids and algae.
		Pillsbury shale		36–46	Tan to blue-gray sandy micaceous shale; sandstone lenses in upper part.
		Zeandale limestone	Maple hill limestone	0.9–1.8	Massive hard gray fossiliferous limestone.
			Wamego shale	8–50	Silty to clayey calcareous gray-brown to blue-gray, shale; contains beds of limestone and fossils locally.
			Tarkio limestone	1.9–10	Massive hard brown limestone. Locally two beds of limestone separated by thin bed of shale. Fusulinids abundant in upper part.
		Willard shale		32–60±	Silty to sandy gray-brown to blue-gray calcareous shale.
		Emporia limestone	Elmont limestone	1.8	Massive hard dark blue-gray fossiliferous limestone.
			Harveyville shale	21	Tan-gray to gray thin-bedded clayey shale.
			Reading limestone	2	Hard dense blue-gray fossiliferous limestone; generally weathers into three beds.
		Auburn shale		6+	Clayey tan-gray thin-bedded shale.

rocks consist of brightly variegated shale beds and light-gray massive beds of limestone. The proportion of limestone to shale in this part of the Permian system is much greater than that seen in the Upper Pennsylvanian and lower Permian.

Glacial sediments such as till, outwash, sand and gravel, and ice-contact deposits, are in the northern part of the county. Terrace sediments are along most of the streams, and talus deposits mantle most of the slopes adjacent to the streams. Loess is on the crests of many of the interstream areas, especially in the southeastern and southwestern parts of the county. In the central part of the county residual soil is common in the interstream areas.

PENNSYLVANIAN SYSTEM

WABAUNSEE GROUP

The outcrop areas of the Wabaunsee group are in the northern part of the county along the south side of the Kansas River valley and along the eastern border of the county as far south as the southeastern part. (See pl. 2.) The exposed part of the Wabaunsee group averages about 225 feet in thickness. The formations of the Wabaunsee group consist of alternating thick, mostly nonfossiliferous beds of shale that are separated by thin fusulinid-bearing limestone beds. Most of the limestone beds are not sufficiently resistant to erosion to form hillside benches. The topography on the exposed Pennsylvanian sedimentary rocks is a low relatively flat plain with shallow valleys (pl. 18). The best exposures of a formation are generally in streambanks and road cuts.

A historical summary of the naming and classification of each member has been presented by Moore (1936a, p. 221–245), therefore, only the more pertinent data will be given in this report. Many of the formations are new, therefore, complete data as to naming and location of the type sections are given.

Most of the limestones, even though acceptable for most engineering uses, are considered too thin to be economically quarried. The Tarkio limestone member of the Zeandale limestone ranges from 4 to 12 feet in thickness and is quarried for construction material. The shales generally consist of silt-size particles and are used as fill material.

Seeps and springs are found at the base of many of the limestone beds. Some of the shale beds contain seeps that can be seen only in the early morning before the rate of evaporation exceeds the rate of flow. This type of seep, although seemingly unimportant, must be considered in the construction of a road.

AUBURN SHALE

The Auburn shale was named by Beede (1898, p. 30) and defined as the shale underlying the Elmont limestone and overlying the Wakarusa limestone. Condra (1927, p. 78) restricted this shale to the beds between the Wakarusa and Reading limestones. This definition has been generally accepted. The type section of the Auburn shale was not designated, but Moore (1936a. p. 221–222) suggested that it is near Auburn, Kans. He observed the shale in a streambank along Wakarusa Creek near the northeast corner of sec. 26, T. 13 S., R. 14 E., southwest of Auburn.

This shale shown on plate 2 as the map unit Ca, is the oldest formation exposed in Wabaunsee County and crops out only in the northwest part.

The Auburn shale is silty, tan gray, and weathers tan. It is nonfossiliferous, and only about 6 feet of its total thickness of 25 feet is exposed.

EMPORIA LIMESTONE

The Emporia limestone was named by M. Z. Kirk (1896, p. 72–85) after Emporia, Kans. As used herein, the Emporia limestone is overlain by the Willard shale and underlain by the Auburn shale. It consists in ascending order, of the Reading limestone member, the Harveyville shale member, and the Elmont limestone member. The type section or locality was not clearly defined by Kirk, but the limestone is well exposed along U. S. Highway 50S a few miles east of Emporia. Moore and Mudge (1956, p. 2276) list an excellent exposure of this formation, classifiable as paratype section, in the road-cut exposures on Kansas Highway 10, in the NW¼ sec. 31, T. 11 S., R. 14 E., Shawnee County, Kans. This section is described by Jewett (1949, p. 9). The Emporia limestone averages 25 feet in thickness.

READING LIMESTONE MEMBER

The Reading limestone was cited by Moore (1936a, p. 224) as equivalent to the lower part of the Emporia limestone as defined by Kirk (1896, p. 80). Owing to inadequate sections and the lack of precise locations, the Reading was called the Emporia blue limestone by Smith (1903, p. 100) and renamed the Reading limestone (Smith, 1905, p. 150). Moore and Mudge (1956, p. 2276) reduce the Reading limestone to member rank and list it as the oldest member of the Emporia limestone as is done here. The Reading overlies the Auburn shale and underlies the Harveyville shale member of the Emporia (table 2).

The type locality of this member is near Reading, Lyon County, Kans., according to Moore (1936a, p. 224), who lists excellent exposures of this limestone in a road cut near the northwest corner of sec. 33, T. 17 S., R. 13 E., 1 mile northwest of Reading. In Wabaunsee County, exposures of this limestone are not complete; an exposure in a road cut (Scott, Foster, and Crumpton, 1958) in the SE¼NE¼ sec. 13, T. 10 S., R. 9 E., along the old route of U. S. 40 between St. George and Wamego in Pottawatomie County, Kans., was selected as a representative and included here.

This member crops out only in the northwestern part of the county.

The Reading limestone member generally weathers into 3 separate beds, each about 6 inches thick. There is a 2 or 3-inch tan-gray to tan-brown weathered zone on the exposed surface of each of the limestones. The limestone beds are blue gray, dense, medium to very hard, and often fracture semiconchoidally. Iron stains (limonite) are abundant on the top and bottom of the limestone which averages about 2 feet in thickness. (See measured section 75.)

Fossils are throughout the member. Small crinoid columnals that generally weather white are the most abundant.

This member, although quarried extensively in northern Nemaha County and northeastern Pottawatomie County (Scott, Foster and Crumpton, 1958) is not recoverable as a construction material in Wabaunsee County because of the excessive overburden. In the northeastern part of the county a small spring was observed at the base of this limestone.

HARVEYVILLE SHALE MEMBER

The Harveyville shale was included in the Emporia limestone (see discussion of Reading limestone member) and later was made a member of that limestone (Condra, 1935, p. 10). Moore, Elias, and Newell (1934) listed it as a formation and two years later it was described by Moore (1936a, p. 226). Moore and Mudge 1956, p. 2276) reduced it to the rank of a member of the Emporia limestone—the classification of Condra (1935, p. 10). The Harveyville shale member overlies the Reading limestone member and underlies the Elmont limestone member (table 2).

The type section listed by Moore (1936a, p. 226) is near Harveyville in the southeastern part of Wabaunsee County. The Harveyville shale member is not exposed in this part of the county but is exposed, according to Moore (1936a, p. 226), in sec. 25, T. 15 S., R. 13 E., Osage County. A complete and representative section is in a road cut in the SE¼NE¼NE¼ sec. 35, T. 10 S., R. 9 E., in the northwest corner of Wabaunsee County.

The Harveyville shale member crops out only in the northwest corner of the county. In the northeastern part, it is near the surface but not exposed.

The Harveyville shale member is clayey, slightly calcareous, and thin bedded. It is tan gray, but weathers gray or tan. Minute flakes of mica are common and limonite stains are on the bedding and fracture planes. This shale is 21 feet thick. (See measured section 75.)

The Harveyville shale member is nonfossiliferous in Wabaunsee County, and is not used as a fill material because it contains a great amount of clay minerals. It may be acceptable as a ceramic aggregate, but large quantities cannot be obtained without removing 10 to 20 feet of overburden.

ELMONT LIMESTONE MEMBER

The Elmont limestone was named by Beede (1898, p. 30). In 1935, Condra (p. 11) listed the Elmont limestone as the upper member of the Preston (Emporia) limestone. Moore (1936a, p. 226–227) lists it as a formation. Moore and Mudge (1956, p. 2276) accepted Condra's classification of it as a member, and placed it in the Emporia limestone. The Elmont limestone member overlies the Harveyville shale member and underlies the Willard shale (table 2).

The type locality is near Elmont in northern Shawnee County, Kans. (Beede, 1898, p. 30). A typical exposure of the Elmont limestone member is in a road cut in the SE¼NE¼NE¼ sec. 35, T. 10 S., R. 9 E., Wabaunsee County. The Elmont limestone member crops out only in the northwest corner of the county. Toward the northeast it is near the surface but covered by colluvial and terrace materials.

The Elmont limestone member consists of a single thin massive hard bed. The unweathered surface is dark blue gray; the weathered surface is tan gray to brown. When exposed to weathering for long periods, it fractures into the rectangular blocks that are characteristic of almost all exposures of this limestone. In most exposures the limestone has a weathered zone 2 inches thick that is heavily impregnated with limonite.

Toward the north there is a thin porous conglomeratic zone in the lower part of the limestone. The conglomerate consists mainly of small (one-eighth to one-half inch in diameter) rounded to subangular clay balls and limonite nodules. The Elmont limestone member is about 1.8 feet thick. (See measured section 75.)

Fusulinids are the most common of the fossils in this member; other fossils are brachiopods, echinoids, crinoid columnals, corals, and bryozoans.

The Elmont limestone member was not sampled for a construction material. It would probably be acceptable for an aggregate, but in Wabaunsee County it is thin and has 6 or more feet of overburden. In Pottawatomie and Nemaha Counties this limestone has been used as riprap, building stone, road metal, and congrete aggregate.

The Elmont limestone member breaks excessively (overbreakage) when removed during excavation (John D. McNeal, written communication).

WILLARD SHALE

The Willard shale was named and first described by Beede (1898, p. 31). It includes the shale between the Tarkio limestone member of the Zeandale limestone, above, and the Elmont limestone member of the Emporia limestone, below.

The type locality is near Willard in western Shawnee County, Kans. (Moore, 1936a, p. 228). The exact location of the type section was not designated, but the best exposure in that area extends across the Wabaunsee County line to near the south city limits of Willard in a road cut in SE¼SE¼ sec. 15, T. 11 S., R. 13 E. In the northwestern part of Wabaunsee County a complete section is exposed in a road cut in the SE¼NE¼NE¼ sec. 35, T. 10 S., R. 9 E. The Willard shale is exposed in the northwestern, northeastern, and southeastern parts of the county.

The Willard shale is calcareous, thin bedded, blue gray to gray brown, and weathers tan. In the northern part of the county it is silty in the lower part, but is sandy and micaceous in the upper part, which contains thin lenses of sandstone and sandy shale that weather platy. These sandstone lenses and sandy shales grade westward from the vicinity of Willard into silty shales, and southward into clayey shales. In the northwestern outcrop area calcareous nodules are common throughout the shale, but they are absent elsewhere in the county. Limonite stains are conspicuous on fracture and bedding planes.

In the northeastern part of the county this shale is 50 to 60 feet thick but elsewhere in the county it averages 32 feet in thickness. (See measured sections 74 and 75.)

Thin-shelled pelecypods, the only fossils seen in this shale, were found in the upper part of the formation in a streambank exposure in the NE¼NE¼ sec. 15, T. 15 S., R. 13 E.

This shale may be suitable as a fill material. No seeps were observed but moisture may be present in the lenses of sandstone and sandy shale.

ZEANDALE LIMESTONE

The Zeandale limestone overlies the Willard shale and underlies the Pillsbury shale. The Zeandale limestone is named after the town of Zeandale in southeastern Riley County (Moore and Mudge, 1956, p. 2276). The type section is in the SE¼NE¼NE¼ sec. 28, T. 10 S., R. 9 E., along a north-south farm-access road south of Deep Creek which is about 1 mile east and one-fourth mile south of Zeandale. This formation consists of three members, which are, in ascending order; Tarkio limestone member, Wamego shale member, and Maple Hill limestone member. The Zeandale limestone ranges in thickness from 53 feet in the southeastern part of the county to about 20 feet in the northern part.

TARKIO LIMESTONE MEMBER

The Tarkio limestone was known first as the "Chocolate limestone" (Swallow, 1867, p. 67). Calvin (1900, p. 420, 430) assigned the name Tarkio to a limestone exposed in Tarkio Creek, north of Coin, Page County, Iowa. Moore (1936a, p. 229) stated that G. E. Condra, after studying this locality concluded that Calvin's Tarkio limestone was correlative to the beds in Kansas called the Emporia. Condra and Bengston (1915, p. 8) assigned the name Tarkio limestone to the upper limestone of the unit Condra called the Nemaha formation. Dunbar and Condra (1932, p. 18) redefined the Tarkio as the limestone overlying the Willard shale and underlying the Wamego shale member, thus correlating it with the Chocolate limestone of Swallow. Moore and Mudge (1956, p. 2276) classify it as a member of the Zeandale limestone.

The type locality was formerly on Tarkio Creek north of Coin in Page County, Iowa, but because it does not contain beds described as the Tarkio limestone, Moore (1936a, p. 229 and 230) reassigned the type section to the exposure noted by Swallow (1867, p. 67). This exposure is on Mill Creek southwest of Maple Hill, Kans., in the SW¼NW¼, sec. 25, T. 11 S., R. 12 E. Here the thickness of the Tarkio is atypical, so the reader is advised to visit, in addition to the type section, any one of the sections in the county that are typical of the member in thickness and in outcrop expression. These exposures are in the SE¼ sec. 27, T. 11 S., R. 13 E.; a stream cut NE¼ sec. 36, T. 11 S., R. 12 E.; and in the SW¼ sec. 36, T. 10 S., R. 9 E.

The Tarkio limestone member crops out in the northeastern and northwestern parts of the county. Only one exposure of this limestone was observed in the southeastern part.

The Tarkio limestone member consists of 1 or 2 massive beds of limestone. In the northeastern part of the county the Tarkio consists of two beds of limestone separated by a thin bed of very calcareous shale. The lower limestone bed is hard, massive, dark brown, and weathers tan brown. It generally fractures in large rectangular blocks that slump on the underlying Willard shale. The upper limestone bed is also dark brown, but is medium hard, locally dense, and tends to weather in plates and small blocks. Both beds of limestone are locally porous and many of the pore spaces are partly filled with celestite. On the surface and along the fractures of these beds, limonite stains are generally conspicuous. The lower limestone forms a prominent bench on many hillsides, but the upper bed commonly erodes farther back on the hillside and is concealed beneath colluvium and soil. This peculiarity of erosion creates the impression that the Tarkio is but a single bed of limestone. In the northwestern part of the county the Tarkio limestone member is a single bed that is correlative to the lower bed of limestone described above.

In the southeastern part of the county the Tarkio is much thinner than in the northern part and consists of a single bed. It is dark gray but becomes brown when weathered. It fractures in trapezoid-shaped blocks.

Toward the northeast the Tarkio is about 10 feet thick, but thins to the southeast to 1.9 feet. In the northwest it is about 6 feet thick. Data are not available to fully explain the thickness of this member at Maple Hill. East of St. George in Pottawatomie County, this limestone is 8.2 feet thick (Scott, Foster and Crumpton, 1958). South and east of Zeandale in Riley County it is 14.3 feet thick (Mudge 1949, p. 19). The thinning of the Willard shale beneath this thick facies indicates a slight warping of the sea floor. (See measured sections 73, 74, and 75.)

A variety of fossils are in the Tarkio limestone member. Large ventricose fusulinids, *Triticites ventricosus* (Moore, 1936a, p. 230), are very abundant and are characteristic of this limestone. Small fusulinids are common, but appear to be more abundant in the southeastern part of the county. Brachiopods, echinoids, and small corals are also common.

The results of tests on two samples of the Tarkio limestone member are given in table 1 under ls 1 and ls 2. Sample ls 1 and ls 2 were obtained from the northwestern and northeastern parts of the county, respectively. Neither sample met the requirements for an aggregate for concrete even though 3 miles west of the county the Tarkio is quarried and used as a concrete aggregate. (See p. 23.) Both samples are acceptable for aggregate for bituminous surface course, bituminous concrete and sheet asphalt surfaces (base, leveling and surface courses), cover material, bituminous retread surface and bituminous drag treatment, surfacing, and for crushed stone base course of the keyed type (pl. 1).

Blocks of the Tarkio limestone member were installed as riprap in the NE¼NE¼ sec. 8, T. 10 S., R. 11 E., to protect the abutments of a bridge spanning the Kansas River. It is doubtful that additional observations can be made on the riprap as the flood of 1951 removed the bridge. The blocks at the waterline are spalling as a result of alternate freezing and thawing.

This limestone has also been installed (before 1937) as hand-laid wash check and riprap in a spillway and on the upstream face of a dam in the NE¼NE¼ sec. 11, T. 11 S., R. 9 E. These blocks of limestone appear to be durable, and exhibit no deterioration by abrasion or by freezing and thawing.

The Tarkio is extensively quarried in the SE¼ sec. 22, T. 10 S., R. 9 E., Riley County, about 3 miles west of the city of Wabaunsee. The limestone is about 12 feet thick and has 6 to 12 feet of overburden. The crushed limestone was recently used as base course and concrete aggregate for highway U. S. 24 between Wamego and Manhattan.

Seeps are common at the base of this limestone which breaks excessively (overbreakage) when removed during excavation (McNeal, John D., 1954, written communication).

WAMEGO SHALE MEMBER

In a classification presented by Haworth and Bennett (1908, p. 114), strata composing the Wamego shale member was part of the Admire shale. Condra (1927, p. 80) named these strata the Pierson Point shale, but included it as a subdivision of the McKissick Grove shale member of the Wabaunsee formation. Moore (1936a, p. 232), not recognizing the McKissick Grove shale, included the Pierson Point as a formation with the boundaries it now has, the shale between the top of the Tarkio and the base of the Maple Hill. Condra and Reed (1943, p. 42) discarded the name Pierson Point and defined this shale as the Wamego shale. The Kansas Geological Survey (Moore, and others, 1951, p. 59) retained the name Pierson Point. Moore and Mudge (1956, p. 2276) reintroduced the name Wamego at the suggestion of Dr. E. C. Reed who found that the Pierson Point, at its type section, did not represent the shale beds between the Tarkio and Maple Hill limestone. Moore and Mudge (1956, p. 2276) list the Wamego shale as a member in the Zeandale limestone.

In Wabaunsee County, good exposures of this shale are in road cuts in the NE¼NE¼ sec. 19, T. 11 S., R. 13 E., and in the SW¼SE¼ sec. 27, T. 11 S., R. 13 E. The Wamego shale member crops out in the northeastern, northwestern, and southeastern corners of the county.

The Wamego shale member consists of beds of shale with thin lenses of limestone, sandstone, and sandy shale. The beds of shale are clayey to silty, and mainly calcareous. They are gray brown to blue gray and generally weather tan gray. Limonite stains are common throughout, and limonite stained sandstone plates are abundant.

In the southern part of the county, a platy limestone 2.3 feet thick is in the middle of this member. This limestone grades eastward into a massive dense fine-grained sandy limestone of comparable thickness. The eastward facies has involute (wavy) bedding, is slightly micaceous, and is gray orange to gray.

Below this limestone the beds of shale are silty to sandy, micaceous, and contain thin lenses of sandstone and siltstone and many iron and sandstone concretions.

The Wamego shale member ranges from a thickness of 8 feet in the northeastern part of the county to at least 50 feet in the southeastern part. (See measured sections 73 and 74.)

Fossils are in this member only in the southeastern part of the county. They are abundant in thin limestone beds, in a 2-foot bed of shale in the middle part of the member, and in the bed of shale just below the Maple Hill limestone member. The fauna in beds of limestone consists of brachiopods and crinoid columnals. The fauna observed in the bed of shale consists of a variety of pelecypods, brachiopods, bryozoans, gastropods, and crinoid columnals. Pelecypods and gastropods are in the sandy facies of the middle limestone. The beds of shale below this sandy limestone contain spirifera-type brachiopods.

Because the limestone units in the Wamego shale member are generally very thin and have a thick overburden, they were not sampled and tested for a construction material. The high plasticity of the shales would probably make them unsuitable as fill material.

MAPLE HILL LIMESTONE MEMBER

The Maple Hill limestone member was originally considered a bed of the Emporia limestone (Adams, 1903, p. 52). Haworth and Bennett (1908, p. 114) included this limestone in the Admire shale, but Condra (1927, p. 80) named it the Maple Hill, a subdivision of the McKissick Grove shale member of the Wabaunsee formation. Moore (1936a, p. 233) retained the name Maple Hill and refers to it as a formation. This report follows the reclassification of it by Moore and Mudge (1956, p. 2276) as a member of the Zeandale limestone. This limestone overlies the Wamego shale member and underlies the Pillsbury shale.

The type locality is on Mill Creek south of Maple Hill in the NW¼SE¼ sec. 26, T. 11 S., R. 12 E. It is well exposed and forms a small waterfall in Mill Creek. Another exposure of this limestone is in a road cut in the SW¼SE¼ sec. 27, T. 11 S., R. 13 E., on U. S. Highway 40. In Wabaunsee County the member is well exposed in the northeast and southeast, but poorly exposed in the northwest.

The Maple Hill limestone member is hard, massive, gray, and weathers light gray to tan gray. The weathered surface has an appearance of an I-beam in that it protrudes at the top and bottom. This bed is usually softer in the lower part which weathers in small irregular plates. In the northern part of the county it generally fractures in rectangular blocks, but in the southern part it fractures in trapezoid blocks.

At the type locality this limestone is 1.5 feet thick, but toward the east it is 1.8 feet thick. It thins southward to 0.9 foot at the Osage County line. (See measured sections 73 and 74.)

Fossils are common in the Maple Hill limestone member. There are more small fusulinids than crinoid columnals, and *Chonetes* sp., *Marginifera* sp., and bryozoans are common only in the northern outcrop area. In the southern outcrop area other brachiopods and some algal deposits are in this limestone.

One sample of the Maple Hill limestone member was tested for its suitability as a construction material (table 1, ls 3) and the results indicate that it would be acceptable for riprap, structural stone, and as a crushed aggregate for most uses except in concrete.

Only minor quantities of this limestone can be quarried under 3 to 6 feet of overburden, so that its use may be limited to small quantites of riprap, wash checks, and structural stone.

PILLSBURY SHALE

The Pillsbury shale was considered a shale in the Emporia limestone by Adams (1903, p. 52). Condra (1927, p. 80) listed it as part of the McKissick Grove shale member of the Wabaunsee formation and named it the Table Creek shale. In 1943, Condra and Reed (p. 42) discarded this name because they found that three other formations were included in the original description, and proposed the name Langdon shale for the shale between the Dover limestone above and the Maple Hill limestone below. At the type section, the Langdon shale is correlative to the Wamego shale member of the Zeandale limestone (Moore and Mudge, 1956, p. 2275) ; therefore, the name Langdon was abandoned and the name Pillsbury assigned to the shale beds between the Dover and Maple Hill limestone members.

The name Pillsbury is derived from Pillsbury Crossing, a ford across Deep Creek, in the NE¼NW¼ sec. 5, T. 11 S., R. 9 E., Riley County. The type locality is in the SE¼NE¼NE¼ sec. 28, T. 10 S., R. 9 E., Riley County. Moore and Mudge (1956, p. 2275–2276) list two paratypes, which are in a streambank in the center of the SW¼ sec. 32, T. 10 S., R. 9 E., Riley County, and in the NE¼NE¼ sec. 19, T. 11 S., R. 13 E., Wabaunsee County. In Wabaunsee County another good exposure of this formation is in the SW¼NE¼ sec. 15, T. 15 S., R. 13 E., about 2.5 miles south of Harveyville.

The Pillsbury shale crops out in the northeastern and southeastern parts of the county, but in the northwest it is covered by thin Quaternary deposits.

The Pillsbury is a calcareous thin-bedded to blocky blue-gray to tan shale with a persistent bed of sandstone in the upper part. On the exposed surface are many thin limonite and sandstone plates, and limonite stains are conspicuous on the bedding planes. In the southern outcrop area beds of sandy micaceous shale dominate the upper part of the formation. The persistent bed of sandstone, which thickens southward, is composed mainly of well-rounded to subangular quartz grains, but it contains some garnet, feldspar, and mica (muscovite). Thin beds of sandstone and sandy shale cemented by calcium carbonate are in the middle of this formation in a few places.

In the northeastern part of the county the Pillsbury shale is about 46 feet thick and thins southward to 36 feet. (See measured sections 66 and 71–74.)

In places, the beds of shale beneath the Dover limestone member of the Stotler limestone contain fusulinids and brachiopods.

The Pillsbury shale is probably acceptable as fill material.

STOTLER LIMESTONE

The Stotler limestone overlies the Pillsbury shale and underlies the Root shale. According to Moore and Mudge (1956, p. 2275) the formation was named after the abandoned Stotler Post Office in the SW¼ sec. 10, T. 16 S., R. 13 E., Lyon County. The type section extends along the south side and into the spillway of a pond in the SE¼ sec. 13, T. 16 S., R. 12 E., which is north of U. S. Highway 50N and about 2 miles west of Miller, Lyon County. The Stotler limestone consists of three members, which are, in ascending order; the Dover limestone member, Dry shale member, and Grandhaven limestone member. The range from 10 to 30 feet in thickness is due almost entirely to the variability in thickness of the Dry shale member.

DOVER LIMESTONE MEMBER

The Dover limestone was named by Beede (1898, p. 31) and designated as the limestone between the Dover shale and sandstone (the nomenclature of the shale and sandstone was never accepted). This limestone was later included as part of the Emporia limestone by Adams (1903, p. 52) ; in the Admire shale by Haworth and Bennett (1908, p. 114) ; and in the McKissick shale by Dunbar and Condra (1932, p. 18, table C). Moore (1936a, p. 235) lists it as a formation that underlies the Dry shale member and overlies the Langdon (Pillsbury) shale. Moore and Mudge (1956, p. 2275) list it as a member of the Stotler limestone, which is the adopted use for this paper.

The type locality as defined by Beede (1898, p. 31) is near Dover, Shawnee County, Kans. This limestone is poorly exposed though it does cap many of the hills north of Dover. Typical sections of the limestone in Wabaunsee County are in road cuts in the SW¼SW¼ sec. 28, T. 11 S., R. 13 E., and in a streambank in the SW¼NW¼ sec. 3, T. 15 S., R. 13 E. The Dover limestone member is poorly exposed in the northwestern part of the county, but is well exposed in the northeastern and southeastern parts. In northern Wabaunsee County the Dover generally consists of two beds of limestone separated by a thin calcareous shale. The upper bed of limestone is massive, medium hard, gray brown, and weathers into small irregular blocks. The lower bed of limestone is light gray to brown, soft, massive, and weathers shaly. The intervening bed of shale is silty, gray, thin bedded, and very lenticular.

In the western part of the southeastern outcrop area the upper limestone is conglomeratic and very thin. It contains limonite, and clay balls that are a maximum of one-eighth inch in diameter.

The lower bed of limestone generally forms a small, but distinctive, hillside bench. The light-gray weathered surface and the abundance of large fusulinids makes it easily distinguishable from other Upper Pennsylvanian limestones. The upper bed of limestone is easily eroded and on most of the hillsides it is generally covered.

In part of the southern outcrop area and in the east-central part of the county the intervening bed of shale pinches out and the two beds coalesce to form a single bed of hard gray to gray-brown limestone.

In the northeastern outcrop area the upper limestone ranges in thickness from 2.1 feet in the northeastern part to 1.9 feet in the western part. South of Harveyville it is 1.9 feet thick, but it thins southwestward to 0.4 foot, and is conglomeratic. The

Dover, when a single bed of limestone, ranges from 1.2 to 2.4 feet in thickness.

In the northeastern outcrop area the intervening shale is 0.7 foot thick in the eastern part and 0.6 foot in the western part. In the east-central part of the county it is absent. In the western part of the southeastern outcrop area this shale bed is 1.1 feet thick, but it pinches out in the eastern part.

The lower bed of limestone is 2.1 feet thick in the southern outcrop area, and ranges in thickness from 1.9 to 3.1 feet in the northern outcrop area. (See measured sections 58, 66, 68, and 70–74.)

In the northwestern outcrop area the fauna in the upper bed of limestone consists of bryozoans, brachiopod fragments, crinoid columnals, and trilobites. In the southeastern outcrop area, algae (*cryptozoon*) are very abundant as nodules that are 1 to 3 inches in diameter. Less abundant fossils are brachiopods, crinoid columnals, fusulinids, and bryozoans.

In the intervening shale the fauna includes many brachiopods and some echinoid spines, bryozoans, and crinoid columnals. Small corals and pelecypods were observed only in the northeastern outcrop area.

The fauna of the lower limestone appears to vary from northeast to southeast. In the northeast outcrop area large fusulinids, algae, crinoid columnals, and bryozoans are common, and here and there a few small corals are found. This same fauna, augmented by some brachiopods, is in the east–central outcrop area and in the western part of the southeastern outcrop area. In the area where the Dover is but a single bed of limestone, algae are generally abundant in the upper part of the bed; fusulinids are abundant in the lower part. In the eastern part of the southeastern outcrop area the fauna consists entirely of fusulinids, crinoid columnals, and brachiopods.

Fusulinids, the most abundant fossil, commonly weather out of the matrix and cover much of the outcrop.

Two exposures of the Dover limestone member were sampled for laboratory tests. The localities are in the SE¼SE¼ sec. 28, T. 11 S., R. 13 E., (table 1, ls. 4) and in the SW¼NW¼ sec. 3, T. 15 S., R. 13 E., (table 1, ls. 44) The lower bed was sampled in ls. 4 and the upper bed in ls. 44. Neither sample passed the Los Angeles abrasion and soundness tests. In this county the Dover limestone member has not been quarried or used as a construction material.

DRY SHALE MEMBER

The shale included in the Emporia limestone by Kirk (1896, p. 80), in the Admire shale by Haworth and Bennett (1908, p.

114), and as a bed in the Pony Creek shale of the McKissick Grove shale member by Condra (1927, p. 74 and 81) was named the Dry shale and defined as the beds between the Dover limestone below and the Grandhaven limestone above by Moore, Elias, and Newell (1934). Moore and Mudge (1956, p. 2275) list it as a member of the Stotler formation, and that classification is followed here.

The type locality is on Dry Creek southwest of Emporia, Kans., in sec. 5, T. 20 S., R. 11 E., Lyon County (Moore, 1936a, p. 236). In Wabaunsee County the best exposure of the Dry shale member is in a road cut in the SE¼SW¼ sec. 30, T. 11 S., R. 13 E., on U. S. Highway 40, 1½ miles southeast of Maple Hill. Other good exposures are in road cuts in the NW¼SW¼ sec. 6, T. 12 S., R. 13 E.; in the NW¼SW¼ sec. 34, T. 12 S., R. 13 E.; and in a stream and road cut in the NW¼SW¼SW¼ sec. 9, T. 15, S., R. 13 E.

The Dry shale member crops out in the northeastern, south-central, and southeastern parts of the county. Most of the exposures are partly covered by Quaternary deposits.

The Dry shale member consists of calcareous thin-bedded shales that locally are sandy. They are mainly silty, but toward the southeast they are clayey. A sandy facies of this shale is exposed 1½ miles southeast of Maple Hill. Here a thin lens of sandstone is in the upper part of the shale. In the east-central part of the county it grades into a sandy shale. In the northeastern part of the country the beds of shale are tan gray to gray brown, but toward the east-central and southeastern parts they are green and tan gray. Limonite stains are very abundant on fracture and bedding planes. Limonite nodules, concretions, and calcareous lentils and nodules are plentiful in the upper part of the sandy facies. The weathered surface of this shale is generally covered by many small limonite-stained plates and nodules.

This shale member ranges from about 23 feet near Maple Hill to 3.4 feet in thickness at a point about 5 miles southeast of that city. It is about 9 feet thick in the east-central part of the county and about 11 feet thick in the southeastern part. (See measured sections 58, 66 and 68–71.)

GRANDHAVEN LIMESTONE MEMBER

The Grandhaven limestone member was first included in the Emporia limestone by Adams (1903, p. 52) and later in the Admire shale by Haworth and Bennett (1908, p. 114). Moore, Elias, and Newell (1934) named this limestone the Grandhaven and designated it as a formation between the Dry shale below and Friedrich shale above. The Moore and Mudge (1956, p.

2275) classification of it as a member of the Stotler formation is adopted for this report.

The type locality is in sec. 31, T. 13 S., R. 14 E., near Grandhaven in Shawnee County, Kans. (Moore, 1936a, p. 237). In Wabaunsee County the best exposures of this member are in road cuts in the SE¼SW¼ sec. 30, T. 11 S., R. 13 E., NW¼SW¼ sec. 34, T. 12 S., R. 13 E., and in the SW¼SE¼ sec. 21, T. 14 S., R. 13 E. The Grandhaven limestone member crops out in the northwestern, east-central, and southwestern parts of the county.

In Wabaunsee County the Grandhaven limestone member is a single layer of limestone. It is hard, dense, massive, brown, weathers brown to tan and fractures in irregular-shaped blocks a maximum of 3 to 4 feet in diameter. Limonite strains are abundant on the weathered surface and normally form an irregular crust on the top of the bed. This limestone forms a small and inconspicuous bench above the Dover limestone member.

The Grandhaven limestone member ranges from 1.6 to 2.6 feet in thickness in the northern part of the county, but in the east-central outcrop area it thins to 0.9 foot. North of Harveyville it thickens to 3.2 feet, but it thins south of that town to about 1.5 feet. (See measured sections 66 and 68–71.)

The Grandhaven limestone member contains a mixed fauna similar to that of the Maple Hill limestone member of the Zeandale limestone. The key fossils for this horizon are large white crinoid columnals and small fusulinids. Other fossils are echinoid spines, brachiopods, and bryozoans. Pelecypods were seen only in the western part of the southeastern outcrop area. Two samples of this limestone were obtained for laboratory testing. They are from road cuts in the SE¼SW¼ sec. 30, T. 11 S., R. 13 E., (table 1, ls. 5) and in the SW¼SE¼ sec. 21, T. 14 S., R. 13 E. (table 1, ls. 35). This member, which has not been used as a construction material in the county, is thin and only small quantities can be obtained without removing an overburden of 6 or more feet. In many places where this limestone was excavated, overbreakage was common because of its fracture pattern.

ROOT SHALE

The Root shale, which overlies the Stotler limestone and underlies the Wood Siding formation, was named by Moore and Mudge (1956, p. 2275) from Root Station on the Atchison, Topeka and Santa Fe Railroad in the SE¼ sec. 23, T. 21 S., R. 11 E., Lyon County, Kans. The type section is the exposure along an eastward-flowing stream near the center of the N½SE¼ sec. 20, T. 21 S., R. 11 E. Originally, the strata comprising the Root shale was included in the McKissick Grove shale member of the Wabaunsee formation by G. E. Condra (1927, p. 75–80). Moore, Elias, and Newell (1934) and Moore (1936a, p. 232–243) discarded the name McKissick Grove and divided the strata into 11 formations of which three are now classified by Moore and Mudge (1956, p. 2275) as members of the Root shale. These members are, in ascending order; Friedrich shale member, Jim Creek limestone member, and French Creek shale member. In Wabaunsee County the Root shale averages about 38 feet in thickness.

FRIEDRICH SHALE MEMBER

The Friedrich shale member was included as part of the Admire shale by Adams (1903, p. 52). Condra (1927, p. 80–81) included it in the Pony Creek shale which was then a subdivision of the McKissick Grove shale member of the Wabaunsee formation. Moore and Condra (1932) listed it as part of the French shale. The name Friedrich was proposed by Moore, Elias, and Newell (1934) to include the shale between the Grandhaven and Jim Creek limestones. Moore and Mudge (1956, p. 2275) list it as a member of the Root shale.

The type locality of the Friedrich shale member is at Friedrich Creek in sec. 6, T. 22 S., R. 11 E., Greenwood County, Kans. (Moore, 1936a, p. 238). In Wabaunsee County an incomplete section of the shale is in a road ditch in the SW¼SW¼ sec. 8, T. 12 S., R. 13 E.

The Friedrich shale member is generally covered by Quaternary deposits. It crops out in the northeastern, east-central, and southeastern parts of the county, but the sections are poor and incomplete.

The Friedrich is generally a clayey and noncalcareous shale with a thin impure bed of limestone in the upper part. It is olive drab to gray and gray green in lower and upper parts and maroon in the middle part. The maroon shale is generally mottled with gray green; in the upper part of the member the gray-green shale is mottled with maroon. In a few places in the upper part there is a bed of thin impure soft tan-brown limestone. Iron specks are abundant within this limestone, and limonite strains are common on the weathered and fractured surfaces and bedding planes, and a few limonite nodules occur in the middle of the shale. The Friedrich shale member averages about 13 feet in thickness. (See measured sections 67–71.)

Brachiopods and crinoid columnals are common in the upper part of this shale which has not been used as a construction material in Wabaunsee County.

JIM CREEK LIMESTONE MEMBER

The Jim Creek limestone member was included in the Admire shale by Adams (1903, p. 52) and in the Pony Creek shale of the McKissick Grove shale member by Condra (1927, p. 80–81). In 1932, Moore and Condra called this limestone a bed in the French shale. In 1934, Moore, Elias, and Newell named it the Jim Creek and defined it as a formation between the French Creek and Friedrich shales. Moore and Mudge (1956, p. 2275) list it as a member of the Root shale.

The type locality is on Jim Creek in sec. 29, T. 7 S., R. 11 E., Pottawatomie County, Kans. (Moore, 1936a, p. 239). In Wabaunsee County the best exposure of this limestone is in a small stream cut in the NE¼SW¼ sec. 29, T. 11 S., R. 13 E. It is also exposed in a stream cut in the NW¼SW¼ sec. 33, T. 12 S., R. 13 E., and in a road cut in the SW¼SW¼ sec. 8, T. 12 S., R. 13 E.

The Jim Creek limestone member crops out only in the northeastern, east-central, and southeastern parts of the county, but it is seldom exposed. As it is not resistant to weathering it does not form a hillside bench.

The Jim Creek is a hard massive limestone that weathers into irregular chips of 2 to 4 inches in diameter. It is dark gray to brown and has a distinctive purplish tint on a fresh surface. The Jim Creek limestone member ranges from 0.6 to 1 foot in thickness. (See measured sections 63, 65, 67 and 68.)

This member has the most diversified fauna of any of the Upper Pennsylvanian limestones. The variety of fossils, with brachiopods predominant, aid in identifying the member. They include small fusulinids, crinoid columnals, a variety of brachiopods, small corals, gastropods, and bryozoans.

The Jim Creek limestone member, has not been used as a construction material. This limestone, because of its limited exposures and thickness, was not sampled.

FRENCH CREEK SHALE MEMBER

The French Creek shale member was included as a bed in the Admire shale by Adams (1903, p. 52). It was later part of the Pony Creek shale unit of McKissick Grove shale member (Condra, 1927, p. 80–81). In 1932, Moore and Condra defined this shale as the upper part of the French shale. In 1934, Moore, Elias and Newell classified this shale as a formation and named it the French Creek shale. Moore and Mudge (1956, p. 2275) reduced it in rank to a member and classified it as a member of the Root shale. It overlies the Jim Creek limestone member and underlies the Wood Siding formation.

The type locality is on French Creek in northeastern Pottawatomie County, Kans. (Moore, 1936a, p. 240). In Wabaunsee County the best exposure of this shale is in a small streambank in the NE¼SW¼ sec. 29, T. 11 S., R. 13 E. It is also exposed in a road cut and ditch in the NE¼SE¼ sec. 17, T. 15 S., R. 13 E., and in the SE¼SW¼SW¼ sec. 29, T. 14 S., R. 13 E.

In most of the outcrop area only the upper part of the French Creek shale member is exposed. This member crops out in the eastern and northwestern parts of the county.

The French Creek consists of beds of clayey to sandy shale that contain one or more thin beds of coal and limestone. In the upper part there are 1 or 2 beds of coal. The uppermost bed of coal, called the Lorton coal, is quite persistent and is at or near the top of the member. It is of subbituminous grade, thin bedded, and ranges from 0.3 to 0.9 foot in thickness. The second bed of coal, present only in the northeastern and southeastern outcrop area, is about 3 to 4 feet beneath the Lorton coal. It is of subbituminous grade, blocky, and ranges from 0.2 to 0.4 foot in thickness. The beds of shale are clayey, noncalcareous, gray to blue gray, and weather tan. In the northeastern part of the county they are micaceous and the upper part contains a thin lens of crystalline limestone. Toward the south, the upper part contains beds of sandy shale. In the lower half of the member there are many small marcasite nodules, and specks of carbon. In the area northwest of Harveyville there are thin lentils of limestone between the beds of coal. The weathered surface of all exposures of this shale has many plates and stains of limonite, and iron nodules.

In the northeastern part of the county the French Creek shale member is 21.3 feet thick, but in the southeastern part it thickens to 26 feet. The total thickness of this member was not obtained in the northwestern outcrop area. (See measured sections 59, 63–65.)

Fossils, which are in this member only in the southeastern part of the county, are in a 1.3-foot bed of shale that overlies the second coal bed. The fauna are crinoid columnals, pelecypods, and brachiopods.

The French Creek shale member has not been used as a construction material in Wabaunsee County. In some places seeps are at the base of the coal beds.

WOOD SIDING FORMATION

The Wood Siding formation was named by Condra and Reed (1943, p. 43) to include the strata between the Brownville limestone above and the French Creek shale (now a member of the Root shale) below.

According to Condra (1949, p. 13), the name was derived from Wood Siding Station, Nemaha County, Nebr. The type locality is in the Missouri River bluff south of the Wood Siding Station and on the Chicago, Burlington, and Quincy Railroad. Moore and Mudge (1956, p. 2273–2274) expanded the Wood Siding formation to include the Brownville limestone as a member. As now defined, the Wood Siding is the uppermost Pennsylvanian formation. It overlies the Root shale and underlies the Onaga shale. The Wood Siding formation contains in ascending order; the Nebraska City limestone member, Plumb shale member, Grayhorse limestone member, Pony Creek shale member, and the Brownville limestone member. In Wabaunsee County this formation averages 25 feet in thickness.

NEBRASKA CITY LIMESTONE MEMBER

The Nebraska City limestone member was named by G. L. Smith (1919, p. 562). The type locality is in South Table Creek Valley southwest of Nebraska City. In Wabaunsee County the Nebraska City limestone member is absent in many exposures of the Wood Siding formation; where absent, its horizon is generally occupied by channel sandstone facies of a younger shale unit.

This member is an iron-stained dark-gray to light-gray medium-hard limestone that weathers into small irregular blocks and chips that generally do not exceed 4 or 5 inches in diameter. Locally, it grades laterally into shaly limestone and very calcareous shale. There is apparently a delicate balance in this member between a limestone and shale facies for it grades from one to the other within a short distance, but it is principally a limestone.

The Nebraska City limestone member ranges from 6 inches to 2.5 feet in thickness and averages about 1 foot. (See measured sections 59, and 63–65.)

Brachiopods are generally very abundant in this member, and in some places they compose the bulk of it. *Derbyia* is the most abundant fossil. Other fossils are bryozoans, pelecypods and crinoid columnals. The member was not sampled for a construction material and it has not been used in engineering structures.

PLUMB SHALE MEMBER

The Plumb shale member is named here after exposures in Plumb Township in a road cut in the SW¼SE¼SE¼ sec. 30, T. 14 S., R. 13 E., about 1½ miles west of Harveyville in southeastern

Wabaunsee County. Here the member is as nearly typical in lithology and thickness as elsewhere along its outcrop in Kansas. Section 64 is the measured type section that describes this shale in detail. The coal at the base is present in this shale only near Harveyville. Another representative exposure of this shale is in a streambank in the NE¼SW¼ sec. 29, T. 11 S., R. 13 E., northeastern Wabaunsee County. (See measured section 63 of the stratigraphic sections.)

This shale varies from silty to clayey, and is generally calcareous. In the areas adjacent to its channel deposits, thin conglomerates, sandstone, and sandy shales are common at various horizons (pl. 4), and locally there is a siltstone bed and a coal bed. About 5 miles south of Maple Hill a ripple-marked sandstone trends S. 28°E., on the south flank of the channel of the Plumb shale member. This sandstone is located about 2 feet beneath the Grayhorse limestone member. The ripple marks are asymmetrical and are probably parallel to the sides of the channel.

Near Maple Hill, the color of the shales just below the Grayhorse limestone member is tan to tan gray. The upper one-third of the shale is maroon but it becomes gray green as it grades laterally toward the north. The beds of maroon shale are mottled with green; the converse is true of the beds of green shale. The lower two-thirds of this member at Maple Hill contains beds of gray-green to gray shale with thin lenses of maroon shale, which grade northward and southward into tan to tan-gray beds of shale. (See pl. 4.)

In the east-central part of the county and near the channel deposits the shale beds are gray to tan gray and contain lentils of limestone. Toward the southeast the shale varies from gray green to gray in the upper part and gray and gray brown in the lower part.

Limonite stains are common on the bedding and fracture planes. Calcareous and limonitic plates weather out of the upper part of the shale.

The channel deposits of the Plumb shale member of the Wood Siding formation extend downward to, and sometimes below, the Dover limestone member of the Stotler limestone (Mudge, 1956, p. 663–666). It crops out in the northeastern and east-central parts of the county. The best exposures are in road cuts in the SE¼SE¼ sec. 27, T. 11 S., R. 12 E.; in the NW¼SW¼ sec. 1, T. 12 S., R. 12 E.; and in the SW¼SW¼ sec. 5, T. 12 S., R. 13 E.

The channel fill consists of sandy shale, sandstone, conglomerates and clayey and silty shale. The units are massive to thin-bedded to distinctly crossbedded tan to tan-brown sandstones and sandy shale that contain fine sand and mica flakes. The sand is composed of rounded to subangular grains of quartz that range from 0.125 mm to 0.50 mm in diameter. The conglomerates are generally hard, gray to brown, massive, blocky to nodular upon weathering. They consist of subangular flattened to near oval-shaped nodules of limestone, shale, clay, and limonite, which range from one-sixteenth of an inch to 2 inches in diameter. The conglomerates are cemented by calcium carbonate and are generally very lenticular. The best exposure of the conglomerates is in a road cut in the SW¼NW¼ sec. 8, T. 12 S., R. 13 E. A conglomeratic shale is above the conglomerates in a few places.

Wood fragments and carbon stains are common in the beds of sandstone and sandy shale. Thin coal lentils are locally present in the lower part and a coal bed about 1 foot thick is near the base of one of the channel deposits.

In a road cut in the SE¼SE¼ sec. 27, T. 11 S., R. 12 E., the upper part of the channel fill consists of silty and micaceous to sandy lenticular beds of tan and maroon shale.

The upper and lower parts of the deposits along the sides of the channel appear to be mostly thin conglomerates that interfinger with sandy shale and sandstone. The center of the channel is filled mostly with sandy shale, but it contains some massive beds of sandstone that are generally overlain by silty to clayey shales. The lower part of the channel consists of crossbedded sandstones, sandy shales, and thin interbedded conglomerates. In a flank of this channel in a road cut in the SW¼NW¼NW¼ sec. 6, T. 12 S., R. 13 E., the thin conglomerates are interbedded with a sandy shale that dips to the southwest. (See pl. 4.) The basal contact, as near as can be determined, is marked by a coal bed. The channel in this exposure cuts through the Grandhaven, the Dry, and possibly through the Dover members of the Stotler limestone. These are exposed in the north end of the road cut.

Other channel deposits of this member were seen in a road cut in the SW¼SE¼ sec. 4, T. 13 S., R. 13 E., and in the road and stream cut along the west edge of sec. 3, T. 13 S., R. 13 E. (Mudge, 1956, p. 665). As shown in plate 3, two channels are at both locations. The younger channel, which will be discussed later, cuts into the channel of the Plumb shale member. The basal contacts of both of the channels were studied at the second location cited here. The lithologic characteristics of the upper part of the channel of the Plumb shale member was studied at the first location.

The upper 50 feet of the channel of the Plumb shale member consists of sandy to silty micaeous gray shale that is noncalcareous and thin bedded to blocky. The beds of shale are sandier in the lower part which contain thin lentils of sandstone. Thick-bedded sandstones and thin-bedded sandy shales underlie these beds of shale. The sandstones are hard, gray, and cemented by calcium carbonate. They weather in blocks which eventually break into irregular plates. Throughout the exposures iron stains and limonite concretions are abundant. The bottom contact of this channel (pl. 4) is exposed in a stream cut in the SW¼SE¼ sec. 4, T. 13 S., R. 13 E. The lower part consists of beds of sandstone and sandy shale that are nearly conformable to the underlying Dry shale member. The sandstones and sandy shales are thin bedded to massive, micaceous, and gray to tan gray. Carbon stains and limonite nodules and plates are abundant. In places the fill material is overlain by a basal conglomerate formed in a younger channel.

The base of the channel of the Plumb shale member, which was cut to within 5.6 feet of the bottom of the Dry shale member of the Stotler limestone, may be a strath terrace that lies south of the main channel which is probably the one exposed in a stream cut in the NW¼SW¼ sec. 3, T. 13 S., R. 13 E. The main channel cuts below the Dover limestone member of the Stotler limestone and possibly as low as the Tarkio limestone member of the Zeandale limestone. The lower part of the main channel consists of beds of massive sandstone, some of which are crossbedded. Calcium carbonate, iron oxide, and barite (locally) are the cements. Small channels were cut in some of the massive beds of sandstone and large concretions and small marcasite nodules are present. The bedding planes are heavily stained by limonite, and carbon stains are present throughout the fill. Thin coal lentils and leaf and wood fragments are common.

Northwest of Maple Hill, the Plumb shale member is 9.7 feet thick, but south of Maple Hill it ranges from 7.8 to 15 feet in thickness. Southeast of Keene it ranges from 11.3 feet to 20 feet in thickness, and on the Lyon–Wabaunsee County line it is about 12 feet (pl. 4). The two channels are not more than 1.5 miles wide and are about 100 feet deep. (See measured sections 54, 55, 57–59, and 61–66.) Pelecypods are abundant in the thin beds of limestone exposed south of Maple Hill. Small quantities of the channel material have been used as fill material along U. S. Highway 40, and along a country road south of Maple Hill.

GRAYHORSE LIMESTONE MEMBER

The Grayhorse limestone member was named by Bowen (1918, p. 138) for exposures on the crest of the Little Grayhorse anticline, in the NW¼ sec. 11, T. 24 N., R. 6 E., Osage County, Okla. Moore (1936a, p. 241–242) included this limestone as a member in the Caneyville limestone. Moore and Mudge (1956, p. 2273–2274) discarded the Caneyville as a formation and listed the Grayhorse limestone as a member of the Wood Siding formation.

The Grayhorse limestone member is a thin bed of hard massive limestone that is gray brown to tan brown and which weathers tan to tan brown. On a fresh surface it often has a greenish tint. The Grayhorse fractures into elongated blocks that weather into small irregular-shaped blocks and sometimes irregular-shaped plates. In almost every exposure the limestone is characterized by fossils, many small angular to rounded clay balls, limonite nodules, and limestone fragments. The particles which range from a small fraction of an inch to as much as one-half inch in diameter, are sometimes flattened and elongated. Limonite stains are abundant on fractures and weathered surfaces.

A maximum thickness of 2.8 feet was measured on the Grayhorse member along Mission Creek about 3 miles east and 1 mile south of Keene. Near Maple Hill this limestone ranges from 0.2 foot to 1 foot in thickness and averages about 0.8 foot. East of Keene it thickens to 2.8 feet and averages about 1.2 feet in thickness. In the southeastern corner of the county, the maximum thickness is 1.6 feet, but the average is about 1.2 feet. (See pl. 4 and measured sections 54, 55, 57, 59, 61, and 63–65.)

The Grayhorse is not abundantly fossiliferous even though it does contain a mixed and sparse fauna. A large pelecypod called *Orthomyalina* is diagnostic for this limestone. Brachiopods, crinoid columnals, bryozoans, and other pelecypods are present. A sample of this limestone (table 1, ls 12) was tested for its suitability as a construction material. Its specific gravity (dry) is 2.46; the freeze and thaw ratio is 0.92; and it has a water absorption of 3.02 percent. Its loss by wear in the Los Angeles abrasion test is 28.8 percent. The results of the test indicate that this limestone is acceptable as structural stone, crushed aggregate, and riprap, but its thinness and overburden will probably limit its use to wash checking and riprapping.

A bridge constructed of this limestone in the NE¼NW¼ sec. 15, T. 12 S., R. 13 E., has been affected very little by weathering.

The Grayhorse will probably break excessively when excavated.

PONY CREEK SHALE MEMBER

The Pony Creek shale member, like the other units in the upper part of the Pennsylvanian system, was included in the Admire shale by Adams (1903, p. 52). It was later part of the Pony Creek shale unit in the McKissick Grove shale member (Condra 1927, p. 81). In 1934 Moore, Elias, and Newell listed it as the shale between the Brownville and Caneyville limestones and classified it as a formation. Moore and Mudge (1956, p. 2273) reduced it in rank to a member of the Wood Siding formation.

The type locality is 2 miles south of Falls City, Nebr., along Pony Creek at the Kansas–Nebraska boundary (Moore, 1936a, p. 243). In Wabaunsee County good exposures of this shale were seen in a road cut in the SW¼NW¼ sec. 33, T. 12 S., R. 13 E., and in a stream cut in the NE¼SW¼ sec. 29, T. 11 S., R. 13 E.

The Pony Creek shale member crops out in the northwestern and eastern parts of the county.

This member is generally clayey, noncalcareous, and gray to gray brown. Locally toward the northeast, the upper part contains a maroon bed of shale. Beneath the Brownville limestone member there is a persistent fossiliferous tan-gray to gray shale about 1 foot thick. In the southeastern part of the county the sandy middle and upper parts of this member contain several sand lenses. Here a thin bed of limestone is in the lower part of the shale. (See pl. 4.)

The channel deposits of the Pony Creek shale member are exposed in this county (Mudge, 1956, p. 668) south of the city of Wabaunsee in sec. 7, T. 11 S., R. 10 E., where the units from the Grayhorse limestone member to the Jim Creek limestone member of the Root shale were eroded during the cutting of the channel. The channel fill is mostly sandy micaceous thin-bedded gray-brown to blue-gray shale. It contains many lenses of sandstone and conglomerate and some septarian concretions, as well as zones of fossil leaves and wood. There are a few zones containing secondary iron, calcium carbonate, and small gypsum crystals. In the upper part of the channel, there are thin beds of limestone and beds of shale that contain marine fossils.

The Pony Creek shale member ranges from about 6 feet to a maximum of 12 feet in thickness, but it averages about 8.5 feet. In Wabaunsee County the channel deposits of Pony Creek age are perhaps about 70 feet thick. A thickness of 58.8 feet of shale comprising channel fill is exposed in a streambank south of Wabaunsee. (See measured sections 54–57 and 59–63.)

Brachiopods, crinoid columnals, and bryozoans are in the upper limestone and the beds of shale. The brachiopods *Chonetes* and *Marginifera* are generally abundant.

This shale is used as a fill material southwest of Maple Hill.

BROWNVILLE LIMESTONE MEMBER

The Brownville limestone member was included in the Admire shale by Adams (1903, p. 53). It was named and defined by Condra and Bengston in 1915, (p. 17), but remained a bed in the

Admire formation. Condra (1927, p. 81) lists it as the lower bed in the Admire shale member of the Wabaunsee formation. Moore (1936a, p. 49 and 244, and 1949, p. 196) classified this limestone as a formation and listed it as the uppermost bed of the Pennsylvanian system. Moore and Mudge (1956, p. 2273–2274) reduced it to the rank of a member in the Wood Siding formation.

The type section of the Brownville limestone member is along the bluffs of the Missouri River just south of Brownville in Nemaha County, Nebr. (Moore, 1936a, p. 244). In Wabaunsee County good exposures (see fig. 4, pls. 3 and 4) are in road cuts in the SE¼SW¼ sec. 17, T. 15 S., R. 13 E.; in the SE¼SW¼ sec. 10, T. 14 S., R. 13 E.; in the NE¼SE¼ sec. 36, T. 12 S., R. 12 E.; and in the SE¼SW¼ sec. 26, T. 11 S., R. 12 E. The Brownville limestone member crops out in the northwestern and eastern parts of the county (pl. 2).

This limestone is easily identified by certain lithologic, paleontologic, and outcrop features. It is generally a massive limestone, but locally consists of two beds of limestone separated by a thin bed of shale. This limestone is medium hard, massive, and weathers into small rounded nodules 2 or 3 inches in diameter. It is gray brown, has a greenish tint, and weathers brown to tan brown. Some of the weathered surface is covered by a maroon stain leached from the overlying Towle shale member of the Onaga shale. This limestone makes a small and distinctive hillside bench that is generally covered by small nodules of limestone.

The Brownville limestone member, which averages about 2.3 feet in thickness is 4.5 feet thick in the northwestern part of the county where there are two limestones separated by a shale. (See pl. 5 and measured sections 54–57, and 59–63.)

The two most distinctive and characteristic fossils of this unit are *Chonetes granulifera* and *Marginifera wabashensis* (fossil names from Moore, 1949, p. 196). In Wabaunsee County these two fossils are abundant throughout the limestone. Brachiopods, bryozoans, and crinoid columnals are common. Fossils rarely seen are gastropods, pelecypods, corals, sharks teeth, and certain genera of brachiopods, trilobites, and bryozoans. Fusulinids are abundant in the southeastern part of the county but they are absent or rare in the northern part. Corals are only in the southeastern outcrop area. The gastropods were observed in this limestone only in the area southwest of Maple Hill.

One sample of the Brownville limestone member was tested for suitability as a construction material. According to laboratory tests (table 1, ls. 16) this limestone is acceptable as a construction material except for use in concrete, but field observations indicate that the limestone disintegrates rapidly.

PERMIAN SYSTEM

In Wabaunsee County the stratigraphic units that outcrop most are those of the Permian system. (See table 2, pls. 2–3, and 6–17.) The Onaga shale is the basal formation of the Permian system. The rocks are divided into three groups which are in ascending order; the Admire, Council Grove, and Chase. The areal distribution of the three groups is shown on plate 2.

The limestone units of the Permian system are thicker and somewhat harder than those of the Upper Pennsylvanian. Almost all of the Permian limestone beds form a conspicuous hillside bench that shows a distinctive pattern on aerial photographs (pl. 5). The topography on these rocks consists of low rolling hills with deeply incised valleys. (See pl. 18.)

The shales of the Permian are green, purple, and dark gray to bright maroon. Unlike most of the shales of the Upper Pennsylvanian, the Permian gray shales are generally fossiliferous.

The lower 100 feet of the Permian rocks (Admire group) lithologically resemble the Upper Pennsylvanian more than they do the rest of the Permian. They consist of thick nonfossiliferous shales separated by thin limestones. Many of the shales are sandy, and contain massive beds of sandstone, small channels, and thin beds of coal.

The many Permian limestones that are acceptable as a construction material have been extensively quarried in the county. (See pl. 2 and table 1.)

ADMIRE GROUP

The Admire is the basal group of the Permian system in Kansas (table 2). This group crops out in a small area in the northern and eastern parts of Wabaunsee County, principally along both sides of Mill Creek as far west as Alma (pl. 2). Most of the units do not form prominent hillside benches, and are exposed only in road cuts and streambanks. This group contains three formations which are, in ascending order; the Onaga shale, Falls City limestone, and Janesville shale.

ONAGA SHALE

The Onaga shale was named by Moore and Mudge (1956, p. 2273) to include the strata between the Falls City limestone above, and the Wood Siding formation below. It was named after the city of Onaga in northern Pottawatomie County, Kans., where the type section is in an east-west road cut in the SW¼SW¼ sec. 2, T. 8 S., R. 10 E. As defined by Moore and Mudge (1956, p. 2273) the Onaga shale contains three members, which are, in ascending order; the Towle shale member, Aspinwall limestone member, and Hawxby shale member.

The Onaga shale as thus defined represents the strata included in the Aspinwall shale of Condra (1927, p. 73, 82, 89). Moore and Condra (1932) subdivided the unit into three formations, discarded the name Aspinwall shale, and retained the name Aspinwall for the limestone bed defined by Condra and Bengston (1915, p. 9, 17, 29). The Moore and Condra classification is used in this report. In Wabaunsee County the Onaga shale averages about 37 feet in thickness.

TOWLE SHALE MEMBER

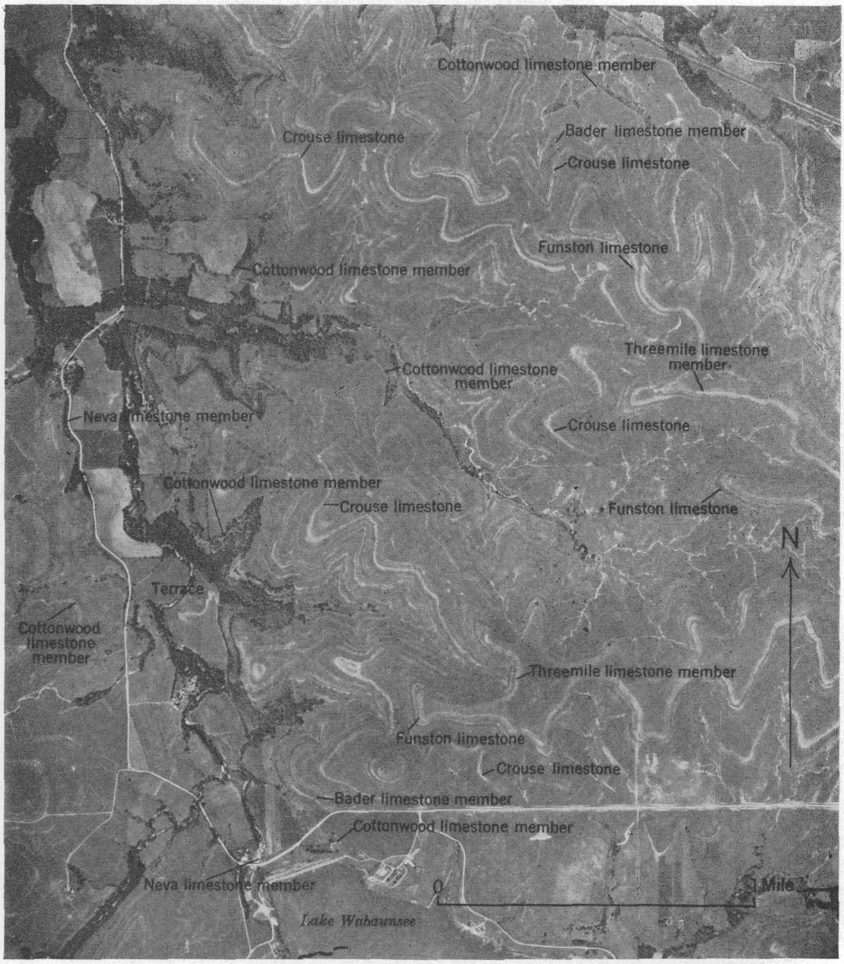
The name Towle shale member was applied by Moore and Condra (1932) to the shale beds above the Brownville limestone and beneath the Aspinwall limestone. These shales were part of the Admire shale in a classification presented by Adams in 1903 (p. 53). Moore (1936a, p. 50) lists the Towle shale as a formation in the Admire group and includes it as part of the Permian system. Moore and Mudge (1956, p. 2273) reduced the Aspinwall to the rank of a member of the Onaga shale.

The type locality is on the Towle farm 2½ miles southwest of Falls City, Nebr., in the SW¼ sec. 20, T. 1 N., R. 16 E., in Richardson County (Wilmarth, 1938, p. 2173). In Wabaunsee County a good exposure of the Towle shale member is in a road cut in the SE¼SW¼ sec. 26, T. 11 S., R. 12 E.

The best exposures of the Towle shale member are in the northeastern part of the county where Moore, Frye, Jewett, Lee, and O'Connor (1951, p. 52) recognized a channel sandstone as the Indian Cave sandstone member of the Towle shale.

The Towle shale member is generally a clayey noncalcareous shale, but here and there it contains thin beds of limestone, sandstone, sandy shale, siltstone, and silty shale. In the northern part of the county, the shales are mostly maroon in the lower part and gray green in the upper part, although in some places thin maroon beds occur in the very upper part and some of the gray-green beds are mottled with maroon. In the middle and southern outcrop area the shales are mainly gray to blue gray, but they are gray green and contain thin maroon beds in the area west of Harveyville. Thin lenses of limestone are locally present in the upper part, and southwest of Maple Hill a thin conglomeratic limestone is present near the middle of this member.

Only two exposures of the channel sandstone were seen in this shale. The largest exposure extends into Shawnee County from about 4 miles east of Keene. This channel bisects, and in part cuts into, the channel facies of the Plumb shale member of the



AERIAL PHOTOGRAPH SHOWING TYPICAL OUTCROP PATTERNS OF MANY OF THE PERMIAN LIMESTONES.

A. Basal conglomerate of the channel of the Towle shale member of the Onaga shale in the NE¼SE¼ sec. 4, T. 13 S., R. 13 E., Wabaunsee County, Kans.

B. Americus limestone member of the Foraker limestone in a road cut in SW¼SE¼ sec. 12, T. 12 S., R. 11 E., Wabaunsee County, Kans.

Wood Siding formation. (See p. 36.) It trends northeast until it reaches the south side of Mission Creek where it trends eastward into Shawnee County. The middle part of the fill is sandy shale interbedded with sandstone. Septarian concretions are in the upper part of the fill and some are 2 feet in diameter. The sandstones consist of fine grains of quartz and mica that are cemented by calcium carbonate and iron oxide. Carbon and iron stains are abundant on bedding planes. Throughout the fill, there are thin seams of coal, iron concretions and nodules, and wood and leaf fragments. Crossbedding and ripple marks are visible in most exposures.

The base of the channel is marked by a conglomerate about 2 feet thick. (See pl. 4.) This conglomerate is in the upper part of the exposure at "Echo Cliff," a streambank in the NW¼SW¼ sec. 3, T. 13 S., R. 13 E. It was seen in a small road cut in the NE¼SE¼ sec. 4, T. 13 S., R. 13 E., and in a streambank in the SW¼SW¼SE¼ sec. 4, T. 13 S., R. 13 E. The composition of this conglomerate indicates that this channel is younger than the Brownville limestone member of the Wood Siding formation. Fragments of this limestone are contained by the conglomerate (pl. 6) which is hard, locally dense, and weathers platy and in small irregular-shaped chips. It is brown to tan brown and, in addition to the fragments of Brownville limestone member of the Wood Siding formation, it contains red siliceous clay balls, limonite nodules and concretions, and clay and other limestone fragments. All particles within the conglomerate are angular and range from a fraction of an inch to 6 inches in diameter with 1-inch fragments most abundant. The conglomerate lies nonconformably on the beds of sandy shales and sandstone of the channel facies of the Plumb shale member of the Wood Siding formation.

Near Maple Hill and in the area east of Keene, the Towle shale member averages about 10 feet in thickness, but near Harveyville it is about 16 feet thick. South of Harveyville it is 19.2 feet thick. The channel fill of the Towle shale member is about 95 feet thick. (See measured sections 52, and 54–59.)

No fossils were observed in the beds of shale, but some of the thin beds of limestone contain a pelecypod fauna similar to that of the Falls City limestone.

Along U. S. Highway 40 southwest of Maple Hill the Towle shale member, which is silty and calcareous in that area, has been used as a fill material.

ASPINWALL LIMESTONE MEMBER

The Aspinwall was named by Condra and Bengston (1915, p. 17) for a limestone bed about 10 to 25 feet above the Brownville limestone. It was included in the Admire shale by Adams (1903, p. 53). Condra (1927, p. 73, 74, 82, and 89) included all beds of shale from the base of the Falls City limestone down to the top of the Brownville limestone, including the Aspinwall limestone, as part of the Aspinwall shale. Moore and Condra (1932) reclassified the rocks between the Falls City and Brownville limestones as separate beds which are in ascending order; the Brownville limestone, Towle shale, Aspinwall limestone, and Hawxby shale. Thus the Aspinwall limestone was restored to its original classification. In 1936, these beds were still part of the Admire shale member of the Wabaunsee formation, and all were considered Upper Carboniferous in age. Moore (1936a, p. 50) lists them as formations in the lower "Permian." Moore and Mudge (1956, p. 2273) reclassified them as members in the Onaga shale.

The type section of the Aspinwall limestone member is at Aspinwall (Condra and Bengston, 1915, p. 17), an old town site southeast of Nemaha City in Nemaha County, Nebr. In Wabaunsee County complete exposures of this member are rare as part of it is generally covered with colluvium or has been eroded (pl. 2). A representative section is exposed in a streambank in the SW¼NW¼ sec. 36, T. 11 S., R. 11 E.

This member crops out in the eastern part of the county, but it is covered by Quaternary deposits in the northwestern part.

The Aspinwall consists of 3 or more beds of limestones and 2 or more beds of shale (pls. 4, 5; table 2) that vary considerably in thickness and lithology across the county. Locally, one or more of the limestones are absent. This discussion of the Aspinwall limestone member will be by individual beds as this formation is divided into five parts (fig. 3).

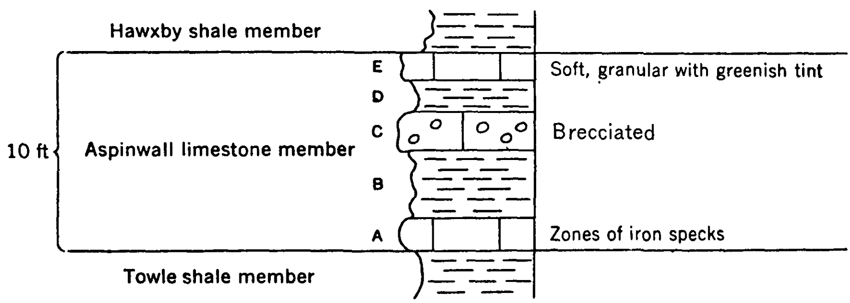


FIGURE 3.—Subdivision of the Aspinwall limestone member of the Onaga shale in Wabaunsee County, Kans.

Bed *A*, the lower limestone unit, is distinctive in that it has thin parallel zones of minute brown specks. Pelecypods are common in this limestone in the area east of Keene and in the southwestern part of the county.

Bed *C*, in the northern and extreme southern outcrop areas, has many small angular fragments of limestone within the lime matrix. The fragments may represent intraformational slumping shortly after deposition. This is the only one of the three beds of limestone that forms a prominent hillside bench. Small gastropods are found in a few places.

Bed *E* is distinctive in that it is softer, has a granular appearance, a greenish tint, and is nonfossiliferous. This bed is easily eroded, and therefore crops out less than bed *C*.

All three of the limestone beds (*A*, *C*, and *E*) contain many minute brown specks throughout, but only in bed *A* are these specks so arranged as to be diagnostic. The beds are gray to tan brown and usually weather tan brown to brown.

Bed *A* is the most persistent of the three limestone beds and is in almost every exposure in the county. Beds *C* and *E* are exposed only locally but are in many of the exposures along its outcrops in Kansas.

In many places beds *A* and *C* have a thin shale parting in the lower or middle parts. The shale beds *B* and *D* are silty to clayey, generally calcareous, and tan gray. In a few places they contain beds of maroon shale mottled with gray green, or beds of gray-green shale. Calcareous nodules are abundant in bed *B*.

The average thickness of each bed is as follows: bed *A*, 1 foot; bed *B*, 4.5 feet; bed *C*, 2.3 feet; bed *D*, 1.5 feet; and bed *E*, 1 foot. The Aspinwall limestone member averages about 10 feet in thickness. (See measured sections 52–57.)

Only limestone beds *A* and *C* contain fossils, and each has a distinctive fauna. Bed *C* contains a few gastropods; pelecypods and brachiopods are common in bed *A* except in the northeastern outcrop area where the bed is nonfossiliferous.

Two samples from bed *A* of the Aspinwall limestone member were tested for use as construction material (table 1, ls. 6, 45). Ls 6 was acceptable as aggregate for concrete, bituminous mixes, crushed stone for bituminous retread surface and bituminous drag treatment, cover material, binder soil stabilized base course, and crushed stone surfacing. Ls 45 was acceptable as aggregate for concrete, bituminous mat surfaces, cover material, binder soil stabilized base course, and crushed stone for surfacing (State Highway Commission of Kansas, 1937).

Bed *A* of the Aspinwall limestone was used in the construction of a 2-story stone house in the NE¼NW¼ sec. 23, T. 11 S., R. 12 E. This limestone reacts slightly with mortar and has an unsightly weathered surface.

A soundness test was not made on the samples tested and its use as riprap was not observed in the county. The specific gravity (2.66) and absorption (0.90) indicate that it would be acceptable as riprap, but tests for soundness should be made before the material is used for that purpose. Possible quarry sites of this member are indicated on plate 1.

HAWXBY SHALE MEMBER

The Hawxby shale member was first included as a shale bed in the Admire shale (Adams, 1903, p. 53) but later was part of the Aspinwall shale as classified by Condra (1927, p. 73, 74, 82, and 89). In 1932, Moore and Condra reclassified the rocks of Pennsylvanian and Permian age in Kansas and Nebraska, therefore, naming this group of shales the Hawxby and defining it as the shale between the Falls City limestone above, and the Aspinwall limestone, below. (See table 2.) They included it as a bed in the Admire shale member of the Wabaunsee formation of the Upper Carboniferous. Moore (1936a, p. 50) listed the Hawxby as a formation in the lower part of the Permian system. Moore and Mudge (1956, p. 2273) reduced it to member rank and included it in the Onaga shale.

The type locality is at the Hawxby farm in the SE¼ sec. 7, T. 4 N., R. 15 E., Nemaha County, Nebr. In Wabaunsee County, a complete section of this shale is exposed in a ditch in the SE¼SE¼ sec. 10, T. 13 S., R. 13 E.

There are a few outcrops of the Hawxby shale member in the northwestern and eastern parts of the county, but the member is generally covered by Quaternary deposits. The overlying Falls City limestone is very soft and does not form a hillside bench. (See pls. 2, 4, and 7.)

The Hawxby consists mainly of gray to gray-green beds of shale that contain one or more beds of impure limestone. The shales are generally clayey, calcareous, and thin-bedded. Limonite stains and calcareous nodules are common. In the east-central part of the county a bed of limestone is present in the middle part of the Hawxby. It is 3 feet thick, medium hard, fine grained, massive, gray brown, and has many specks of iron. This bed resembles bed *A* of the Aspinwall limestone member. The Hawxby shale member ranges from 6 to 17 feet in thickness. (See measured sections 49 and 52.) No fossils were seen in the Hawxby shale member.

The beds of limestone and shale, which have not been used in construction within the county were not tested as a construction material.

FALLS CITY LIMESTONE

A limestone bed in the Admire shale of Adams (1903, p. 53) was named the Falls City limestone by Condra and Bengston (1915, p. 17) who included it as a bed in their classification of the Admire formation and defined it as the limestone lying about 18 feet above the Aspinwall limestone. Moore (1936a, p. 50) discarded the name Admire shale and elevated the Falls City to the rank of a formation.

The type section is in the Lehmer quarry in sec. 32, T. 1 N., R. 16 E., 2½ miles southwest of Falls City in Richardson County, Nebr. (Condra, 1927, p. 82). In most of the outcrop area in Kansas, exposures of the limestone are exceedingly poor. In Wabaunsee County the best exposure is in a ditch along a road on the Wabaunsee-Shawnee County line in the SE¼SE¼ sec. 10, T. 13 S., R. 13 E. In Wabaunsee County the limestones of similar lithology and paleontology were combined to form the Falls City limestone, and some of these may not correlate with the type section in Nebraska. The Falls City limestone crops out in the northwestern and eastern parts of the county. It does not form a prominent hillside bench.

The Falls City ranges from 12 to 17 feet in thickness and consists of two or more beds of limestone separated by relatively thick beds of shale. The beds of limestone are hard, dense in part, gray to gray brown and fracture into irregular-shaped blocks. The beds of shale separating the limestones are generally clayey, gray, and thin bedded.

The upper bed of limestone has a relatively constant thickness of 0.8 foot, but the other beds of limestone do not exceed 0.5 foot in thickness. (See measured sections 49 and 52.)

In almost all of the beds of limestone and in some of the shale beds, the fossils are diagnostic of this formation. Pelecypods are especially abundant; they appear to comprise the bulk of many of the limestones, and are common in some of the beds of shale. Other fossils in the beds of limestone and shale are brachiopods, bryozoans, gastropods, and crinoid columnals.

The Falls City limestone was not sampled as a construction material due to the thinness of the beds of limestone.

JANESVILLE SHALE

The Janesville shale, defined as the strata between the Foraker limestone above and the Falls City limestone below, was named by Moore and Mudge (1956, p. 2273) after Janesville township in Greenwood County, Kans. The type section is in an east-west road cut in the SW¼SE¼ sec. 23, T. 23 S., R. 10 E., Greenwood

County. The Janesville contains three members which, in ascending order are the West Branch shale member, Five Point limestone member, and Hamlin shale member. The Janesville shale averages about 75 feet in thickness.

WEST BRANCH SHALE MEMBER

A unit of the Admire shale of Adams (1903, p. 53) was named the West Branch by Condra (1927, p. 82) who restricted it to the beds of shale between the Americus and Falls City limestones. It thus became the upper bed of the Admire shale member of the Wabaunsee formation, Pennsylvanian system. Moore and Condra (1932) revised the classification of the Admire shale to include, in ascending order, the Towle shale, Aspinwall limestone, Hawxby shale, Falls City limestone, West Branch shale, Five Point limestone, Stine shale, Houchen Creek limestone, and Oaks shale beds. Moore (1936a, p. 50) reclassified all these beds to formations except the Stine shale, Houchen Creek limestone, and Oaks shale which he made members of the Hamlin shale. He discarded the formation name, Admire shale, and included these new formations in the Admire group of the Permian system. Moore and Mudge (1956, p. 2273) reduced the Hamlin shale to the rank of member.

The type locality is in the West Branch township of Pawnee County, Nebr. (Condra, 1927, p. 82). The best exposures in Wabaunsee County, Kans., are in road cuts in the SE¼SE¼ sec. 10, T. 13 S., R. 13 E., in the NE¼SE¼ sec. 4, T. 14 S., R. 13 E., and in the SE¼SW¼SW¼ sec. 19, T. 11 S., R. 12 E.

The West Branch shale member crops out in the northwestern and eastern parts of the county. Exposures in many road cuts and streambanks include only the middle and upper parts of the member. (See pl. 3.)

The West Branch is mostly shale, but it contains 1 or more thin lenses of limestone and 1 or more beds of coal. The shale is silty to sandy, micaceous, and tan gray and gray brown to gray green. The beds of limestone are lenticular, clayey, massive, and tan gray. A bed of limestone averaging 1 foot in thickness is present about 6 feet beneath the Five Point limestone member. It grades from a limestone in the northern half of the eastern outcrop area to a calcareous shale in the southern half, and is absent near Harveyville. A bed of limestone 4 feet thick is in the lower half of this member. It is soft, tan to tan brown, and is generally porous to cavernous with many small fractures filled with calcite. Thin lenses of siltstone and micaceous sandstone are in the middle and upper parts of this member. In a few places the sandstone fills a small channel. (See pl. 7.)

A thin persistent bed of coal is a few feet beneath the Five Point limestone member and another thin bed of coal locally is in the lower part of the member. East of Eskridge in the NW¼NE¼ sec. 8, T. 14 S., R. 13 E., two coal mines were operated in the early 1920's at a depth of 40 feet beneath the surface. The local geology is such that it can be assumed that the coal bearing horizon is either in the Hawxby shale member of the Onaga shale or West Branch shale member of the Janesville shale. There are no coal beds in the Hawxby shale member of the Onaga shale, so these mines were probably producing from one of the beds common in the West Branch shale member of the Janesville shale. The coal bed was reported by local inhabitants to be about 32 inches thick. This must have been a local thickening of the coal bed because neither of the exposed two beds in the West Branch member are as much as 6 inches thick.

In the upper part of the member iron stains are abundant on fracture and bedding planes. Carbon stains are on some of the bedding planes.

This member averages about 27 feet thick. Toward the southeast it is as much as 30 feet thick. (See measured sections 48–52.)

Fossils in the beds of limestone and in the shale facies of the upper limestone bed consist of brachiopods, pelecypods, bryozoans, and crinoid columnals. Wood and leaf fragments are present in some of the beds of shale, sandy shale, and sandstone.

The West Branch shale member has not been used as a construction material in the county.

FIVE POINT LIMESTONE MEMBER

In his reclassification of the Admire shale of Adams, Condra (1927), p. 74 and 82) included a limestone in the West Branch shale that Moore and Condra (1932) named the Five Point limestone. It remained a bed in the Admire shale member of the Wabaunsee formation of the Pennsylvanian system, however, until Moore (1936a, p. 50) classified it as a formation. Moore and Mudge (1956, p. 2273) reduced this limestone to the rank of a member and placed it in the Janesville shale. The Five Point limestone member overlies the West Branch shale member and underlies the Hamlin shale member.

The type locality is on Five Point Creek near Five Point school in sec. 25, T. 1 N., R. 15 E., east Richardson County, Nebr. This location is 2 miles south and 4½ miles west of Falls City, Nebr. In Wabaunsee County there are several good exposures of this limestone, therefore, the reader is referred to the measured sections which typify the facies changes seen in this member.

The Five Point limestone member crops out in the northern and eastern parts of the county, and commonly forms a prominent hillside bench.

This member consists of a thin bed of limestone in the basal part, a bed of shale in the lower and middle parts, and one or more thick beds of limestone in the upper part. (See pls. 3, 7.) The lower limestone is gray, persistent, and ranges from 0.3 to 0.7 feet in thickness. It is medium hard and weathers in small blocks or plates.

The intervening bed of shale is generally silty and calcareous, but near Harveyville it contains a thin bed of clay in the upper part. This shale is gray to gray brown except in the southeast where it is gray green.

The upper part of the member is generally a massive bed of limestone; the lower part consists of thin beds of shale and limestone. The beds of limestone are hard, massive, and gray, and normally weather platy. In the northern outcrop area the upper bed is massive, soft and tan brown. It consists almost entirely of fragments of fossil shells that give it an "oatmeal" texture. A good exposure of this coquina facies is in a road cut in the NW¼NW½ sec. 14, T. 13 S., R. 12 E., where it forms a prominent hillside bench and slumps in large rectangular blocks on the West Branch shale member.

The Five Point limestone member ranges from a minimum thickness of about 4 feet in the northern outcrop area to a maximum of about 8 feet in the southeastern outcrop area. From north to south it thickens and thins many times (pl. 7), but averages about 6 feet in thickness. (See measured sections 48–51.)

The fossils in the lower limestone are brachiopods, crinoid columnals, bryozoans, and fusulinids. The fossils in the intervening shale are corals, crinoid columnals, and brachiopods.

The fossils in the upper bed of limestone are brachiopods, bryozoans, gastropods, echinoid spines and plates, and pelecypods. Small fusulinids are associated with the coquina facies.

Two samples of the Five Point limestone member were tested for construction material (table 1, ls 23 and ls 37). Ls 23 is a sample of the coquina facies and ls 37 is a sample of platy facies; both are from the upper limestone. Ls 19 probably would not be acceptable as a construction material because of its high abrasion loss (46 percent, as indicated by the Los Angeles abrasion test) and its high absorption (7.66 percent). Ls 37 was rejected as a construction material under sections 107 to 112, and 114 of the Kansas Highway standard specifications (1945). It has a loss of 41.9 by the Los Angeles abrasion test; a soundness factor of 0.65 and an absorption factor of 6.20.

The upper bed of the Five Point limestone member (coquina facies) has been quarried in the NE¼SW¼ sec. 14, T. 11 S., R. 11 E. This stone was used in the foundation of a large church 1 mile north of Paxico. It has an acceptable appearance as a trim stone and appears to have adequate strength for use as a foundation stone. Small quantities of this upper limestone have been quarried in the northeastern and southeastern outcrop areas. The locations of suitable quarry sites are shown on plate 1.

HAMLIN SHALE MEMBER

The strata now known as the Hamlin shale member was included in the West Branch shale by Condra (1927, p. 74 and 82) in his reclassification of the Admire shale of Adams (1903, p. 53). Moore, Elias, and Newell (1934) included the Stine shale, Houchen Creek limestone and Oaks shale as members of the Hamlin shale. Moore and Mudge (1956, p. 2273) reduced the Hamlin shale to the rank of member. The Hamlin shale member overlies the Five Point limestone member and underlies the Foraker limestone. The type locality is not known, but the Hamlin shale member crops out in the northern and eastern parts of the county.

It is suggested here that Houchen Creek limestone bed be used as a formal name. It was discovered during recent field work in Kansas that this bed of the Hamlin shale member could not be correlated south of Pottawatomie County. The algal limestone identified as Houchen Creek in Chase County (Moore, Jewett, and O'Connor, 1951, p. 15) and in Lyon County (O'Connor, 1953, p. 14) does not correlate with the type section on Houchen Creek in Nemaha County, Nebr. In Wabaunsee County the algal bearing limestone that correlates with that limestone of Chase and Lyon Counties coalesces with the lower bed (as formerly defined) of the Americus limestone member of the Foraker limestone (see p. 53–54). This algal limestone and the calcarenite underlying it have been traced northward into Pottawatomie County where the Houchen Creek limestone bed lies about 25 feet beneath them. In Pottawatomie County the Houchen Creek limestone bed does correlate northward with the type section in stratigraphic position and lithologic and paleontologic characteristics.

The Hamlin consists of silty to clayey shales, beds of sandy shale and sandstone, and thin beds of siltstone, limestone, and conglomerate.

The shale is generally gray to gray green, but in some places it contains green and maroon beds. Gray beds mottled with maroon and maroon beds mottled with green are present in a few places at the same stratigraphic positions as the green and maroon beds.

Thin beds of lenticular limestone are throughout this member. These beds of limestone are clayey, very hard, and tan gray to gray. The middle bed, which is slightly fossiliferous, may be correlative to the Houchen Creek limestone bed.

Thin conglomerates are present in the upper, middle, and lower parts of the shale and consist of subangular to rounded clay balls and limonite nodules having a maximum diameter of about one-fourth inch. In the area north and south of Keene, the conglomerate in the middle part is persistent and overlies a massive sandstone. North of Keene a thin bed of coal separates the sandstone from the upper conglomerate. (See pl. 8.)

The lower conglomerate, which is interbedded with a clay shale, lies about 6 feet beneath the persistent sandstone bed in the middle part of the member. The upper conglomerate resembles the others in composition; it lies about 10 feet beneath the Americus limestone member of the Foraker limestone.

The conglomerates are as much as 0.6 foot thick and average 0.3 foot in thickness. The micaceous beds of sandstone and sandy shale consist principally of well-rounded grains of quartz. The generally thick massive beds of sandstone are separated by thin partings of sandy shale. Crossbedding and ripple marks are rare in the sandstones.

In the northwestern part of the county and in a few places elsewhere there is a thin tan siltstone in the upper part of the Hamlin shale member. A bed of calcarenite as much as 0.8 foot thick is common above the siltstone and just below the algal-bearing bed of the Americus limestone member of the Foraker limestone. This calcarenite consists of fragments of limestone and of ostracodes.

The Hamlin shale member ranges in thickness from 35 to 45 feet and averages about 42 feet. (See measured sections 42, 43, 45, 46, 48, and 49.) Pelecypods, bryozoans, and brachiopods are present in the thin bed of limestone in the middle of this member in the SE¼SW¼SW¼ sec. 24, T. 12 S., R. 12 E. Leaf and wood fragments are common in the sandstones and sandy shales.

The Hamlin shale member has been used as fill material along Highway U. S. 40. Seeps were observed at the base of the beds of sandstone.

COUNCIL GROVE GROUP

The Council Grove is the middle group of that part of the Permian system present in this area. (See table 2.) The group includes the formations from the Foraker limestone up to and including the Speiser shale. Outcrops of the Council Grove group are distributed over nearly three-fourths of the county, but they are most extensive in the central part. (See pl. 2.) The limestone formations form conspicuous hillside terraces and the intervening shale beds form the nearly vertical slopes between terraces.

FORAKER LIMESTONE

The name Foraker limestone was given by Heald (1916, p. 21, 25) to the beds of limestone that lie about 18 feet beneath the Red Eagle limestone and overlie shale and sandstone beds. Bass (1929, p. 48, 49, 52) defined the Foraker limestone in a measured section as overlying the Admire shale and underlying the Elmdale shale (at that time the Elmdale shale included all beds from the Americus limestone member up to the base of the Neva limestone member of the Grenola limestone). Bass restricted the Elmdale shale to include about 80 feet of beds extending from the base of the Neva limestone above to the top of the Foraker limestone below. The type section is near Foraker in Osage County, Okla.

The Foraker limestone consists of three members which are, in ascending order, the Americus limestone member, Hughes Creek shale member and Long Creek limestone member. This formation crops out in the northern and eastern parts of the county (see pl. 2) and averages about 47 feet in thickness. (See pls. 3, 7 and table 2.)

AMERICUS LIMESTONE MEMBER

The Americus limestone was named by Kirk (1896, p. 80) from exposures near Americus in Lyon County, Kans. There are many exposures of this limestone in Wabaunsee County, and the reader is referred to the measured sections listed under this limestone for the location and detailed descriptions.

The limestone formerly called Houchen Creek limestone south of Pottawatomie County does not correlate with the type section in Nebraska, but it coalesces with the Americus limestone member in Wabaunsee County. This limestone has a distinctive type of algae in the lower part of the Americus limestone member that can be traced north into Pottawatomie and Jackson Counties.

The Americus limestone member formerly consisted of 1 or 2 beds of limestone 12 or more inches thick in the lower part, 4 to 8 feet of gray fossiliferous shale in the middle part, and a bed of gray limestone 18 or more inches thick in the upper part. In this paper the upper contact of the Americus is restricted to the top of the lower 1 or 2 beds of limestone. This places the upper bed of limestone, which is absent in some places and the beds of shale in the Hughes Creek shale member. This grouping is based on lithologic and paleontologic similarities.

The lower part of the Americus limestone member is redefined to include the algal bed heretofore referred to as the Houchen

Creek limestone in Chase County (Moore, Jewett, and O'Connor, 1951, p. 15) and in Lyon County (O'Connor, 1953, p. 14). In the southern part of the Wabaunsee County the Americus now consists of 3 beds of limestone separated by 2 beds of shale but northward the lower bed of shale pinches out and the lower bed of limestone coalesces with, and becomes part of, the middle bed of limestone in the northern part of the county. (See pl. 7.)

The lower bed (the algal limestone) is generally a thin-bedded medium-hard limestone. In the north-central part of the outcrop area it consists of two or more beds of hard limestone separated by gray to gray-green silty calcareous shale (pl. 6B). The most distinctive feature of this bed of limestone is its algal deposits.

The shale that lies above the algal limestone was called the Oaks shale member in Chase County by Moore, Jewett, and O'Connor (1951, p. 15) and in Lyon County by O'Connor (1953, p. 14). In southern Wabaunsee County this is the lower shale bed of the Americus limestone member. It is silty, calcareous, gray to dark gray, and thin bedded. It pinches out in the northern part of the county.

The other two beds of limestone are separated by a thin bed of shale, are quite distinctive, and easily identified. The limestones are gray to dark gray, hard, massive, generally tan gray when weathered into large irregular shaped blocks. The upper limestone is thicker and more massive than the lower one which is shaly in most outcrops. The intervening bed of shale is silty, calcareous, thin bedded, and gray (pl. 6B).

This sequence of two limestones separated by a thin shale occurs once or twice in the middle part of the Hughes Creek shale member. (See pl. 7.) The upper beds of the Americus may be readily mistaken for these beds by the casual observer. Attention must be given to hardness, color, fossil content, and outcrop characteristics; each of which aids in distinguishing the Americus limestone member from the limestones of the Hughes Creek shale member. The upper bed of the Americus is finer grained, harder, more massive, and is a deeper blue gray than the limestones in the Hughes Creek. The upper bed of the Americus forms a prominent and somewhat distinctive hillside bench. In places many large rectangular blocks of limestone occur along the outcrop. On aerial photographs the outcrop pattern of many small white dashes distinguishes it from other limestones. This aerial photograph pattern is particularly distinctive in the northwestern outcrop area but is recognizable in a few places in other parts of the county. In Wabaunsee County the limestones of the

Hughes Creek do not form a hillside bench or have a distinctive outcrop pattern.

In the southern outcrop area the lower bed of limestone averages 0.8 foot in thickness, but in the north-central outcrop area it is a maximum of 2.8 feet thick. (See pl. 6B.) The intervening bed of shale ranges from a featheredge to about 1 foot in thickness. The upper two limestones do not vary lithologically in the county but do vary slightly in thickness. Each limestone averages about 1 foot in thickness. The intervening shale averages about 0.6 foot in thickness in the northern outcrop area but thickens to about 2 feet in the southern area. (See measured sections 38, 42–47, and 49.)

The plant fossils in the lower bed of limestone are large circular convex-shaped masses of the algal division *Spongiostroma* (J. Harlan Johnson, oral communication). In many places they are 10 to 12 inches in diameter; generally they appear to be almost continuous so that they form a dark-gray wavy band within this limestone. The algae is dense, finely laminated, and is a darker gray than the limestone matrix. In Wabaunsee County this massive algae is present only in this bed of limestone, making it quite distinctive from other limestone beds. North of Eskridge pelecypods and small solitary corals are associated with the algae.

The fossils in the upper two limestones also are an aid in the identification of the member. Each limestone bed contains a somewhat different fauna. The lower limestone which is fossiliferous only in a few places, contains pelecypods and corals in the exposures south of Wabaunsee and Paxico. The fossils in the upper limestone are diagnostic and consist mainly of fusulinids, crinoid columnals, and brachiopods. Most of the crinoid columnals are one-fourth inch in diameter, but some are one-half inch. They weather white and are lighter in color than the matrix. Other fossils are bryozoans and echinoid spines and plates. There are no fossils in the upper bed of shale.

Three samples of the Americus limestone member were tested for construction material (table 1, ls. 8, 13 and 14). The material represented by sample ls. 8 is acceptable as crushed aggregate for most engineering uses including concrete aggregate. Although the percent loss (loss-ratio of 80 hundredths) in the soundness test is somewhat lower than the maximum prescribed in the Kansas Highway standard specifications (1945), it is possible that ls. 14 may be accepted as an aggregate for cover material, bituminous retread surface and bituminous drag treatment, and for surfacing. Sample ls. 13 was obtained in the NE¼NE¼ sec. 13, T. 11 S., R. 12 E., where the lower bed is 5.6 feet thick. The results indicate that it would not be acceptable as a construction material.

In the northern outcrop area the Americus is thick enough to be quarried economically and in large quantities. Plate 1 shows only the outcrop areas where limestone 4 to 8 feet thick can be quarried without removing large quantities of shale.

Crushed limestone obtained from quarries in the Americus in the SW¼NE¼ sec. 36, T. 11 S., R. 11 E., and in the NE¼ sec. 3, T. 12 S., R. 11 E., is used as surface material on the county highway extending from Paxico to a point 8 miles south. (See pl. 8.) Blocks of this limestone from a quarry in the SE¼SW¼NW¼ sec. 10, T. 11 S., R. 11 E., were used as hand-laid riprap in a spillway of a small earthen dam in the SW¼NW¼ sec. 10, T. 11 S., R. 11 E. What appears to be field stones of the Americus limestone member were used as hand-laid riprap on the upstream face of a small dam in the SE¼NW¼ sec. 16, T. 15 S., R. 12 E. In both cases where this limestone has been used as riprap, no effect from wear or from the action of freezing and thawing is apparent on the limestone blocks.

The Americus limestone member is an aquifer in many places. In many road cuts overbreakage of this limestone is common (John D. McNeal, 1953, written communication).

HUGHES CREEK SHALE MEMBER

The Hughes Creek shale was named by Condra (1927, p. 85) for exposures along Hughes Creek in Nemaha County, Nebr. Good exposures of this shale are in road cuts along U. S. Highway 40 at NE¼SE¼SW¼ sec. 27, T. 11 S., R. 11 E., and in the SE¼SE¼ sec. 25, T. 11 S., R. 11 E.

The Hughes Creek shale member is mainly silty and calcareous, but locally is clayey in the lower part. This member is gray to tan gray often dark gray and it contains two thin beds of limestone in the middle part that are separated by a thin bed of shale. Another pair of thin limestone beds separated by a thin bed of shale lie about 6 feet above the first pair (pl. 7) which grades laterally into 3 thin beds of limestone separated by thin beds of shale. There are 6 beds of limestone in the northwestern outcrop area. Although thinning is not noticeable, the beds of limestone are thicker in the northern part of the county. In the southernmost outcrop area the upper limestone of each pair is absent. The intervening shale beds in both sets of limestone beds are also thicker in the northern outcrop area and thin toward the south (pls. 3, 7).

The limestone beds are medium hard to soft, dark gray, shaly in some places, and weather into small blocks with rounded corners or into small irregular plates. In many exposures one or more of the limestones, which do not form hillside benches, are composed almost entirely of fusulinids.

An impure limestone about 3 feet thick occurs in a few places in the upper part of this member. It is generally soft and composed of fusulinids, and weathers shaly. This bed grades laterally into a very calcareous shale. A lens of micaceous sandstone is present in the lower part of this member in SW¼SE¼SE¼ sec. 27, T. 11 S., R. 11 E.

The Hughes Creek averages about 38 feet in thickness. (See measured sections 38, 39, and 42–46.)

The generally abundant fossils are an aid in the identification of this member. Fusulinids are abundant in almost all of the thin limestones and in the upper bed of shale, and are common in the lower beds of shale. Brachiopods are common to abundant throughout the member. In most exposures crinoid columnals, bryozoans, and echinoid spines and plates are common. Pelecypods, trilobites, and sharks teeth are rare. Corals are in the upper limestone bed of the upper pair in the SW¼NW¼ sec. 3, T. 13 S., R. 12 E.

South and southeast of Paxico, the Hughes Creek has been used as a construction material in many of the fills along U. S. Highway 40.

Two samples of the limestone beds in this member were tested and the results are shown in table 1 (ls. 7). The upper limestone is acceptable as an aggregate for concrete, bituminous mat surfaces, bituminous retread surface and drag treatment, cover material, binder-soil stabilized base course, and crushed stone for surfacing. The lower limestone is unsound and was rejected as an aggregate for the uses listed above.

Many seeps are in some of the beds of shale and at the base of many of the limestones.

LONG CREEK LIMESTONE MEMBER

The Long Creek limestone was named by Condra (1927, p. 84) for exposures at the foot of a bluff above Longs Creek west of the cemetery at Auburn in Nemaha County, Nebr.

The Long Creek limestone member generally consists of a thick massive bed of limestone and locally contains thin lentils of shale. It is soft dolomitic massive and gray to gray-orange. The upper part of the limestone contains pink crystals of calcite and celestite(?) that line geodes and the sides of small fractures. In many places the weathered surface is covered with fragments of calcite and celestite(?). This feature is distinctive, but was also noted in the Howe limestone member of the Red Eagle limestone, a younger and somewhat similar bed of limestone. The Long Creek is generally granular and porous and seldom forms a hillside bench. In road cuts and streambanks it is generally covered with colluvium or other Quaternary sediments. In the northern part of the county, the lower part of this member contains thin lentils of tan-gray silty shale.

In the northern outcrop area the Long Creek limestone member ranges from 2.5 to 8 feet in thickness, but in the southern outcrop area its thickness is constant at about 6.5 feet. (See measured sections 38, 39 and 42–44.)

A few pelecypods are locally present in the middle of this member. This limestone, because of its softness, was not sampled as a construction material. It has not been used in the county as an aggregate, but south of Paxico it was used as part of the fill material along U. S. Highway 40.

JOHNSON SHALE

The Johnson shale was included first as a bed in the Elmdale shale by Prosser (1902, p. 708), but was named and defined by Condra (1927, p. 86) as the shale between the Glenrock limestone above and Long Creek limestone below. Moore, Elias, and Newell (1934) discarded the Elmdale shale and elevated all of its units to the rank of formation. The type locality is 1½ miles north of Johnson in Johnson County, Nebr. (Condra, 1927, p. 86). In Wabaunsee County the best exposure is southeast of Paxico near U. S. Highway 40, in the SW¼SW¼ sec. 30, T. 11 S., R. 12 E. The Johnson shale outcrops in the northern and eastern parts of the County, but is poorly exposed.

The Johnson shale is generally silty, calcareous and tan to gray in the upper part and olive drab to gray green in the lower part. In a few places a thin lenticular clayey limestone is in the middle and upper parts. Some of the hard, more calcareous beds of shale show penecontemporaneous deformation. Many small angular blocks of these calcareous beds and many calcareous plates weathered from the shales cover the exposed surface. Iron stains are on many of the bedding and fracture planes. This formation averages 25 feet in thickness. (See measured sections 38, 39, 42 and 44.) No fossils were observed in this formation in Wabaunsee County. The Johnson shale is used as fill material along U. S. Highway 40, southeast of Paxico.

RED EAGLE LIMESTONE

The Red Eagle limestone was named by Heald (1916, p. 24–25) and defined as a member in the Elmdale formation. Moore, Elias, and Newell (1934), Condra (1935, p. 8), and Moore (1936a, p.

50) listed it as a formation, and discarded the name Elmdale. They also divided it into three members which are in ascending order, the Glenrock limestone member, Bennett shale member, and the Howe limestone member. The type locality is near the Red Eagle school southwest of Foraker, Okla. (Heald 1916, p. 24).

The Red Eagle limestone overlies the Johnson shale and underlies the Roca shale. The Glenrock limestone member is absent in a belt about 10 miles wide that extends northeast through McFarland from a point south of Alma. Where this limestone is absent, the contact between the Bennett shale member and the Johnson shale is evident by the contrast of the dark-gray shales of the Bennett to the light-gray-green shales of the Johnson (pls. 3, 7).

Exposures of the Red Eagle limestone are common throughout the outcrop area which includes most of the northern part of the county and a narrow north-south belt in the eastern part.

GLENROCK LIMESTONE MEMBER

The Glenrock limestone was named by Condra (1927, p. 86) after exposures high on the side of a valley northwest of Glenrock in Nemaha County, Nebr.

The Glenrock is a hard massive blocky tan-gray limestone. It generally weathers into small irregular-shaped blocks, but locally it weathers into large rectangular blocks. In the SW¼NW¼ sec. 27, T. 14 S., R. 12 E., this member contains a conglomerate composed of limonite balls and fragments of limestone and clay. Some iron stains discolor the upper part of this limestone and are common on the fractured surfaces throughout the member. This limestone forms a small but not too distinctive hillside bench, and averages about 1.5 feet in thickness. (See measured sections 38 and 40–42.)

Fusulinids are abundant throughout this member, and fragments of chitinous brachiopods are abundant on the top surface. In the northern outcrop area there are pelecypods and brachiopods, and in a few places echinoid spines are common.

The Glenrock, which was not sampled for a construction material because of its thinness and great overburden, has not been used as a construction material in Wabaunsee County.

BENNETT SHALE MEMBER

The Bennett shale member was named by Condra (1927, p. 86) after exposures along the Little Nemaha River and its tributaries south of Bennett in Lancaster County, Nebr.

In the northern part of the outcrop area the Bennett is a silty calcareous thin-bedded to fissile gray-brown to dark-gray shale, but in the southern outcrop area it is a dark-gray clayey shale. Southeast of Paxico a thin argillaceous bed of limestone is in the middle part of the member, and in the area south of Eskridge the shales are carbonaceous. Iron stains are conspicuous in a few places on some of the bedding planes.

A biostrome originates in the middle part of the shale in the area south of Eskridge. It extends southward from northern Lyon County (O'Connor and Jewett, 1952, p. 338) and northward to about 3 miles south of Eskridge, then trends northeast to Bradford where it has been eroded. It consists of thick medium-hard tan-gray massive beds of limestone in the lower part, and thin irregularly bedded gray brecciated limestone in the upper part. In some places they are hard dense and contain a thin bed of shale and nodules of chert. The biostrome, which is about 1½ miles wide, thickens upward; the west side is steep, and the east side has a gentle slope. In the lower part there is a small coquina zone, and in the middle part small chert nodules are common. The limestone beds are porous and contain many solution channels. Many limestone sinks associated with the biostrome were seen in secs. 30–33, T. 14 S., R. 12 E.; secs. 7 and 18, T. 15 S., R. 12 E.; and sec. 12, T. 15 S., R. 11 E. The Howe limestone member rests directly on the biostrome and in most exposures is distinguishable from it only by the change in fauna

The west flank of the bistrome is exposed well enough to permit a detailed study. The limestone contains a thin lens of chert in the upper part, but otherwise it is normal in thickness and in lithologic and paleontologic character. An exposure on the west flank in the SW¼SE¼NE¼ sec. 17, T. 14 S., R. 12 E., consists of a thick (4.2 feet) soft dolomitic limestone bed in the lower part and two thin but otherwise similar beds in the upper part that are separated by silty tan-gray shale. A conglomerate in the lower part of the lower bed consists of angular fragments of limestone ranging from one-sixteenth to one-fourth inch in diameter. Iron stains are common.

In the area where the biostrome persists, the beds of limestone form a very conspicuous hillside bench with about 8 to 15 feet of the limestone forming a vertical cliff.

In the northern outcrop area the Bennett ranges from 6 to 11.5 feet in thickness; in the southern outcrop area the shale facies has a minimum thickness of 2.3 feet and a maximum of 3.8 feet. In Wabaunsee County the biostrome facies is about 14 feet thick, but is reported to be as much as 28 feet. In Lyon County, O'Connor and Jewett (1952, p. 341) list as much as 28 feet of Bennett in the area where the biostrome attains maximum development. (See measured sections 38–42.)

The typical fossils of this member are thin-shelled brachiopods. East of Alma, some fusulinids are present in the upper part, and in the lower part of the member there are small chitinous brachiopods. In the northern outcrop area, brachiopods are present in the middle and upper parts. Other fossils restricted to the northern outcrop area are crinoid columnals and other brachiopods.

In the northern extension of the biostrome the only fossils are brachiopods and crinoid columnals. In the southernmost outcrop areas chitinous brachiopods are abundant in the lower foot of this limestone. Fusulinids, crinoid columnals, and echinoid spines are also present. At the same exposures algae and small solitary corals are common about 3 feet from the base of the biostrome. The Bennett shale member has been used as a fill material along U. S. Highway 40 north of Alma.

Several samples of the biostrome facies of the Bennett were obtained south of Eskridge, and tested by the materials laboratory of the State Highway Commission of Kansas. Six of the test results are recorded on table 1. (See ls 36–41.) Three of the samples, ls 38, 39, and 41 were of material acceptable as a coarse aggregate for concrete and all 6 were acceptable as aggregate for bituminous surface course, bituminous concrete and sheet asphalt surfaces, cover material, bituminous retread surface, and bituminous drag treatment, surfacing, and for crushed stone base course (keyed type). Samples ls 40 and 41 were of material acceptable as riprap.

Crushed limestone from a large quarry in the NE¼NW¼ sec. 31, T. 14 S., R. 12 E., has been used extensively as a surface material on township roads in the southeastern part of the county and on Kansas Highway 99 from Alma to Eskridge. (See pl. 8.)

The foundation of a barn in the SE¼SE¼NE¼ sec. 12, T. 15 S., R. 11 E., was built with biostrome limestone beds. Plate 1 shows the outcrop area of the biostrome in the Bennett which furnishes important construction material in the county.

A byproduct from the quarry mentioned above is lime for agricultural use. This lime is generally in silt- to clay-size particles, and is obtained by crushing the larger blocks. The calcium carbonate ($CaCO_3$) content of this limestone is 82.9 percent.

HOWE LIMESTONE MEMBER

The Howe limestone member was named by Condra (1927, p. 86) from exposures south of Howe, Nebr., in T. 4 N., R. 14 E.

The Howe limestone member is a single bed of limestone that generally is soft, massive, and tan to gray orange. It is slightly dolomitic and contains small crystals of pink and white celestite (?) and calcite. In some places the beds are wavy and appear to be lenticular. This limestone is porous, weathers into small irregular blocks, and forms a small hillside bench. The Howe limestone member ranges from 2 to 5 feet in thickness. (See measured sections 36–42.)

The many ostracodes in this limestone characteristically form a zone in the upper 3 or 4 inches of this bed and locally in the lower part. This ostracode zone is diagnostic for this member. In the area southeast of Paxico brachiopods and pelecypods are present in the lower part.

The Howe was not sampled as a construction material. It is used locally as part of fill material.

ROCA SHALE

The unit now known as the Roca shale was included as part of the Elmdale shale in a classification by Prosser (1902, p. 708). Condra (1927, p. 84 and 86) named it the Roca shale and referred to it as a member in the Elmdale shale, but in 1935 (p. 8) he elevated it to the rank of a formation and discarded the name Elmdale. Moore, Frye and Jewett (1944, p. 167) included the older subdivisions—the Legion shale and Sallyards limestone at the top of the Roca—but Moore, Frye, Jewett, Lee, and O'Connor (1951, p. 48) replaced the Legion shale and Sallyards limestone in the overlying Grenola limestone. The original definitions of the Grenola limestone and Roca shale, established by Condra and Busby (1933, p. 7), are followed in this report.

The Roca shale was named after the town of Roca in Lancaster County, Nebr. The location of the type section is not known. For representative sections in Wabaunsee County see the following road cut exposures: SW¼NW¼ sec. 13, T. 13 S., R. 12 E.; SW¼NW¼NW¼ sec. 9, T. 12 S., R. 12 E.; and in the center of the NE¼ sec. 10, T. 12 S., R. 10 E.

The poorly exposed Roca shale crops out in a relatively narrow band in the northern and eastern parts of the county (see pl. 2).

The Roca shale consists mainly of gray to gray-green beds of shale that locally contains one or more thin beds of limestone. In the northwestern and southeastern outcrop areas the Roca shale is silty, but it is clayey in the northeast. The upper 2 or 3 feet is generally calcareous and tan gray to gray; the middle and lower parts are gray green to gray. In the middle part there is a persistent bed of purple shale that is either mottled with maroon, or grades laterally into a maroon shale. In the northern part of the county there are 2 or more thin medium-hard dense beds of limestone in the lower part and 1 or more soft beds of limestone in the upper part. Northeast of Eskridge these beds pinch out or grade laterally into calcareous shales, but they reappear south of that city. The beds of limestone weather into irregular nodules and blocks that are generally porous. The Roca shale averages about 25 feet in thickness. (See pls. 3 and 9, and measured sections 33, and 36–40.)

Gastropods, the only fossils observed in the Roca shale, are abundant in the upper limestone bed in the NW¼SW¼SE¼ sec. 35, T. 12 S., R. 10 E., but are absent elsewhere.

A small quantity of the Roca shale was quarried in the SW¼SW¼ sec. 28, T. 10 S., R. 11 E., and used as a road metal on the nearby land-access road. In that section the Roca has a high percentage of silt, is very calcareous, and forms a selfbonding type of macadam. Northwest of McFarland this formation has been used as a fill material along U. S. Highway 40.

GRENOLA LIMESTONE

The Grenola limestone is probably equivalent to the Dunlap limestone as named by Kirk (1896, p. 81). The name Dunlap was abandoned when Prosser (1902, p. 709), included in his classification of the Elmdale shale all of the present units of the Grenola except the Neva limestone member which he described as a formation. Condra and Busby (1933, p. 7) restricted the Elmdale shale and included in the Grenola all strata lying between the Roca shale below and the Eskridge shale above. They divided the Grenola into the following members, which are in ascending order, the Sallyards limestone member, Legion shale member, Burr limestone member, Salem Point shale member, and the Neva limestone member. Moore, Frye, and Jewett (1944, p. 167) gave the Grenola only the Burr limestone, Salem Point shale, and Neva limestone members, and placed the Sallyards limestone and Legion shale members as beds in the Roca shale. Moore, Frye, Jewett, Lee, and O'Connor (1951, p. 47 and 48) redefined the Grenola as originally proposed by Condra and Busby.

The type section is in the ravines and creeks north and south of Highway 160 and 4 to 5 miles west of Grenola in Elk County, Kans. (Condra and Busby, 1933, p. 9). The Grenola crops out in a narrow band in the northern and eastern parts of Wabaunsee County, it averages about 37 feet in thickness.

SALLYARDS LIMESTONE MEMBER

The Sallyards limestone member was named by Condra and Busby (1933, p. 9 and 25) for exposures in the south bank of a ravine 1 mile northeast of Sallyards in Greenwood County, Kans.

The Sallyards is medium hard, gray to tan gray, and weathers into small irregular blocks. In some exposures the upper part of the limestone has a hackly fracture. In the southern part of the county there are 2 thin beds of limestone separated by 0.8 foot of shale. Iron stains are common on the fractured and weathered surfaces. (See pls. 3, 10.)

The Sallyards averages 1.2 feet in thickness in the northwestern outcrop area but thins slightly in the east and southeast. A minimum thickness of 0.4 foot was seen northeast of Eskridge. (See measured sections 33–39.)

The most common fossils in almost all exposures of this member are crinoid columnals, pelecypods, and small high-spiralled gastropods, but pelecypods are abundant in the northwestern outcrop area. Most exposures of this limestone contain ostracodes and fragments of other fossils. Small algal deposits which are commonly referred to as cryptozoon, are in this limestone in road-cut exposures in the SE¼NW¼ sec. 3, T. 11 S., R. 10 E., and in the NE¼SE¼ sec. 20, T. 12 S., R. 11 E. Fusulinids were observed only in the extreme northern outcrop area. Brachiopods, bryozoans, and trilobites are in this member in a few places.

The Sallyards limestone member was not tested for a construction material. It is thin, and generally has at least 12 feet of overburden.

LEGION SHALE MEMBER

The Legion shale member was named by Condra and Busby (1933, p. 10) after the American Legion Golf Club about 1¾ miles southwest of Manhattan, Kans. The type locality is the road cuts on old U. S. Highway 40 just southwest of the American Legion grounds.

The Legion consists of beds of shale that are thin bedded and gray to tan gray. North of a line extending from Alma to Keene this member is primarily a clayey shale. South of that line (in the north-central part of the county) it is silty, and 4 miles south of Alma there is a small outcrop containing clayey shale. The Legion generally contains thin calcareous lentils—particularly in the lower part. These lentils generally weather out as small plates and cover the surface of this member. In the NE¼SE¼ sec. 27, T. 11 S., R. 10 E., the Legion is a black fissile shale.

The Legion ranges in thickness from 1.4 feet south of Keene to 8.7 feet north of that city. In the area south and southeast of Alma, north of Keene, and south of Eskridge, it averages 8 feet. From a point about 2 miles south of Keene to about 4 miles north of Alma, it averages about 1.6 feet in thickness. Elsewhere in the county this shale averages 5 feet in thickness. (See measured sections 33–37.)

Fusulinids, brachiopods, and crinoid columnals are in only the upper 0.7 foot of this shale in the SE¼SE¼ sec. 8, T. 12 S., R. 12 E.

The Legion shale member was not tested for a construction material. It was probably used as fill material along U. S. Highway 40 in the NW¼SW¼ sec. 26, T. 11 S., R. 10 E., and along Highway 99 in the NW¼ sec. 3, T. 11 S., R. 10 E.

BURR LIMESTONE MEMBER

The Burr limestone member was named by Condra and Busby (1933, p. 10), who designated the type locality as "the bluffs and ravines west of South Fork of the Little Nemaha River, in section 20, at a point one-fourth mile west of the north-south road, distance 2½ miles northwest of Burr." There are many good exposures of this limestone in Wabaunsee County. The Burr generally consists of two beds of limestone separated by a thin bed of shale. In the central part of the county at least one and sometimes both of the beds of limestone contain a thin shale lentil. About 3.5 miles north of Alma the lower bed of limestone contains a thin bed of shale. In the eastern outcrop area south of Keene, the lower limestone has pinched out and the equivalent of the upper limestone (0.6 foot thick) overlies 2.1 feet of fossiliferous shale. The lower bed of limestone is generally medium hard and gray brown. It weathers in small and irregular blocks that fracture into small chips. In the NW¼NE¼ sec. 36, T. 14 S., R. 11 E., the lower part of this limestone contains clay nodules. The intervening bed of shale is silty, tan gray to gray, and calcareous. In the eastern part of Townships 11 and 12 of Range 10 this bed is mainly a clay shale. In a few places it grades into the overlying limestone.

The upper bed of limestone is soft to medium hard, somewhat dolomitic, gray brown to tan, and weathers into small and irregular blocks that decompose further into small chips. (See pls. 3, 10.)

The Burr ranges in thickness from 2.7 feet south of Keene to 9.6 feet near Alma. This member thickens in the northwest, even though it is relatively thin in a small area about 2 miles northwest of McFarland. The upper limestone ranges in thickness from 1.1 feet north of Hessdale to 4.4 feet northwest of Alma; the intervening shale ranges from 0.2 foot north of Alma to 3.6 feet northeast of that city; and the lower bed of limestone ranges from a featheredge in the east-central part of the county to 4.2 feet northwest of Alma. (See pl. 10 and measured sections 33–36.)

The Burr contains a diagnostic fauna that is helpful in its identification. Iron-stained pelecypods are generally in the lower bed of limestone; but bryozoans, echinoids, brachiopods, fusulinids, crinoids, and high-spiralled gastropods are local occurrences. In the northeastern outcrop area the only fossils seen in the shale bed are fusulinids and thin-shelled brachiopods. The upper limestone beds contain a few crinoids, pelecypods, echinoids, and brachiopods. Ostracodes were seen only in the upper part of this bed where they often form a 0.3- to 0.5-foot crust at the top.

The Burr limestone member because of its softness was not sampled as a construction material. Along U. S. Highway 40, it was used as part of a fill. Seeps are locally present at the top of this limestone.

SALEM POINT SHALE MEMBER

The Salem Point shale member was named by Condra and Busby (1933, p. 10) after exposures in road cuts at Salem Point which is 1½ miles northwest of Salem, Richardson County, Nebr. This shale is well exposed in the northern and central parts of Wabaunsee County, but toward the south it is generally covered with colluvium.

The Salem Point consists of beds of shale and, in some places, of 1 or more thin beds of impure limestone. The beds of shale are silty, gray to tan gray, and thin bedded, or clayey, gray, green to olive drab, and blocky. From a point 2.5 miles north of Alma there is a bed of impure limestone about 0.8 foot thick in the middle of this member that extends 7 miles to the southwest. In the outcrop area east of Alma this limestone pinches out. Thin lentils of shaly limestone, however, are present in the lower part of this shale in the NE¼SE¼ sec. 30, T. 12 S., R. 12 E. A distinguishing feature of the Salem Point shale member is the many small calcareous plates that cover the surface (pls. 3 and 10). This feature was also noted in Riley County (Mudge, 1949, p. 63).

The Salem Point ranges in thickness from 4.2 feet southeast of Alma to about 9.7 feet west-northwest of Paxico. This shale attains its greatest thickness (9.7 feet) about 4 miles north of Keene, in the vicinity of Hessdale, and in the area southwest and north of Alma. In the area southwest and southeast of Paxico the Salem Point is 5.7 feet thick. (See pl. 10 and measured sections 33–36.)

No fossils were observed in the Salem Point.

The Salem Point was not tested for a construction material; it has been used locally as a fill material.

NEVA LIMESTONE MEMBER

The Neva limestone member is better exposed, because of its thickness and hardness, than either of the other two limestone members of the Grenola limestone. Condra and Busby (1933,

p. 5 to 7) have adequately reviewed the naming and early descriptions of the Neva. Prosser (1902, p. 709) named the Neva limestone from exposures near the junction of Diamond Creek and Cottonwood River valleys in Chase County, Kans. The original designation of this type section included the origin of the name, which is from the Neva railroad station on a line of the Atchison, Topeka, and Santa Fe Railway between Strong City and Elmdale in Chase County. The Neva station has been moved since this limestone was named. The Neva is well exposed in Wabaunsee County; a typical section is in a road cut in the NE¼SE¼ sec. 27, T. 11 S., R. 10 E., about 2.5 miles north of Alma.

The Neva limestone member generally consists of three beds of limestone separated by thin beds of shale. In many exposures, however, there are 4 beds of limestone and 3 beds of shale. The additional beds of limestone and shale appear in the lower part of the member and apparently are a facies of the middle bed of limestone. The upper bed of limestone ranges from 0.6 to 2.9 feet in thickness and is usually gray brown. It is medium hard and in the upper part contains a few small areas of very dense limestone. This bed generally weathers into irregular blocks, but is very platy in the upper part. The shale beneath this bed of limestone is silty, calcareous, and gray. It overlies a massive limestone bed that is referred to here as the middle limestone. The middle limestone is generally soft to medium hard, gray brown, very porous, and ranges from 8.2 to 10.8 feet in thickness. In many exposures large cavities give it a rotted appearance. These cavities are irregular and generally are lined with calcite crystals. In some of these exposures there are many thin lentils of very calcareous shale. Nodular fragments of limestone are in the upper part of this bed in the NW¼SW¼ sec. 30, T. 12 S., R. 10 E. Jewett (1941, p. 54) described this limestone as brecciated in Riley County. The lower part of this bed generally contains a silty, calcareous, tan-gray shale that attains a maximum thickness of 1.8 feet. Where this shale is exposed, it is underlain by a bed of limestone about 1.2 feet thick which is very similar lithologically to the rest of the middle limestone.

The lower bed of shale is persistent throughout the outcrop area. It is usually silty, calcareous, tan gray, and thin bedded. It ranges in thickness from 0.4 foot to 3.9 feet, but averages 1.7 feet thick. In the SE¼NW¼ sec. 31, T. 12 S., R. 10 E., there is a 0.2-foot bed of impure limestone in the middle of this shale. The lower limestone is also persistent over its outcrop area and ranges from 1.1 to 1.8 feet in thickness. This limestone is medium hard, tan gray, weathers into small and irregular blocks and commonly appears shaly in the lower part. Rarely, it contains a very thin calcareous bed in the lower part (pls. 3 and 10).

The Neva ranges in thickness from 13.8 to 16.7 feet, but is generally about 16 feet thick. (See pl. 9 and measured sections 30 and 32–36.)

The Neva contains a variety of fossils that aid in its identification. The upper bed of limestone contains algae, brachiopods, pelecypods, and fragments of bryozoans and echinoids. Fragments of brachiopods are generally present in this bed of limestone. These fragments are often very abundant in the lower part, thus giving it a coquinoidal appearance. The upper shale generally contains fusulinids, echinoid spines, and brachiopods. The echinoid spines are diagnostic. The middle limestone is characterized by echinoid spines and crinoid columnals, and in a few places it contains small corals, fusulinids, and trilobites. In the NE¼SE¼ sec. 17, T. 13 S., R. 11 E., ostracodes are present in the upper part of this bed. Fusulinids, brachiopods, and algal(?) deposits are common in the lower part of this bed. The lower shale contains brachiopods, crinoid columnals, and many fusulinids. In some places a similar fauna is in the lower limestone. Many of the fossils are restricted to certain zones, especially within the beds of shale. Those that are in zones are *Crurithyris*, linguloids, and fusulinids.

The results of laboratory tests on 4 samples of the Neva are given in table 1 (ls. 15, ls. 24, ls. 43, and ls. 46). The tests performed on this limestone indicate that most of it is acceptable for use as an aggregate for bituminous surface course, for bituminous concrete and sheet asphalt surfaces, for cover material, coarse aggregate for concrete, for binder soil stabilized course, and crushed stone for surfacing. The second sample of ls. 24 was unsound and was not accepted as a general-purpose aggregate.

The Neva was quarried in the NE¼SW¼ sec. 19, T. 11 S., R. 9 E., and was used as a road metal on the county road which extends 6 miles south from Wabaunsee (pl. 8, locality 15). Although many small quarries have been established in this limestone, this is the only location where it has been used as a road metal.

The chief use of this limestone has been as a structural stone in civic buildings and in houses in residential districts in Eskridge and Alma, and in rural schoolhouses and farmhouses. In 1890 a schoolhouse was constructed in the NE¼ sec. 11, T. 12 S., R. 12 E., and nearly all of the stone in this building is of the Neva limestone. The larger blocks used as trim stone, are from the Cottonwood limestone member of the Beattie limestone. Pitting is noticeable in some of the blocks of the Neva. Other schoolhouses built during the years 1883-1891 are constructed almost entirely of the limestone of the Neva; they are in the SW¼NW¼ sec. 20, T. 12 S., R. 12 E.; SE¼SW¼ sec. 16, T. 10 S., R. 10 E.; and SE¼SE¼ sec. 17, T. 13 S., R. 11 E. In buildings at Eskridge and Alma certain blocks of limestone of the Neva have been fractured by freezing and thawing.

The Neva has been used in small quantities as wash check in the spillway at Lake Wabaunsee. Limestone of the Cottonwood and of part of the Threemile was also used; in fact, most of the riprap on both faces of the dam and in the spillway are blocks of limestone from the Threemile limestone member of the Wreford limestone. In the retaining wall of the lower splash pool, the blocks of limestone from the Threemile limestone member have been exfoliated by freezing and thawing. The many undamaged blocks are from the Neva limestone member. The upstream face of the spillway has failed because the unsound limestone of the Threemile was used as a lining. Within a two-year period most of the lining and much of underlying shale has been eroded.

The Neva is used in a double arch bridge in the NW¼SE¼ sec. 30, T. 12 S., R. 10 E. The bridge was constructed in 1891, but was partly rebuilt in 1946 and again in 1951 after serious flood damage. The blocks of the Neva in this bridge apparently cannot withstand prolonged weathering.

The outcrop area of the Neva is shown in plate 1. North of Alma and southeast of Paxico there are good quarry sites with 6 feet or less of overburden. Small quarries can also be established in a few other places in the outcrop area.

The Neva is regarded as one of the best limestone aquifers in this area. The many springs and seeps along much of its outcrop area emerge mainly from the middle bed of limestone.

The upper and lower beds of the Neva may break excessively during excavation.

ESKRIDGE SHALE

The Eskridge shale is the most brightly variegated shale cropping out in the county. This shale was named by C. S. Prosser in an unpublished manuscript, according to Beede (1902, p. 181). The type locality is in the vicinity of Eskridge, Wabaunsee County, Kans. An exposure of the upper half of this shale is about 1⅛ miles south of Eskridge in the SW¼NW¼NW¼ sec. 17, T. 14 S., R. 12 E., and is probably the type section. An exposure of a complete and more representative section of this formation is in a road cut in the NE¼SE¼ sec. 27, T. 11 S., R. 10 E. The Eskridge shale overlies the Grenola limestone and underlies the Beattie limestone.

The Eskridge is mainly a silty shale even though clayey beds are common (pl. 11). It is a variegated shale with green and gray green predominant. In most of the county the upper part of this shale is gray green, but in the northern part maroon and purple beds interfinger with the green beds. The middle part of the formation is mainly a maroon shale that in some places is mottled and interbedded with green shales. In the north, this part of the formation contains green beds. In the southern outcrop area it grades southward into purple, green, and gray beds. The lower part of the formation contains purple, green, gray-green, and maroon beds of shale. Beds of purple shale persist in the central outcrop area but in the north they grade into green shales and in the south into maroon shale. Green and gray green is generally dominant in the lower part.

In this formation there are generally 2 and sometimes 3 beds of limestone (pl. 11). The uppermost bed generally lies about 10 feet below the Cottonwood limestone member of the Beattie limestone. This bed is gray, hard, and contains small lentils that are dense and very fine grained. It weathers into blocks a few inches in diameter, that has a hackly fracture. The middle bed of limestone is mainly hard, gray and dense. It weathers into small blocks and plates. In the northwestern part of the county and in the area 1 mile south of Eskridge the upper part of this limestone is conglomeratic; it contains rounded to angular fragments of carbonate and siliceous limestone—some a maximum of 1½ inches in diameter. In the southern outcrop area a thin bed of shale is present in the middle bed of limestone. The lower bed of limestone is not as persistent as the other two beds. In fresh exposures this limestone is gray, hard, dense and, in a few places, crystalline. It normally weathers into irregular plates and porous blocks, it averages about 0.6 foot in thickness.

In the southern part of the county in the SW¼NW¼NW¼ sec. 36, T. 14 S., R. 11 E., a bed of impure coal 0.3 foot thick lies about 15 feet beneath the Cottonwood (pl. 11). A similar bed of coal in this formation was found in Lyon County by O'Connor (1953, p. 11). A bed of coal is present in the upper part of this formation in Morris County (Mudge, Matthews, and Wells, 1958, p. 10).

The Eskridge shale averages 34.5 feet in thickness. It thickens from 32.6 feet in the northern outcrop area to 38 feet in the south-central part of the county. The general trend of the thickening of this shale is to the southwest. (See pl. 11 and measured sections 25 and 29–34.)

Fossils are found only in the upper and middle beds of limestone. Microfossils are generally in the upper part of the upper limestone; and thin lentils throughout the middle limestone. These lentils of minute fossils give the limestone bed a flaggy appearance. Toward the south, pelecypods were seen in both the upper and middle beds of limestone.

The Eskridge shale was not tested for a construction material. In the center of sec. 26, T. 11 S., R. 10 E., and NW¼ sec. 4, T. 14 S., R. 11 E., it has been used as a fill material. At both places most of the Eskridge is a silty shale. The seeps in this shale are normally at the base of the beds of limestone, but may emerge at the lower contact of a silty shale that overlies a clayey shale.

BEATTIE LIMESTONE

The classification of the Beattie formation was first published by Condra and Busby (1933, p. 13) although this classification had been unofficially proposed by the Kansas Geological Survey. The formation thus defined includes, in ascending order, the Cottonwood limestone member, Florena shale member, and Morrill limestone member. The type locality is at Beattie in Marshall County, Kans. (Condra and Busby, 1933, p. 13). The Beattie limestone is well exposed along its outcrop. The average thickness of Beattie is about 20 feet.

COTTONWOOD LIMESTONE MEMBER

The Cottonwood was studied by many of the early workers in Kansas. According to Jewett (1941, p. 57) this limestone has been referred to as the "Cottonwood stone," "Cottonwood Falls limestone," "Cottonwood formation," "Cottonwood shale" and "Manhattan stone." It was named the Cottonwood Falls limestone by Haworth and Kirk (1894, p. 112–114) after exposures near Cottonwood Falls in Chase County, Kans. Prosser (1894, p. 37–41) named it the Cottonwood formation and included the overlying beds of shale which were called the Cottonwood shale. Prosser (1902, p. 712) renamed the overlying shale the Florena, and described the Cottonwood as the limestone bed overlying the Eskridge shale and underlying the Florena shale (table 2). In Wabaunsee County this limestone forms a conspicuous hillside bench in most of its area of outcrop. It is well exposed in a road cut in the NE¼SE¼ sec. 27, T. 11 S., R. 10 E., and at the south end of Lake Wabaunsee in a road cut in the NW¼NE¼ sec. 9, T. 14 S., R. 13 E.

The Cottonwood limestone member generally consists of a hard massive bed of limestone in the upper part and a thin bed of soft limestone underlying a thin bed of calcareous shale in the lower part. They are tan gray to light gray, and fine grained. There are 2 or 3 thin bands of chert nodules in the middle part, and nodules of chert are present throughout the rock. (See pl. 12A.)

Solution channels are common and some are a maximum of 12 inches in diameter. This limestone generally contains many small pores and pits. Some of the pits are the result of the weathering of the fusulinids. In some places the exposed surface is given a bedded appearance where the massive part of the Cottonwood fractures into 3 or 4 distinct beds. The Cottonwood develops a very conspicuous hillside bench characterized by massive light-gray limestone blocks and locally by a persistent growth of bushes at the base of the outcrop. (See pls. 3, 5, 11, and 12B.)

The Cottonwood ranges in thickness from 4.1 feet in the northwestern part of the county to 8.8 feet south of Paxico (pls. 3 and 11). The maximum thickness of this limestone is in the area south of Paxico and southwest of Hessdale (pl. 11). It is very thin in the northwestern part of the county, southwest of Alma, and south of Eskridge. (See measured sections 25 and 28–33.)

The fauna of the Cottonwood limestone member is quite distinctive and contributes greatly in making this limestone a key bed. Fusulinids, which are abundant in the upper 2 or 3 feet of this limestone, are less common in the lower half of the bed which also contains a few brachiopods, bryozoans, crinoid columnals, and small corals. The corals are generally restricted to a zone near the middle of the bed. The abundance of fusulinids was noted by Meek and Hayden (1859, p. 16–18) in their bed no. 22, who reported that this was the youngest limestone containing fusulinids. Jewett (1941, p. 75) reported fusulinids in rocks as young as the Florence limestone member of the Barneston limestone.

The Cottonwood limestone member is the most extensively quarried limestone in Wabaunsee County (pl. 2). At least part of this limestone is used as a construction stone in engineering projects. It has been used in the construction of buildings, roads, abutments, piers, and retaining walls, and as riprap, wash check, and as a concrete aggregate. The locality and test results of the samples obtained from this limestone in Wabaunsee County are listed in table 1 (ls. 9, 10, 17, 20, 25, 26, 27, and 42). Although the Cottonwood is one thick bed that apparently does not vary lithologically along its outcrop; its test characteristics are not constant. This limestone was sampled at 8 different places in Wabaunsee County; samples number 9, 17, 27, and part of 42 were rejected as construction stone. The other samples (10, 20, 25, 26, and part of 42) were accepted for many uses, including coarse aggregate for concrete.

Many of the county roads have been surfaced with crushed limestone quarried from this member and are numbered 2, 14, 16, 19, 20, and 21 on plate 8. The performance of this limestone as a road metal is good, but it is moderately hard and tends to become subrounded after a short period of use. The abrading of the fragments of limestone contributes a large quantity of clay and silt to the road; thereby causing the roads surfaced with this limestone to dust excessively. The 2½ miles of county road number 14 that extends east from Kansas Highway 99 and county roads 13 and 14 which extend north from Paxico are surfaced with a combination of crushed limestone and sand and gravel. The performance of this combination of road metal is better. The sand and gravel fills the voids between fragments of limestone and act as a binder material. Surface wash, even on hillsides, is greatly reduced, and dusting appeared to be at a minimum. Washboards, common on roads surfaced only with sand and gravel, are absent.

In Wabaunsee County, the Cottonwood has been used extensively as a structural stone. As mentioned on page 68, the Cottonwood is used mainly as a trim stone and is generally a companion stone with the Neva limestone member because both of the limestones form conspicuous hillside benches and only 35 feet of shale separates them in the outcrop. Unlike the Neva, the Cottonwood is used in the construction of entire buildings. Most of the public buildings in Alma have been constructed of material from the Cottonwood. Near Alma and Eskridge, many houses, barns, and schoolhouses are of this limestone, but the Neva has also been used in some of the buildings.

The Cottonwood is little affected by weathering, and its appearance is generally a pleasing one. Its effectiveness as a building stone or as riprap depends mainly on how it is laid; that is, the stone must be so oriented that the surface of the bedding plane is the upper surface of the block.

Abutments, piers, and the span of a double-arch bridge in the NW¼SE¼ sec. 30, T. 12 S., R. 10 E., were constructed in 1891 of material from the Cottonwood and Neva. The Cottonwood has withstood weathering in all parts of the structure, but blocks of Neva in the abutments had to be replaced in 1946.

At Hessdale a 2-story schoolhouse built in 1881 and previously mentioned on page 69, has trim stone of the Cottonwood. It does not show any effect of weathering, and the edges of the stone are still quite angular.

The upper part of the spillway at Lake Wabaunsee in the center of NW¼ sec. 4, T. 14 S., R. 11 E., is cut into the middle of the Cottonwood which is 5 feet thick at that point, thus giving about 2½ feet of natural stone along each side. The limestone also provides a natural floor for the road across the spillway. It was necessary to install a concrete roadway in 1948 because the fractures in the limestone had widened to a dangerous extent. Grouting was necessary to reduce the seepage of water at the contact of the Cottonwood and underlying Eskridge shale. The Cottonwood has been used as structural stone in the two bridges at the south and east ends of the lake, and in small quantities as riprap on both faces of the dam. When used as randomed-placed riprap, this limestone does not appear to withstand freezing and thawing as well as blocks of the Neva.

Between Alta Vista and Alma, the Cottonwood has been used as riprap on railway embankments. It was quarried in the NW¼ sec. 30, T. 12 S., R. 10 E., and was originally used as a structural stone in the Rock Island railroad station at Topeka, Kans. In recent years the station was replaced and the stone is now used as riprap.

A sample of the Cottonwood limestone member tested for use as agricultural lime was obtained from a quarry in the SE¼ sec. 33, T. 13 S., R. 11 E. This lime was a byproduct of the crushed rock that was quarried for road metal. (See ls. 42, table 1.) Wendell Becroft (written communication) stated that the cumulative average of five samples from this quarry show 96 percent passing through a no. 8 screen and 26 percent through a no. 100. It has a $CaCO_3$ content of 85.7 percent, which is acceptable by the standards of the U. S. Production and Marketing Administration. He also stated that the gradation percentage is entirely dependent on the efficiency of the crushing equipment and screening facilities which the producer has available. Where the agricultural lime is a byproduct, the $CaCO_3$ content reported does not reflect the correct calcium content of the principal rock; the byproduct includes fragments of all material that went through the crusher. Because the associated rocks are low in calcium carbonate, it is assumed that the correct $CaCO_3$ content of the Cottonwood is more than 85.7 percent. In Wabaunsee County the demand for agricultural lime has not necessitated quarrying a limestone specifically for this use; the lime has always been a byproduct of crushed rock for road metal.

In the county there were about 30 individual quarries seen in the Cottonwood and these are located on plate 2. Plate 1 shows the outcrop of the Cottonwood and the quarry sites that can be established for quantities of 10,000 or more cubic yards under moderate overburden. South of Alma, in the eastern half of T. 13 S., R. 10 E., and south of Paxico in the center of sec. 22, T. 12 S., R. 11 E., the Cottonwood is 8 feet or more thick. (See measured sections 28–31.) Insofar as the thickness of the bed is concerned these two areas are probably the most suitable for quarries.

The Cottonwood is one of the best limestone aquifers in the region. Many of the springs at the base of this limestone serve as a source of water for livestock. The bush line at the base of this member indicates many of these seeps.

FLORENA SHALE MEMBER

The Florena shale was included in the Cottonwood formation by Prosser (1894, p. 37–41). Prosser (1902, p. 712–713) named this shale the Florena, and listed it in the Garrison formation which included all the beds from the base of the Wreford limestone down to the top of the Cottonwood limestone. Condra (1931, p. 6 and 7) discarded the Garrison formation and classified its units as part of the Council Grove group. He retained the rank of member for the units in this group. Condra and Busby (1933, p. 13) grouped the Cottonwood limestone, Florena shale, and Morrill limestone as members under the Beattie formation. The type section of this member is exposed in a quarry near Florena in the Blue River valley of Kansas (Prosser, 1902, p. 712).

The Florena consists of beds of shale that are generally tan to tan gray and silty. Toward the west, it is mostly dark gray and clayey. Usually the upper part is clayey, blocky, gray to gray green, and nonfossiliferous. The lower part which is thin-bedded and mainly a silty shale is almost always fossiliferous. It is apparent that an increase in clay content in this bed is directly related to the fauna and quantity of fossils. In areas where this bed is highly plastic, fossils are rare or absent; but they apparently increase in number and genera as the silt content increases. (See pls. 3, 12.)

The Florena shale member averages 8.6 feet in thickness. Near Eskridge it is 10.7 feet thick, but about 5 miles south of Paxico it has a minimum thickness of 6.9 feet. About 2 miles east of Alma the Florena is 9.5 feet thick, but thins in all directions from that point. (See pl. 11 and measured sections 25 and 28–30.)

The basal 2 feet of the Florena is generally very fossiliferous, but in some places the member is sparsely fossiliferous to nonfossiliferous. The fauna consists of brachiopods, bryozoans, fusulinids, crinoid columnals, and trilobites. The brachiopod *Chonetes* sp., is very abundant in this shale.

The Florena shale member has not been used as a construction material. It may be suitable as a fill material.

MORRILL LIMESTONE MEMBER

The Morrill limestone was named by Condra (1927, p. 234) for the beds of limestone overlying the Florena shale and underlying the Stearns shale (table 2). The type locality is 2 miles northwest of Morrill in Brown County, Kans. The beds were originally part of the Neosho member of the Garrison formation (Prosser, 1902, p. 712) that was later subdivided by Condra (1927, p. 234). Condra and Upp (1931, p. 17–18) stated that the type section was no longer exposed, but this limestone is exposed half a mile north of the type locality and east of a north-south road in the northwestern corner of sec. 27 and the southwestern corner of sec. 22, T. 1 S., R. 15 E.

The Morrill limestone member generally consists of 2 thin beds of limestone separated by a bed of shale (pl. 11). The limestone is medium hard, tan gray to gray brown, and in some places has wavy banding. The lower bed of limestone contains minute iron specks in a few places, and chert nodules are common in the upper part of the lower bed in the SE¼NE¼NW¼ sec. 32, T. 11 S., R. 10 E. The upper bed of limestone is softer than the lower bed. Both of the beds weather in small porous cavernous blocks that are locally platy. In both of the limestones, secondary calcite and quartz fill many of the pore spaces. The shale is calcareous, silty, tan gray, and thin bedded to blocky. It generally contains thin calcareous lentils.

In the southeastern part of the county the Morrill is a succession of thick beds of massive limestone separated by many thin partings of shale. Near Eskridge, however, this member is very platy and its weathered surface resembles that of the Crouse limestone. (See pl. 11.)

The Morrill is of variable thickness. In the southern outcrop area it is 7.5 feet thick; it thins northwestward to between 3.3 feet and 5 feet northwest of Alma. The lower limestone ranges in thickness from 5.9 feet to 0.5 foot; the shale bed is generally 1.2 feet thick and the lower limestone bed averages 1.8 feet. (See pl. 11 and measured sections 25 and 27–30.)

There are a few microfossils and pelecypods near the base of the lower bed of limestone. The bed of shale and upper bed of limestone are barren. The Morrill was not sampled for a construction material and has not been used for that purpose. The lower limestone where exceedingly thick is soft and very porous.

STEARNS SHALE

The Stearns shale was named by Condra (1927, p. 234) to include the shale between the Eiss and Morrill limestones (table 2). The type locality is south of Stearns school at a point 1½ miles east of the north edge of Humboldt, Nebr. (Condra, 1927, p. 234). Condra and Upp (1931, p. 18) state: "The section at the type locality is now obscured but the member is typically exposed along a north-south road 6 miles south and 1½ miles east of Humboldt." Condra (1935, p. 7) discarded the Garrison formation and listed the Stearns shale as a formation.

In Wabaunsee County it is well exposed in road cuts in the NE¼NW¼NW¼ sec. 23, T. 13 S., R. 10 E.; SW¼SE¼ sec. 4, T. 12 S., R. 10 E.; SE¼NE¼SW¼ sec. 24, T. 13 S., R. 11 E.; and in the SE¼SW¼ sec. 4, T. 14 S., R. 11 E.

The Stearns is mostly shale, but it generally contains a thin bed of impure limestone in the middle part, and, in a few places, in the lower part. The beds of shale are mainly silty, thin bedded and tan gray to gray, but in some exposures they are gray green in the upper part. In a road cut about 4 miles west of Hessdale in the NE¼NW¼NW¼ sec. 23, T. 13 S., R. 10 E., a thin lens of coal is present in the upper part of this formation. Northwest of Alma a carbonaceous bed of shale at the same horizon has thin calcareous lentils that contain fragments of wood. The middle limestone is medium hard to soft, and grades laterally into a claystone or, in some areas, into a cavernous shale. This limestone, which is gray and weathers into irregular blocks and plates, contains small cavities lined with calcite and quartz. Thin calcareous lentils are generally present in the upper beds of shale. The lower bed of limestone lies a few feet above the Morrill. It is very lenticular and generally grades laterally into a claystone before pinching out. It is gray, dense, and weathers into irregular blocks. (See pl. 3 and measured sections 16, 25, 27, and 28.)

The Stearns shale ranges in thickness from 18.3 feet 4 miles west of Hessdale to 10.2 feet at the south end of Lake Wabaunsee—a loss in thickness of about 8 feet in 5 miles. Elsewhere in the county the Stearns shale ranges from 13.1 to 14.8 feet in thickness.

Below the lens of coal there is a thin bed of shale that contains ostracodes. Microfossils are locally present in the bed of limestone and in calcareous lentils.

The Stearns shale has not been used as a construction material. In places, small seeps are present at the base of the beds of limestone.

BADER LIMESTONE

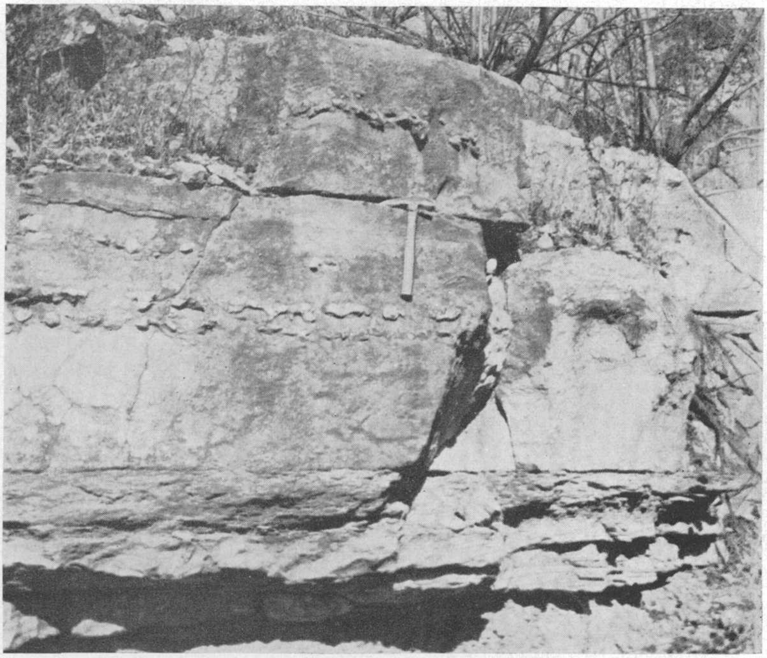
The Bader limestone was named by Moore, Elias, and Newell (1934) as a formation containing the following members which are, in ascending order, the Eiss limestone member, Hooser shale member, and Middleburg limestone member (table 2). Its type exposure is near Bader in Chase County, Kans. (Jewett, 1941, p. 61). The beds that are now part of the Bader limestone were formerly part of the Neosho shales of the Garrison formation as defined by Prosser (1902, p. 712). The Bader limestone overlies the Stearns shale and underlies the Easly Creek shale (pls. 3 and 13). The Bader limestone averages 21 feet in thickness.

EISS LIMESTONE MEMBER

The Eiss limestone was named by Condra (1927, p. 234) who included it as a member of the Garrison formation. Condra (1935, p. 7) discarded the Garrison formation and in redefining its units included the Eiss limestone as a member of the Bader limestone. The type exposure of this member (Condra and Upp, 1931, p. 19) is on the Eiss farm 8 miles south of Humboldt, Nebr., in the SE¼ sec. 3, T. 1 N., R. 13 E.

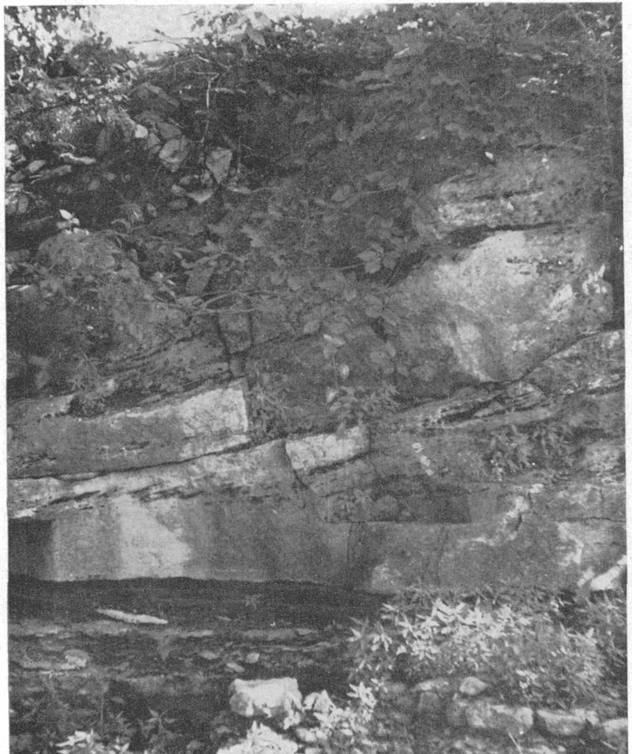
The Eiss generally consists of two beds of limestone and a thin bed of shale. The lower limestone weathers blocky and is generally medium hard and gray, but in the northeastern corner of T. 13 S., R. 11 E., and in the southeastern corner of T. 13 S., R. 10 E., this limestone contains a thin bed of gray silty shale. About 1 mile north of Hessdale there is a very calcareous shale with a thin bed of limestone in the upper part that is probably the lateral facies of the lower limestone. The upper limestone is generally a single bed of limestone, but in the areas cited above and in the northwestern part of the county a thin bed of silty to clayey shale is in the lower part. The upper limestone is gray, hard, and contains thin irregular zones of very dense rock. This limestone generally fractures into porous irregular-shaped blocks 1 foot or more in diameter that in most places are scattered over the outcrop. These porous blocks of limestone aid in identifying the moderate hillside bench formed by this member. The intervening bed of generally silty shale is gray, calcareous, and thin bedded; in a few places it contains thin calcareous lentils and lenses of limestone. (See pl. 13.)

The Eiss averages 10.9 feet in thickness. In the northeast corner of T. 13 S., R. 11 E., it is 15 feet, but thins to the south and west. About 6 miles southwest of Alma it is only 6.4 feet thick. Over most of the outcrop area the lower bed of limestone averages about 2.2 feet in thickness, but near Hessdale and southwest of that town, it thickens to about 4 feet. The upper bed of limestone which ranges from 1.8 to 4.2 feet in thickness, attains its maximum thickness in the eastern outcrop area and its minimum thickness in the western outcrop area. The intervening bed of shale ranges in thickness from 1.4 feet to 7.9 feet; its minimum thickness is in the northwestern corner of the county and the maximum is about 5 miles west of Eskridge. (See pl. 13 and measured sections 16 and 24–28.)



A. Cottonwood limestone member of Beattie limestone exposed in road cut in the center of sec. 12, T. 12 S., R. 10 E., Wabaunsee County, Kans.

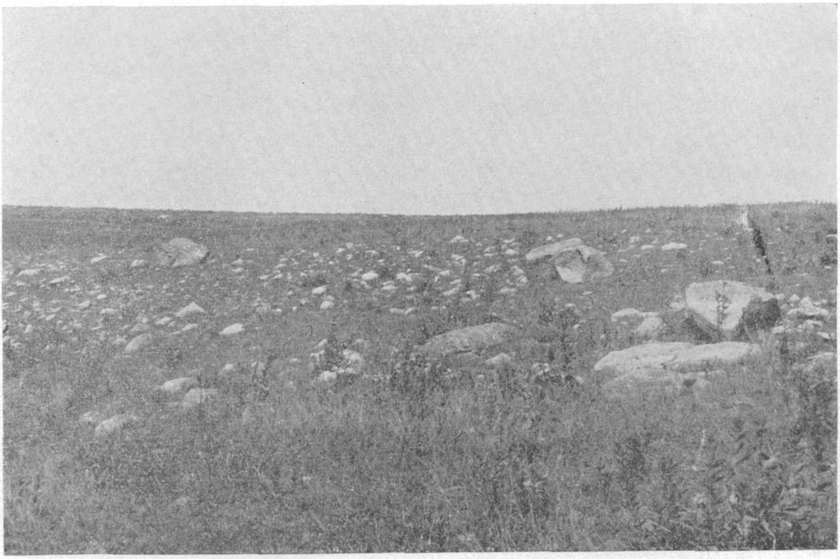
B. Typical outcrop of the Cottonwood limestone member of the Beattie limestone in the NW¼NE¼ sec. 9, T. 14 S., R. 11 E., Wabaunsee County, Kans.



A. Oolite beds in Funston biostrome in a streambank in the NE¼NW¼ sec. 24, T. 13 S., R. 9 E., Wabaunsee County, Kans.

B. *Somphospongia?* sp., in beds of limestone that flank the biostrome in the Funston limestone in the SE¼NE¼ sec. 9, T. 12 S., R. 9 E., Wabaunsee County, Kans.

A biostrome in the Threemile limestone member of the Wreford limestone exposed in a streambank in the SW¼SE¼ sec. 26, T. 13 S., R. 9 E., Wabaunsee County, Kans.



A. Glacial boulders and till in the SW¼ sec. 1, T. 11 S., R. 10 E., Wabaunsee County, Kans.

B. Yarmouth silt and clay impregnated with calcium carbonate and overlain by loess of Loveland silt member of the Sanborn formation in a streambank in the SW¼ sec. 22, T. 14 S., R. 12 E., Wabaunsee County, Kans.

The fauna of the Eiss limestone member is distinctive and helps to identify this unit. The lower bed of limestone contains brachiopods, crinoid columnals, bryozoans, and a few pelecypods, gastropods, and echinoid spines and plates. The brachiopod, *Derbyia* sp., is generally abundant, in this bed. Fusulinids are present in the eastern outcrop area. The upper bed of limestone contains a pelecypod fauna; there are a few brachiopods, gastropods, crinoid columnals, fusulinids, and microfossils. In the northern part of the county this bed is composed primarily of clusters of partly silicified pelecypods.

The upper bed of the Eiss was sampled (table 1, ls 19) for a construction material. It may be acceptable as an aggregate for bituminous surface course, for bituminous concrete and sheet asphalt surfaces, for bituminous retread surface and bituminous drag treatment, for surfacing, and for crushed stone base course (keyed type). The Middleburg limestone member forms a moderate hillside bench and is separated from the Eiss by a few feet of shale. The overburden of shale and Middleburg would probably restrict quarrying of the Eiss to a narrow zone along its outcrop. This limestone has not been quarried in Wabaunsee County. A few small seeps are at the base of the beds of limestones—especially the upper bed.

HOOSER SHALE MEMBER

The Hooser shale was named by Condra and Upp (1931, p. 20). It was formerly a part of the Garrison formation as defined by Prosser (1902, p. 712) and of the Easly Creek shale (Condra, 1927, p. 233–234). The Easly Creek shale as defined by Condra included the beds from the top of the Eiss limestone up to the base of Speiser shale. Condra and Upp (1931, p. 19 and 20) restricted the Easly Creek shale to those beds between the Bader and Crouse limestones (table 2). The type locality of the Hosser shale is a highway cut and ravine just east of Hooser in Cowley County, Kans. (Condra and Upp, 1931, p. 20). In Wabaunsee County a representative exposure of this member is in a road cut in the SE¼SW¼NW¼ sec. 36, T. 13 S., R. 10 E.

The Hooser shale member is mainly a variegated shale but locally contains a few thin beds of limestone (pl. 13). It is clayey only in the lower 2 feet, but the rest is silty. Most of the exposures of the member contain the following sequence of variegated beds which are in ascending order, gray green with a thin band of purple in the upper part; maroon; gray, and gray green that changes to tan gray in the upper part. North of Eskridge the lower half of the member is primarily a maroon shale with a thin purple bed in its upper part. About 1 mile east of Lake Wabaunsee this member consists of gray to tan-gray shale beds with a thin bed of limestone in the middle part. The bed of limestone is hard, dense in part, and tan gray. About 2½ miles east of Alma there is a thin soft lenticular bed of argillaceous limestone in the lower part of this shale. In the northwest outcrop area a thin persistent argillaceous bed of limestone is present in the upper part of the Hooser shale. (See pls. 3 and 13.)

The Hooser ranges in thickness from 5.5 feet in the northwestern part of the county to 15.2 feet in the middle of the county. It thins southward and southeastward, and about 1 mile northwest of Alma it is 9.4 feet thick. (See pl. 13, and measured sections 16, 24, and 25.)

Brachiopods, pelecypods, and some microfossils, which were the only fossils observed in the Hooser, are present in this limestone bed.

The Hooser has been used locally as a fill material. This shale was not sampled and tested, but its silty beds probably make it suitable for fill material. There are no springs or seeps noted in the Hooser shale.

MIDDLEBURG LIMESTONE MEMBER

The Middleburg limestone, named by Condra and Upp (1931, p. 20), was formerly a bed of limestone in the Garrison formation. In 1927 Condra (p. 233–234) discarded the Garrison formation and established the Easly Creek shale which included the limestone beds now called the Middleburg limestone member. Moore, Elias, and Newell (1934) established the Middleburg limestone as a member of the Bader limestone. The type locality is on Easly Creek 1½ miles south of Middleburg school in the eastern quarter of sec. 36, T. 1 N., R. 13 E., Richardson County, Nebr. (Condra and Upp, 1931, p. 20).

The Middleburg limestone member generally consists of two beds of limestone separated by a thin bed of shale (pls. 3 and 13). Only the lower bed of limestone is persistent; it is medium hard and gray, but weathers into blocks that have a shaly appearance. It forms a small hillside bench. The upper limestone is absent in the eastern outcrop area, and is split by a thin bed of shale where it crops out in the rest of the county. This bed is medium hard to soft and tan to tan gray; it weathers into irregular porous plates, and generally has a shaly appearance, an iron-stained surface, and a few spots of iron stains within the bed. The intervening bed of gray calcareous clayey shale is silty in a few places (pl. 13).

The lower bed of limestone in the Middleburg, which ranges from 5.6 to 8.6 feet in thickness, averages about 2.5 feet. However, about 2 miles east of Lake Wabaunsee it is 4.4 feet thick. The upper bed of limestone ranges in thickness from 0.2 to 3.4 feet, but is seldom more than 0.5 foot thick. The intervening bed of shale ranges from 1.5 to 3.4 feet in thickness. East of Lake Wabaunsee, where the shale has its maximum thickness, the upper fossiliferous part probably represents a shale facies of the lower part of the upper limestone. (See measured sections 16, 24, and 25.)

The Middleburg has a characteristic fauna that aids in identifying this member. This fauna is especially conspicuous in the lower bed of limestone. It contains brachiopods and pelecypods, but the most significant fossil is a small high-spiralled gastropod. This gastropod is generally very abundant throughout the limestone. Locally, the upper bed of limestone contains brachiopods, pelecypods and microfossils. In the area east of Lake Wabaunsee the shale bed contains pelecypods.

The lower bed of the Middleburg was sampled for use as a construction material and its test results are listed under ls 18 in table 1. The results of this test show that this limestone will withstand abrasion, but is suitable for use as riprap or wash check. The Middleburg has not been used as a construction material. Seeps or springs were not seen in this member, but the conspicuous iron stains on the upper bed of limestone indicate that some seepage occurs.

EASLY CREEK SHALE

The Easly Creek shale was named by Condra (1927, p. 234) who described it as a member of the Garrison formation and defined it as the beds from the top of the Eiss limestone to the base of the Crouse limestone. In 1931 Condra and Upp (p. 19) redefined the Easly Creek shale to include the beds between the Middleburg and Crouse limestones, and that is the classification used in this report (table 2). The type locality is in the NE¼ sec. 35, T. 1 N., R. 13 E., on Easly Creek about 10 miles south and 1¼ miles east of Humboldt in Richardson County, Nebr. (Condra and Upp, 1931, p. 19). In Wabaunsee County this formation is well exposed in road cuts in the SW¼SE¼ sec. 13, T. 12 S., R. 10 E., and in the SW¼SE¼ sec. 36, T. 13 S., R. 10 E.

The Easly Creek is a variegated shale that in a few places contains thin beds of limestone in its lower and upper parts and a bed of sandstone in its upper part. (See pls. 3 and 13.) The lower part of the shale is gray green with maroon lenses and the middle part is a maroon shale. Southwest of Hessdale, a 0.3-foot bed of purple shale overlies the maroon shale. The upper part of this formation is mainly a gray-green shale. The Easly Creek is mainly a silty thin-bedded to blocky shale that has a bed of sandstone in the upper part, but contains some beds of clayey shale in the southern and northeastern parts of the county. In the southern outcrop area the formation contains a bed of sandstone that trends northwestward. West of Lake Wabaunsee a sandy nodular limestone is at the same horizon; south of Lake Wabaunsee this sandstone is interbedded with a sandy shale, is very fine-grained, crossbedded, tan brown, and ripple marked. The beds of limestone that in places are in the upper and lower parts of this formation are medium hard, argillaceous, and gray. In the NW¼SW¼ sec. 33, T. 12 S., R. 11 E., the upper bed of limestone is conglomeratic; it consists of rounded to subangular nodules of limonite and lime that are as much as one-half inch in diameter.

The Easly Creek shale averages about 14.5 feet in thickness. Near Hessdale and between Lake Wabaunsee and Eskridge, this shale ranges from 10 to 12 feet in thickness, and elsewhere in the county is 14 to 18 feet thick. Its maximum thickness is in the southern and easternmost outcrop areas. (See pl. 13 and measured sections 16, 19, and 23–25.)

Fossils, which occur only in the conglomeratic limestone, are mainly fragments but some are complete specimens of pelecypods.

The Easly Creek shale was not sampled for a construction material, although it is used locally as a fill material. No seeps or springs were observed.

CROUSE LIMESTONE

The Crouse limestone was named by Heald (1917, p. 21–22). In 1927 Condra (p. 234) named these beds the Sabetha limestone, but Condra and Upp (1931, p. 21) discarded the name Sabetha when they discovered that it was correlative with Crouse. The Crouse limestone overlies the Easly Creek shale and underlies the Speiser shale. The type locality is Crouse Hill in the NE¼ sec. 23, T. 29 N., R. 6 E., about 2¼ miles west of Frankfort in Osage County, Okla. (Condra and Upp, 1931, p. 21). In Wabaunsee County the Crouse limestone is well exposed. (See pls. 3 and 13.)

The Crouse limestone consists of two limestones and a shale. The lower limestone is fine-grained, medium hard and gray. It fractures into irregular blocks in the lower part, but weathers to a shaly appearance in the upper part. About 1 mile northwest of Alma it contains a few limonite nodules and clay balls that have a maximum diameter of one-fourth inch. The intervening bed of shale is silty in the eastern outcrop area, and clayey in the western outcrop area. It is generally gray and tan gray and thin bedded. In the lower 1 foot the upper limestone contains a massive gray fossiliferous bed that weathers to small porous blocks. The rest of the upper limestone consists of many thin beds that weather into small plates. The lower part of the upper limestone forms a prominent hillside bench that is covered by thin limestone plates. This cover makes the Crouse bench easily identified in the field and on aerial photographs (pl. 5).

The Crouse limestone averages about 14 feet in thickness. The lower bed of limestone ranges from 1.1 to 3.3 feet thick; and the intervening bed of shale ranges from 6.6 to 11.3 feet in thickness; but averages about 8.0 feet. The upper bed of limestone ranges from 3.4 to 13.4 feet; the maximum thickness was measured in the western part of the county, and the minimum was observed in the central part. (See pl. 13 and measured sections 15, 16, 17, 19, 23, and 24.)

Fossils are more abundant in the lower part of the formation than in the upper part. A persistent fauna in the lower bed of limestone consists of pelecypods, crinoid columnals, brachiopods, and bryozoans. Locally, there are ostracodes, algal deposits, and small high-spiralled gastropods. In the southeastern area, brachiopods, pelecypods, bryozoans, and crinoid columnals are present in the lower part of the intervening shale. Generally they are only in the lower 2 feet of the shale but in some places they occur throughout the lower half of the shale bed. Pelecypods and microfossils in the upper limestone are generally restricted to the lowest bed. A few microfossils which are restricted to small zones, were seen in the platy part of the upper limestone. Bryozoans are abundant west of Lake Wabaunsee, and in a few other places.

The Crouse limestone was sampled for a construction material (table 1, ls. 11). It was accepted as an aggregate for concrete, bituminous surface course, bituminous concrete and sheet asphalt surfaces, cover material, bituminous retread-surface and bituminous drag treatment, and for surfacing.

Northeast of Volland in the NW¼ sec. 2, T. 13 S., R. 9 E., a house was constructed in the 1870's of limestone 1-foot square that were obtained from the lowermost bed of the upper limestone of the Crouse. They show no effect of weathering. This limestone was quarried southwest of the house and at that time it was soft enough to be easily trimmed.

The Crouse limestone is used along with limestone of the Funston and Threemile as riprap on the upstream face of a dam in the SW¼NW¼ sec. 9, T. 15 S., R. 11 E. There is no apparent effect of freeze and thaw on the blocks of limestone.

Seeps are common in the upper part of this formation, but they are most abundant at the base of the upper limestone.

BLUE RAPIDS SHALE

The Blue Rapids shale was named by Condra and Upp (1931, p. 22) for the lower part of the Easly Creek shale as defined by Condra (1927, p. 234) and redefined by Condra and Upp (1931, p. 22–24). The Blue Rapids overlies the Crouse limestone and underlies the Funston limestone (table 2). The type locality is in road cuts along U. S. Highway 77 about 1¼ miles north of Blue Rapids in Marshall County, Kans. (Condra and Upp, 1931, p. 22).

The Blue Rapids is a variegated shale in which beds of tan-gray to gray shale predominate. The lower half of this formation generally consists of beds of tan-gray to gray-green clayey shale. In the southeastern and northwestern outcrop area these beds are silty; elsewhere in the county they are clayey. In the lower part of the upper half of the Blue Rapids there is a bed of maroon shale. It is overlain by beds of gray-green and gray shale which are mainly silty and thin-bedded. In some places a thin bed of purple shale overlies the maroon beds. In the eastern part of the county, nodules of calcium carbonate are in the upper part of this formation.

Southwest of Hessdale there is a thin gray clayey limestone in the lower part of the Blue Rapids shale. In the NE¼NE¼ sec. 9, T. 14 S., R. 10 E., this limestone is sandy and contains fragments of wood. (See pls. 3 and 13.)

The Blue Rapids shale averages 18 feet in thickness. The maximum thickness of 21.6 feet was measured in the northwestern part of the county, and the minimum of 14.9 feet was measured southwest of Hessdale. (See pl. 13 and measured sections 12, and 14–19.)

The fossils in the thin bed of limestone near Hessdale are mainly pelecypods and bryozoans. The beds of shale are nonfossiliferous.

The Blue Rapids shale was not sampled for use as a construction material. It has been used as a fill material on local secondary roads.

FUNSTON LIMESTONE

The Funston limestone was named by Condra and Upp (1931, p. 23). It was formerly the middle part of the Speiser shale of the Garrison formation as defined by Condra (1927, p. 232 and 234). The type section of the Funston limestone is along the Kansas River bluffs south of Camp Funston in Riley County, Kans. (Condra and Upp, 1931, p. 23). This limestone overlies the Blue Rapids shale and underlies the Speiser shale (table 2). The Funston is well exposed in the central and western parts of Wabaunsee County.

The Funston limestone generally consists of 3 beds of limestone and 2 beds of shale (pls. 3 and 14). The beds of limestone are massive, medium hard, porous, and light gray. In the northeastern and southern outcrop areas the middle limestone is absent. (See plate 14.) The beds of shale are gray, silty to clayey, thin bedded, and in some places calcareous.

There is a biostrome in this limestone, which extends into parts of four counties in east-central Kansas. A part of this biostrome was seen in southeastern Riley County. In western Wabaunsee County it is well exposed and was studied in detail. In northwestern Lyon County, Jewett and O'Connor (1951, p. 4 and 21) noted an unusual thickening of the Funston limestone that may represent an extension of the east flank of the biostrome. At the southeastern edge of Council Grove in Morris County, oolite beds comprise the upper half of the Funston biostrome. There is no information on the occurrence of this biostrome in the subsurface.

The base of the biostrome is at the base of the middle bed of limestone in the Funston. Study of the many exposures shows that the biostrome is composed mainly of beds of oolite. The oolites are bound on all sides by algae of the *Spongiostroma* division. The west flank has a maximum westerly dip of 20 degrees (pl. 15A). On the east flank the beds have less slope and dip to the east (pl. 14). The fresh surface of the oolitic beds is light gray. The bedding, which is not noticeable on a fresh exposure, is discernable on the dark-gray weathered surface of these beds which are very porous and generally soft enough to be carved with a knife. Most of the oolites are small hollow calcareous shells. They occur in many shapes, but most are well rounded. Some of the oolites are crushed and eroded so that they superficially bear some similarity in shape to that of ostracodes (I. G. Sohn, written communication). Thin lenses of conglomerate are interbedded with the beds of oolites on the flanks of the biostrome (pl. 14). These conglomerates consist of fragments of lime that have a maximum diameter of 1½ inches but most are 1/32 inch. They are subrounded to angular; many occur as flattened, elongated nodules. Iron and carbon stain these conglomerates in a few places.

The maximum thickness of the Funston limestone was measured in the biostrome where it is more than 26 feet. Just north of Eskridge a minimum thickness of 8.8 feet was measured. The variation in thickness of the formation is well illustrated on plate 14. (See also measured sections 12 and 14–22.)

Most of the sediments in the biostrome are probably cemented by algal felt. In some places the top of the biostrome contains mounds of encrusting algae that are about 4 to 6 inches thick. Along both flanks of the biostrome another genera of the algae *Somphospongia* (?) sp. is very common in the middle and upper beds of the Funston limestone (pl. 15B). The surface of this particular algal deposit when weathered has a spongelike texture. Small pelecypods, gastropods, and bryozoans are present in the oolite beds. On the east side of the biostrome, in the SE¼NE¼NW¼ sec. 3, T. 13 S., R. 10 E., the middle limestone contains a coquina layer of small pelecypod fragments. A similar coquina was seen in the same bed on the west flank of the biostrome in the center of SE¼ sec. 13, T. 13 S., R. 9 E. These are the only areas where fossil fragments are abundant. The fauna in the biostrome is the same as that which persists elsewhere in the Funston limestone.

Two samples of the Funston limestone were tested for use as a construction material (table 1, ls 21 and 32). Both samples were obtained from the oolite beds of the Funston biostrome. The material represented by sample ls 21 was accepted for use as a coarse aggregate for concrete, as an aggregate for bituminous surface course, for bituminous concrete and sheet asphalt surfaces, as cover material, for bituminous retread-surface and bituminous drag treatment, for surface or resurfacing, and as stone for crushed stone base course (keyed type). (Kansas highway standard specification Ed. 1945.) The percent lost by abrasion may reject sample ls 32 as a construction material. Thorough sampling of the biostrome is required as its hardness is quite variable over a short distance.

In Wabaunsee County the Funston limestone has been used only in small quantities as a construction material. East of Alma the upper bed of limestone of the Funston has been quarried and was used in some of the buildings in the business district of Alma. In the SW¼NW¼ sec. 9, T. 15 S., R. 11 E., field stones of the Funston were used as hand-laid riprap on the upstream face of a small dam. Limestone of the Crouse and Threemile are also used as riprap on this dam. At both places the Funston limestone appears to be suitable as riprap and structural stone. Springs and seeps are abundant at and near the base of the Funston biostrome. In the eastern outcrop area they are uncommon. John D. McNeal (oral communication) noted that during the excavation of this formation the limestone bed breaks excessively. The Funston limestone, especially the biostrome facies, is considered potentially important for a construction material (pl. 1).

SPEISER SHALE

The Speiser shale, as named by Condra (1927, p. 234) in his classification of the Garrison member, included all beds from the top of the Crouse limestone up to the base of the Threemile limestone. Condra and Upp (1931, p. 23) redefined the Speiser as the shale overlying the Funston limestone and underlying the Threemile limestone. That definition is adopted in this report. The type locality is in the W½ sec. 35, T. 1 N., R. 13 E., Speiser Township, Richardson County, Nebr. (Condra and Upp, 1931, p. 23). In Wabaunsee County the Speiser is well exposed—especially the upper half of the formation. Good exposures are in road cuts in the SW¼SW¼ sec. 31, T. 13 S., R. 11 E., SW¼NW¼NW¼ sec. 10, T. 14 S., R. 10 E., and in the SW¼NW¼ sec. 10, T. 13 S., R. 9 E. (See pls. 3 and 5.)

The Speiser consists of variegated beds of silty and clayey shale with a thin persistent bed of limestone in the upper part. Beds of tan-gray shale are dominant in the upper part; green and maroon beds are conspicuous in the lower part. In some places this formation consists entirely of tan, gray, and gray-green beds of shale. In the northwestern part of the county there is a bed of purple shale in the middle part of the formation and a thin bed of hard massive limestone in the upper part. In the area of the Funston biostrome and in the southwestern outcrop area this limestone grades laterally into a very calcareous shale. The bed of limestone is hard and gray, and weathers into small blocks.

The thickness of the Speiser shale is quite variable as it is directly affected by the thickness of the Funston limestone. The Speiser thins to less than 6 feet where above the Funston biostrome, but thickens on the flanks of the biostrome. North of Eskridge the Speiser shale is about 30 feet thick; this appears to be a result of the thinness of the underlying Funston limestone. The formation averages about 17 feet in thickness. (See pl. 14 and measured sections 9 and 12–17.)

The only fossils seen in the Speiser shale are in the uppermost bed of shale and in the bed of limestone. The bed of limestone generally contains fragments of brachiopods, echinoids, and crinoids, but in some places it has complete shells of brachiopods and pelecypods. The upper bed of shale is fossiliferous only in the western and southern outcrop areas, where it has mainly a brachiopod fauna. A variety of well-preserved brachiopods was seen in a road cut exposure in the SW¼NW¼NW¼ sec. 10, T. 14 S., R. 10 E.

The Speiser shale was not sampled for use as a construction material, but it has been used locally as a fill material. Seeps are seldom present in this formation.

CHASE GROUP

The Chase group is the uppermost group of that part of the Permian system present in this region (table 2). Only the lower part of the Chase group crops out in Wabaunsee County (table 2, pls. 1 and 2).

WREFORD LIMESTONE

In Wabaunsee County the Wreford limestone is the oldest of the thick chert-bearing limestones of the Permian that form the Flint Hill escarpment. This formation was named by Hay (1893, p. 104). It overlies the Speiser shale and underlies the Matfield shale (table 2). The type section is in a quarry near Wreford, Geary County, Kans. A complete study on the environment of the Wreford is given by Hattin (1957). The Wreford limestone consists of three members which, in ascending order, are the Threemile limestone member, Havensville shale member, and Schroyer limestone member. Hillside benches formed in this formation are conspicuous west, south, and east of Alma and southwest and west of Eskridge. The Wreford limestone averages about 40 feet in thickness.

THREEMILE LIMESTONE MEMBER

The Threemile limestone was named by Moore (1936b, p. 12) who listed it as the basal member of the Wreford limestone. Hay (1893) is generally given credit for the name Threemile as he suggested it as a possible name for this stratum. Condra and Upp (1931, p. 31) recommended that the lowest member of the Wreford limestone be named the Fourmile limestone. This name was rejected, however, because it has been previously applied to a sandstone in the Pennsylvanian system. The type locality is along Threemile Creek on the Fort Riley Military Reservation, a few miles southwest of Ogden, Riley County, Kans.

In Wabaunsee County the Threemile limestone member forms a conspicuous hillside bench (pl. 5). This bench is recognized by the abundance of chert nodules that cover it and by its smooth rounded shoulders. A similar hillside bench is formed by the Florence limestone member of the Barneston limestone which lies 50 to 70 feet above the Threemile limestone member.

The Threemile caps most of the interstream areas west and south of Mill Creek in the western, central, and south-central parts of the county. This limestone is well exposed in road cuts and streambanks in these areas. Representative exposures are in road cuts in the NW¼NE¼NE¼ sec. 1, T. 14 S., R. 11 E.; SW¼NW¼ NW¼ sec. 10, T. 14 S., R. 10 E.; and in the SW¼NW¼ sec. 10, T. 13 S., R. 9 E.

The Threemile consists mainly of many layers of limestone, most of which contain nodules and thin lenses of chert. There is a thick noncherty bed of limestone near the top of the member, and a thin gray fossiliferous shale near the base. The basal limestone of this member contains 2 or 3 lenses of chert. The beds of limestone are medium hard, fine-grained, massive, and white to light gray. They weather into irregular gray blocks, some of which are porous. The chert is gray; its upper and lower surfaces are generally weathered to tripoli, are very irregular, and generally contain fossils. The chert lenses could not be correlated from one exposure to another. Iron stains are abundant in this member, especially on the surfaces of the chert nodules and lenses. Only in the NE¼NW¼NW¼ sec. 10, T. 15 S., R. 10 E., where the Threemile is 19.3 feet thick, does the member contain a very fossiliferous shale in the upper part (pl. 16).

A biostrome, composed mostly of algal deposits, forms the bulk of this limestone in places in Wabaunsee, Geary, Riley, and Morris Counties. The biostrome exposed in these counties is excellently discussed by Hattin (1957, p. 68–76, 91–99). In Wabaunsee County, the biostrome is exposed in a streambank in the SW¼SE¼ sec. 26, T. 13 S., R. 9 E. (pl. 17). In Geary County this biostrome is exposed in a streambank and road cut in the SE¼NW¼ sec. 35, T. 13 S., R. 5 E. In Morris County, Mudge, Matthews, and Wells (1958, p. 14) traced this biostrome eastward in exposures along the Neosho River from a point 1 mile south of Parkerville to a point 1 mile north of Council Grove.

From the streambank location cited above, this biostrome trends east to near Eskridge in Wabaunsee County where it forms massive bluffs along the stream valleys (pl. 17). This irregular ridge-shaped biostrome projects about 20 feet above the adjacent beds of limestone; it is about 1 mile wide in the southeast corner of T. 13 S., R. 9 E. Ridgelike structures are in the Threemile in secs. 2 and 3, T. 13 S., R. 11 E.; in sec. 36, T. 13 S., R. 11 E.; and sec. 1, T. 14 S., R 11 E This limestone is poorly exposed between these areas; it can only be assumed, therefore, that these are two separate biostromes and that the latter is an extension of the biostrome in the western part of the county The probability must be noted, however, that the outcrop may indicate just one biostrome which is wider in the east. In southeastern Riley County a similar biostrome of smaller dimensions is exposed in a road cut of U. S. 40 (John D. McNeal, oral communication, 1954).

The biostrome is a soft, massive, almost structureless bed of limestone containing abundant algal deposits of the division *Spongiostroma* (J. H. Johnson, written communication, 1953). The unweathered surface of this bed is white and chalky. A thin crust forms on the dark-gray weathered surface. The limestone is porous to cavernous and generally weathers in large irregular blocks. Barely discernable planes, which are probably inclined bedding planes, are on the flanks of the biostrome. The beds of limestone are brecciated on the flanks. Some of the angular fragments of limestone are 3 inches across, and most of them blend into the limestone matrix.

The Threemile limestone member averages about 13 feet in thickness. It is about 36 feet thick in the biostrome; the shale bed in the lower part of this member ranges from a featheredge to 1 foot in thickness. (See measured sections 9–13 and 15.)

The fauna of the Threemile consists of a few brachiopods, bryozoans, gastropods, crinoid columnals, and microfossils. The fossils are locally abundant in the thin bed of shale and persist along with the algae, in the biostrome.

In Wabaunsee County only the upper noncherty part of the Threemile is used as a construction material. Four samples of this limestone were tested for its engineering properties (table 1, ls 22, 28, 30, and 33). Ls 22 was accepted as an aggregate for concrete, as a material for binder-soil stabilized base course, and as a crushed stone for surfacing. Ls 28 was accepted as an aggregate for concrete and for bituminous mat surfaces, cover material, and as stone for crushed stone or sledged stone base course. Ls 30 was accepted as an aggregate under Kansas State Highway specification 37–299, of May 19, 1939. Ls 33, because of its high abrasion loss, is not suitable for most aggregate uses, but may be acceptable as a calcareous binder.

The Threemile limestone member is used as a road metal in the southwest corner of the county (pl. 8, nos. 22, 25). The performance of this limestone as a road metal appears to be very good. The crushed fragments become subrounded during use.

In the central part of the county, this limestone was used as a building stone in homes of some of the early settlers. Although most of these one-room houses have been abandoned and partly destroyed, the blocks of limestone are only slightly weathered.

The Threemile is used as riprap on two dams in the county located in the SW¼NW¼ sec. 9, T. 15 S., R. 11 E., and at Lake Wabaunsee, 5 miles west of Eskridge. The blocks of Threemile have been exfoliated by alternating freezing and thawing. The spillway at Lake Wabaunsee was examined in 1949 when the failure was first noted. At that time the area that failed was about 6 feet in diameter, but almost all of the blocks of Threemile in the spillway were badly fractured from alternating freezing and thawing. Two years later, almost all of the lining of the floor of the spillway and much of the underlying shale were eroded. An examination of the outcrop of this limestone confirmed its instability as riprap. The elements of weathering have reduced the exposed bed of limestone to small irregularly-shaped blocks. A chert residue completely covers the outcrop.

The Threemile used as riprap on a small dam in the SW¼NW¼ sec. 9, T. 15 S., R. 11 E., appears to withstand weathering. There is very little fracturing of the limestone blocks that are along the waterline. The success of this limestone at one place and its failure at another emphasizes the importance of thorough sampling and testing of a limestone before it is used for certain engineering structures.

The many springs and seeps along the outcrop of the Threemile limestone member occur at various horizons, but are most abundant at the base of the member. About 1 mile west of Eskridge on Kansas Highway 99, subdrains were installed beneath the subbase of the road at the contact of the Threemile and the underlying Speiser shale. Springs and seeps are abundant in the area of outcrop of the Threemile biostrome.

HAVENSVILLE SHALE MEMBER

The Havensville shale member was named by Condra and Upp (1931, p. 32) from exposures in road cuts along Kansas Highway 63 about 2 miles south of Havensville in Pottawatomie County, Kans. They designated it as the middle member of the Wreford limestone (table 2). In Wabaunsee County the Havensville is well exposed in a road cut in the SW¼NW¼ sec. 10, T. 13 S., R. 9 E. Complete exposures of this shale are uncommon as the overlying Schroyer limestone member does not form a very resistant hillside bench.

The Havensville shale member consists mainly of shale, but its upper part and locally its middle part contains a thin lens of limestone. The shales are clayey near the base, but are silty in the upper part. They are gray green to gray, and thin bedded to blocky. Calcium carbonate nodules are common in the middle part of the member. The lens of limestone is hard, tan, and massive and ranges from 0.5 foot to 1.8 feet in thickness. Where the bed of limestone is in the lower part of this member it is medium hard and gray, contains clay balls, and weathers porous and platy.

The Havensville averages about 18 feet in thickness, but over the Threemile biostrome in the western part of the county it thins to about 6 feet. (See measured sections 9–11.)

Fossils are present only in the beds of limestone. The fauna consists of pelecypods, crinoid columnals, brachiopods, and echi-

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noids. Fossil fragments are abundant in the lower bed of limestone.

The Havensville was not sampled for a construction material even though it has been used locally as a fill material along secondary roads. Seeps are common in the upper part of the Havensville; they emerge from the silty beds of shale and from the base of the bed of limestone. The clayey beds of shale are highly plastic and unstable when wet.

SCHROYER LIMESTONE MEMBER

The Schroyer limestone was named by Condra and Upp (1931, p. 33) as the upper member of the Wreford limestone. The type locality is on the east side of the valley of the Big Blue River about 1½ miles below Schroyer, Marshall County, Kans. This member consists of the chert-bearing limestone beds that overlie the Havensville shale and underlie the Matfield shale. Outcrops of the Schroyer limestone member are closely associated with those of the Threemile limestone member. Where these two members are present, the Schroyer generally forms a less conspicuous bench above and farther back on the hillside than the prominent round-shouldered bench formed by the Threemile. The bench of the Schroyer is generally covered by a thin mantle of material from the Sanborn formation. This member is well exposed in a road cut in the NE¼SW¼ sec. 12, T. 15 S., R. 9 E.

The Schroyer limestone member consists of alternating beds of thick limestone, thin lenses of chert, and some thin beds of shale. The limestone is medium hard, tan brown to gray, massive, and generally weathers into porous blocks. Chert nodules are scattered throughout the beds of limestone. The chert is dark to light gray, hard, and dense. The beds of shale in the upper and lower parts of the member are silty, calcareous, tan gray to gray, thin bedded, and contain nodules of calcium carbonate. The mantle of chert fragments on the weathered surface of the Schroyer gives it an appearance similar to that of the weathered Threemile and Florence.

The Schroyer averages about 12 feet in thickness. In the southwest corner of the county it is about 19 feet thick, but is much thinner elsewhere in the outcrop area. It thins to about 8.5 over the biostrome of the Threemile limestone member. The thickness of the biostrome was compensated for by the thinness of sediments composing the Havensville shale member and Schroyer limestone member of the Wreford limestone and the Wymore shale member of the Matfield shale. (See measured sections 9 and 10.)

Brachiopods, crinoid columnals, echinoids, and bryozoans are present in the beds of limestone and shale. Microfossils are abundant in a few places in the upper part of the upper limestone.

The Schroyer limestone member was not sampled for use as a construction material because it contains a high precentage of chert. In Wabaunsee County the Schroyer has not been used as a construction aggregate or stone.

MATFIELD SHALE

The Matfield shale was named by Prosser (1902, p. 714) who defined it as the varicolored shales that overlie the Wreford limestone and underlie the Florence flint. The type locality is in the Matfield township, Chase County, Kans. The Matfield shale is beneath the prominent benches formed by the Florence limestone member of the Barneston limestone, but it is generally covered by colluvium. Part of the formation is exposed in road cuts, ditches, streambanks, and at the heads of some tributary streams. The Matfield shale is divided into three members which, in ascending order are, the Wymore shale member, Kinney limestone member, and Blue Springs shale member. (See table 2.) The Matfield shale ranges from about 50 to 70 feet in thickness.

WYMORE SHALE MEMBER

The Wymore shale member is the basal member of the Matfield shale. This member was named by Condra and Upp (1931, p. 37) who describe the type locality in Gage County, Nebr., as: "Ravines west side of creek 2½ miles east of south side of Wymore, in E½ sec. 27, T. 2 N., R. 4 E. This is about one-fourth mile north of where the highway crosses the Burlington and Union Pacific railroads." In Wabaunsee County, almost all of this member is well exposed in a streambank and road cut in the SE¼SE¼ sec. 27, T. 13 S., R. 9 E.

The Wymore is a calcareous clayey to silty and blocky to thin-bedded shale. Tan-gray, gray-green, purple, and maroon shale beds predominate in the lower part of the member and gray-green, green, gray, and olive-drab shale beds persist in the upper part. Iron stains are abundant on fracture and bedding planes. The Wymore ranges in thickness from 15.9 feet to about 25 feet. (See measured section 8.) No fossils were seen in the Wymore shale member. This shale was not tested for a construction material, but it has been used as a fill material in farm-access roads. Small seeps are common in the silty and blocky beds.

KINNEY LIMESTONE MEMBER

The Kinney limestone was named by Condra and Upp (1931, p. 37) who list the type section as in the Burlington Railroad cut east of Kinney in Gage County, Nebr. The Kinney is overlain by the Blue Springs shale member and underlain by the Wymore (table 2). In Wabaunsee County it is well exposed in road cuts in the SE¼SE¼ sec. 27, T. 13 S., R. 9 E.; NE¼SW¼ sec. 15, T. 13 S., R. 9 E.; and in the NE¼NE¼ sec. 14, T. 13 S., R. 8 E.

The Kinney limestone member generally consists of two beds of limestone separated by a bed of shale. In the eastern part of the outcrop area the upper limestone and, in places, the shale is absent. The lower bed of limestone, which is persistent over the outcrop area, is hard, massive, and tan gray. It generally weathers into irregular blocks, but in some places it weathers into small irregular chips that give it a shaly appearance. Clay balls and lentils are common. The upper part is generally stained red by iron oxide derived from the overlying Blue Springs. On many hillsides this limestone crops out about 40 feet beneath the Florence, but rarely does it form a recognizable bench. Knolls capped by this bed of limestone are in sec. 16, T. 12 S., R. 9 E.; secs. 7 and 32, T. 12 S., R. 10 E.; and in secs. 5 and 30, T. 13 S., R. 10 E. The bed of shale varies from thin bedded to blocky and from silty to clayey, but it is always calcareous and gray. The shale is absent in the outcrop area northeast of Alta Vista. The upper limestone is medium hard, gray, weathers shaly, and is less persistent than the intervening bed of shale and the lower bed of limestone.

The lower bed of limestone ranges in thickness from 1.1 feet to 3.2 feet; the bed of shale ranges from a featheredge to 11.9 feet; the upper bed of limestone is generally less than 0.5 foot. (See measured section 8.)

Brachiopods and bryozoans are common throughout the three beds of the Kinney, and brachiopods are abundant in some places. In the upper and middle parts of the lower bed of limestone, microfossils, mainly ostracodes, are commonly abundant. Pelecypods are in the upper part of this limestone in the NE¼SW¼ sec. 15, T. 13 S., R. 9 E.

This member was not sampled for use as construction material because it is generally overlain by about 40 feet of the Blue Springs. Seeps are common at the top and base of the lower bed of limestone.

BLUE SPRINGS SHALE MEMBER

The Blue Springs shale was named by Condra and Upp (1931, p. 38) for exposures at the base of the bluffs along the Blue River southeast of Blue Springs in Gage County, Nebr. The Blue Springs shale member overlies the Kinney limestone member and underlies the Florence limestone member of the Barneston limestone (table 2). In Wabaunsee County, outcrops of the Blue Springs are associated with those of the Florence. An exposure of this shale is in a streambank in the SW¼NW¼NE¼ sec. 19, T. 13 S., R. 9 E.

The Blue Springs consists of many thin beds of brightly colored variegated shale and one or more thin lenses of argillaceous limestone. The lower and middle parts of the member are mainly gray, gray-green, green, maroon, and purple beds of shale that are silty to clayey, and calcareous. The upper part of the Blue Springs is gray, gray green, calcareous, and silty to clayey. The upper and lower surfaces of the beds are very irregular. All of the beds of shale are commonly blocky and many grade laterally into silt or claystones. North of Alta Vista there are two thin soft argillaceous limestone beds in the middle part of the member. The Blue Springs ranges in thickness from 19.9 feet to about 30 feet. (See measured sections 7 and 8.) No fossils were observed in the Blue Springs.

This member was not sampled for use as a construction material in the county. Seeps are present in some of the beds of silty shale, and locally seepage occurs in the fractured beds of clayey shale. The beds of siltstone, especially in the middle part of the Blue Springs contain seeps.

BARNESTON LIMESTONE

The Barneston limestone was named by Condra and Upp (1931, p. 41) for exposures in the bluffs west and southwest of Barneston, Gage County, Nebr. The Barneston limestone crops out in the western part of the Wabaunsee County and forms conspicuous hillside benches that are easily recognized. This limestone is divided into three members which are in ascending order, the Florence limestone member, Oketo shale member, and Fort Riley limestone member (table 2). The Barneston limestone averages about 60 feet in thickness.

FLORENCE LIMESTONE MEMBER

The strata now known as the Florence limestone was named the Florence Flint by Prosser (1895, p. 771–786, 798). The type locality is near Florence in Marion County, Kans. Moore, Elias, and Newell (1934) redefined the units of the Barneston and designated the Florence as the limestone overlying the Blue Springs shale and underlying the Oketo shale (table 2).

The Florence is a conspicuous and easily recognized flint-bearing limestone that forms prominent hillside benches south and southwest of Alma. The benches are characterized by smooth, rounded shoulders covered by fragments of chert 3 to 4 inches in diameter. Between Illinois Creek and South Branch Mill Creek many isolated knolls of the Florence rise 50 to 70 feet above the broad flat bench formed by the Wreford limestone.

The Florence member consists of massive beds of limestone that contain many nodules and lenses of chert. The chert is dense, hard, and fractures conchoidally. It is generally steel gray to light gray, and in most places its surface is iron stained. Chert, which is more resistent to weathering than the limestone that encloses it, weathers out in small blocks and generally covers the surface of the outcrop. The beds of limestone are medium hard, gray, and massive. In a few places the lower bed is a soft dolomitic and argillaceous limestone that weathers to a shaly appearance. It is overlain by one or two thin beds of silty calcareous gray shale. At places, a thin bed of shale is in the upper part of this member. The Florence ranges in thickness from 35 feet to about 38 feet. (See measured sections 6 and 7.)

Brachiopods, bryozoans, and echinoid fragments are common throughout this member. In the SW¼NW¼NE¼ sec. 19, T. 13 S., R. 9 E., the lower bed of shale contains thin-shelled pelecypods.

Material from the limestone beds of the Florence was tested and found unsuitable for most construction purposes (table 1, ls 31) under Kansas Highway standard specifications of 1937. However, crushed limestone from the Florence has been used on secondary roads in the southwestern part of the county. (pl. 8). Seeps and springs are common in the lower part of the Florence.

In the SE¼NE¼ sec. 35, T. 13 S., R. 8 E., the Florence limestone member and the lower part of the Fort Riley limestone member were quarried extensively for railroad ballast. This abandoned quarry, which was the largest in the county, had a total production of about 150,000 cubic yards. Crushed limestone of the Florence is used also as base course material on Kansas Highway 13 south of Manhattan (John D. McNeal, written communication).

OKETO SHALE MEMBER

The Oketo shale was named by Moore, Elias, and Newell (1934) from exposures found near Oketo in Marshall County, Kans. (See also Jewett, 1941, p. 76.) Prosser (1902, p. 714) had included this shale as part of the Fort Riley limestone. The Oketo shale member crops out in the southwestern part of the county. In most places it is covered by weathered material from the overlying Fort Riley.

The Oketo is thin bedded to blocky, silty, and calcareous. It is commonly hard, and well cemented as a result of its lime content. Calcite-lined geodes are common in the blocky shales. In some places there is a thin soft bed of dolomitic limestone in the lower part. The Oketo is tan gray to gray, and in some places is mottled blue gray. It ranges in thickness from a featheredge in secs. 18 and 19, T. 13 S., R. 9 E., to 8 feet in sec. 36, T. 13 S., R. 8 E. (See measured section 7.)

The Oketo is sparsely fossiliferous to nonfossiliferous in most outcrops. Its fauna consists of brachiopods, bryozoans, crinoid columnals, and locally pelecypods.

The Oketo was not sampled for a construction material nor has it been used for that purpose.

FORT RILEY LIMESTONE MEMBER

The Fort Riley limestone was named by Swallow (1866, p. 14). The type locality is at Fort Riley in Geary County, Kans. (Condra and Upp, 1931, p. 42). Prosser (1895, p. 771–786, 798) described the Fort Riley as including the Florence limestone. Prosser (1902, p. 714) redefined the Fort Riley limestone to include the noncherty units now comprising the Barneston limestone. Condra and Upp (1931, p. 42) in naming the Barneston limestone, included the Florence flint and the Fort Riley limestone as members. Moore, Elias, and Newell (1934) revised the terminology of the unit and included the Fort Riley limestone as the upper member of the Barneston limestone. The Fort Riley limestone member overlies the Oketo shale member and underlies the Holmesville shale member of the Doyle shale. In the area north and east of Alta Vista there are many conspicuous outcrops of the Fort Riley. (See FR in pl. 1, and Pb in pl. 2.)

The Fort Riley consists of massive layers of limestone separated in places by thin layers of shale. A bed of shale is common near the base of this member. Some of the beds of limestone form conspicuous ledges. The tan to tan-gray limestone varies from hard massive beds to soft massive dolomitic beds. The porous limestones exhibit limonite-stained zones.

The Fort Riley contains two rimrock ledges—one near the base and the other near the middle. Most of the rimrock exposures are those of the lower ledge. The term rimrock is of local application and denotes a massive limestone that it very resistant to weathering and other erosional forces and which forms a conspicuous rim on the shoulders of many hillsides. The rimrock is distinctive at a distance, or on aerial photographs, because it makes a narrow white line on the hillside. The ledge ranges from 3 to 6 feet in thickness, and is generally porous. Rimrock outcrops are conspicuous on hillsides in secs. 27, 28, 29, and 30, T. 13 S., R. 9 E., where there are two relatively hard limestone beds in the Fort Riley that have the rimrock characteristics. Each limestone is 4 feet thick in the eastern outcrop area and thins toward the west; they are separated by 6 feet of calcareous shale. This member is about 25 feet thick. (See measured sections 6 and 7.)

The Fort Riley which is sparsely fossiliferous, contains brachiopods, echinoids, and bryozoans.

The rimrock of the Fort Riley limestone member was tested for a construction material (table 1, ls 29, 34). Ls 29 was not acceptable as an aggregate under most of the sections of the Kansas Highway standard specifications of 1937. Ls 34 was acceptable as aggregate for bituminous surface cover, for bituminous concrete and sheet-asphalt surfaces, for cover material, for bituminous retread-surface and bituminous drag treatment, for surfacing or resurfacing, and as stone for crushed stone base course (keyed type) under Kansas Highway standard specifications of 1945.

The Fort Riley has been used extensively near Alta Vista. Many quarries north and east of that city have produced large quantities of rock for building stone, for road metal, and for railroad ballast. Most of the civic buildings of Alta Vista were constructed of the Fort Riley limestone. In these structures, which are 50 or more years old, this stone shows only slight weathering effects, although some of the blocks have become porous and are stained dark gray to yellow brown.

The Fort Riley has been used as a structural stone in the abutment and span of a single arch bridge in the NE¼SW¼ sec. 6, T. 13 S., R. 9 E. No effects of weathering were seen even at the waterline.

In the southwestern part of the county, the Fort Riley is used as road metal (pl. 1, no. 24).

North and east of Alta Vista, there are many excellent quarry sites in the Fort Riley (pl. 1).

Many of the abundant springs and seeps at the base of the rimrock ledges supply water for stock use.

DOYLE SHALE

The Doyle shale was named by Prosser (1902, p. 715) from exposures along Doyle Creek southwest of Florence in Marion County, Kans. Bass (1929, p. 68 and 69) included in the Doyle shale all beds from the base of the Winfield limestone to the top of the Fort Riley limestone. Condra and Upp (1931, p. 43) divided the Doyle shale into three members which are in ascending order, the Holmesville shale, Towanda limestone and Gage shale. Moore, Elias, and Newell (1934) and Moore (1936b, p. 12) dropped the name Doyle shale and raised the members proposed by Condra and Upp to the rank of formations. Moore, Frye, and Jewett (1944, p. 163) reverted to the classification of Condra and Upp (1931), and that classification is also followed in this report.

The Doyle shale crops out only in a small area in the southwestern part of the county (table 2, and pl. 2). Only the Holmesville shale member is represented in the outcrop.

HOLMESVILLE SHALE MEMBER

The Holmesville shale was named by Condra and Upp (1931, p. 43) for exposures 1½ miles west and half a mile north of Holmesville in Gage County, Nebr. The Holmesville overlies the Fort Riley limestone member of the Barneston limestone and underlies the Towanda limestone member.

Exposures of the Holmesville occur in the ditches of a section line road that extends from the northern city limits of Alta Vista to a point 4 miles east. It is a silty calcareous tan-gray to gray shale that varies from blocky to thin bedded. Only about 8 feet of the shale is exposed.

No fossils were seen in the Holmesville which has not been used as construction material in Wabaunsee County and has not been sampled for that purpose.

QUATERNARY SYSTEM

The most recently deposited sediments in Wabaunsee County are those of the Quaternary system which are unconsolidated except for cemented zones of small extent in the basal parts of a few gravel deposits. (See table 2.) These sediments are nonmarine in origin and were deposited by winds, streams, springs, and glaciers, or by mantle creep. Deposits formed by the wind (loess) are on the tops of some of the interstream areas and along some of the valley sides. Stream-deposited sediments are present along all major streams and their tributaries. These sediments are generally restricted to the stream valley, but along some of the larger streams they are found high on the sides of the valleys. Spring deposits (travertine) are present at three localities in the county. Glacial deposits cover much of the area north of Mill Creek. The materials that were moved by creep or slopewash are present along the sides of most of the valleys as well as on some of the rock benches.

The subdivisions of the Pleistocene epoch as adopted by the U. S. Geological Survey and used in this paper are tabulated as follows:

Period	Epoch	Stage	Substage
Quaternary	Recent		
	Pleistocene	Wisconsin glacial	Mankato Cary Tazewell Iowan
		Sangamon interglacial Illinoian glacial Yarmouth interglacial Kansan glacial Aftonian interglacial Nebraskan glacial	

The Quaternary deposits will be discussed under the headings used to designate map units on pl. 2, starting with the oldest, the older gravels.

OLDER GRAVELS

In Wabaunsee County there are many deposits of gravel that are older than glacial outwash. These stream-deposited gravels are pre-Kansan in age; they may have been deposited during the Nebraskan glacial stage, or even during the late Pliocene. J. E. Todd (1918b, p. 190–191) cites similar chert gravels on the north side of the Kansas River valley near the towns of Manhattan, St. George, and Wamego, and at Alma and Paxico in Mill Creek Valley. Todd (1918b, p. 190) states: "In all these localities red quartzite boulders occur, lying on the chert, but never in it." He believed that these gravels were deposited prior to the advance of the Kansan ice sheet into the area and thought that they might be as old as Pliocene.

In Wabaunsee County thick beds of chert gravel are present on strath terraces along the Marais des Cygnes River, Rock Creek, Mill Creek and its tributaries, and in the area about 4 miles east of Alta Vista (pl. 2). These deposits are from 60 to 120 feet above the present stream beds, a maximum of 15 feet thick, and exposed best on the west side of Mill Creek. Thick beds of chert gravel extend from a point 2 miles southwest of Alma to the Kansas River terrace south of St. Marys, Kans. Mudge (1955, p. 275–276) believes these gravels were deposited by a pre-Kansan Mill Creek that had a more direct route to the Kansas River than the present Mill Creek has (pl. 18). Similar deposits are west of Alma along Mill Creek and its larger tributaries. The deposits in the area between Paxico and the Kansas River terrace south of St. Marys are overlain by, but not intermixed with, glacial till. The deposits, restricted to a narrow belt about 1½ miles wide, are at 2 different altitudes in sec. 6, T. 11 S., R. 12 E.; the 2 horizons probably denote periods of aggregation separated by a period of degradation.

The gravels consist mainly of chert fragments of pebble and granule size. The particles, some of which have a thin crust of tripoli, are subrounded to angular, and are intermixed with red-brown silt and clay. The lower part of many of the deposits contain a 1-foot bed of well-cemented conglomerate that has about the same composition as the gravel deposit. Any fragments of limestone that were in these chert gravels, have been leached out. Most of the fragments of chert were derived from the chert-bearing Wreford and Barneston limestone beds, but some probably came from the Cottonwood limestone member of the Beattie limestone. The deposits, which are a maximum of 15 feet thick and average 8 feet in thickness, include some lenses of clay, silt, and very fine sand.

The pre-Kansan chert gravels were sampled at four localities; the results of the tests are listed in table 1 (cg 2–5). The results of tests on cg 2 and 3 indicate that the chert gravel is acceptable as material for calcareous binder-base course. The sieve analysis of these samples shows a maximum of 33 percent of the material retained on the three-fourths inch sieve; a maximum wash of 29.8 percent passed the no. 200 sieve. The chert gravel obtained from a pit in the SE¼ sec. 6, T. 11 S., R. 12 E. (pl. 8, No. 11), is used on county and farm-access roads in the northeastern part of the county. North of Alma and west of McFarland, many small pits in deposits of this gravel furnish material for use on nearby farm-access roads. The performance of these gravels is generally good. Field observation indicates that the older chert gravels are best for metal because they contain a clay binder and the particles of chert are slightly rounded. Many seeps were seen at the base of these gravels.

GLACIAL TILL

In the northern part of the county considerable glacial material was deposited during the Pleistocene epoch. (See pl. 18.) Todd (1918, p. 43) and other writers believed that it was laid down by, or in association with, the Kansan ice sheet. Frye and Leonard (1952, pl. 1) restrict Nebraskan glacial till to the northeastern corner of the state, but the area of Kansan till extends south into Wabaunsee County. The till was deposited directly by melting ice, and large areas of it are partly covered by the Sanborn formation of more recent age. It is difficult to distinguish till from the clayey silt of the Sanborn where the latter has been derived from the till. There are many exposures of till in streambanks in sec. 1, T. 11 S., R. 10 E.

The area covered by the glacier is north of a line that marks the maximum advance of the ice sheet. This line extends from the northwestern corner of the county to 1.5 miles north of McFarland, east along Mill Creek to Maple Hill, and southeastward to a point about 1 mile north of Dover in Shawnee County. (See pl. 18.) The drift border, in Wabaunsee County, as defined by B. B. Smyth (1898) was modified slightly by Schoewe (1930 and 1939) and by Mudge (1955, p. 274, fig. 2). The drift border is marked by a belt of boulders that probably represents the residue of the terminal moraine.

Till is a heterogeneous mixture of unstratified particles of clay, silt, and larger size material. Clay is the main constituent of till, but also included are particles the size of silt, sand, granules, pebbles, cobbles, and boulders. Quartzite is the most abundant of the erratics,[1] although acidic and basic igneous rocks, greenstone and other metamorphic rocks, and petrified wood, sandstone, chert, shale, and limestone are common. The larger fragments of granite where incorporated in a clay till matrix are generally rotten and will crumble easily when struck with the sharp point of a geologic pick. Almost all fragments of chert, limestone, and shale were derived from local sources; many of the fragments are still identifiable as shale. In some places there are lenses of fine cross-bedded sand, and small zones of erratic-free clay. In Wabaunsee County, most exposures of gray-brown to tan till probably represent soil horizons *A* or *B*. Much of the till is iron stained and contains traces of carbon. Calcium carbonate nodules are abundant in the B soil horizon. The dark-gray calcareous till of the *C* soil horizon may have a bluish tint.

Banded sediments (possibly varves) are in the lower parts of road cuts in the SE¼SE¼ sec. 28 and 29, T. 11 S., R. 13 E., and SW¼SW¼ sec. 7, T. 11 S., R. 12 E. They consist of very fine sand, silt, and clay. The color banding alternates between light and dark shades of gray brown. Granule-size erratics are common in these sediments.

The many concentrations of glacial boulders in the area covered by till are most conspicuous where the finer materials have been removed by surface waters. (See pl. 2.) The larger boulders crowd the shoulders and tops of the hills, but smaller boulders

[1] Erratic as used in this report is material of various grain sizes, mainly pebble or larger, that was transported into the region by the ice sheet.

and cobbles are abundant in many of the valleys of small streams. The largest concentration of boulders is in secs. 1, 2, and 3, T. 11 S., R. 10 E., and secs. 24, 26, 34, and 35, T. 10 S., R. 10 E. (See pl. 19A.) The composition of the boulders is the same as that of those in the till. The larger boulders are mainly quartzite and gneiss. The largest erratic found, a quartzite boulder, measured 18 by 17 by 6 feet. The 6 feet represents only the exposed thickness.

Small elongate ridges on the east side of a hill in the NW¼ sec. 25, T. 10 S., R. 10 E., consist mainly of boulder- and cobble-size erratics. These northeastward trending ridges are probably remnants of drumlins.

Glacial till ranges in thickness from a featheredge to about 50 feet. In most places, drilling is necessary to determine the exact thickness of the till.

Till contains a large amount of clay and is unsuitable as material for most construction purposes, but it is potentially useful as a ceramic material. Tests by Plummer and Hladik (1948, p. 82–83) show the specific gravity of a sample of Kansan till to be 2.06. The clayey till is suitable for use as a ceramic railroad ballast and as aggregate in construction.

Most of the area mantled by glacial till has a well integrated drainage pattern. Seeps and springs were seen at the base of some of the sand lenses, at the contact of the till and underlying bedrock, at the contact of the till and the overlying Sanborn formation, and in zones of the till that contain small fractures and lenses of gravel.

GLACIAL ICE-CONTACT DEPOSITS

Glacial ice-contact deposits are formed by the accumulation of sediments upon or against melting glacial ice. They were seen only in secs. 9 and 10, T. 12 S., R. 13 E, but other ice-contact deposits are undoubtedly in the area; they are either unrecognized or concealed by younger sediments.

The ice-contact deposits consist of particles that range in size from fine sand to boulders. Although smaller particles are the most abundant, cobble-size fragments are common. Fragments of limestone, shale, and chert are intermixed with a variety of igneous and metamorphic rocks. Almost all of the granite boulders and cobbles are badly weathered, and most of the erratics, including some of the limestone particles foreign to this area are well rounded. Size sorting and crossbedding is poorly displayed in the deposit, which contains masses of glacial till, at least 6 feet in diameter, and zones of material firmly cemented with calcium carbonate. The gravels were deposited directly upon the Pennsylvanian units in this area. In sec. 10, T. 12 S., R. 13 E., they fill a small preglacial valley cut in Pennsylvanian shales and spread over the adjacent interstream areas. The ice-contact deposits average about 30 feet in thickness.

The ice-contact deposits are thick and are in producible quantities. A pit located in the NE¼SE¼ sec. 10, T. 12 S., R. 13 E., was operating commercially until 1952. The 50,000 cubic yards of gravel that remains in this pit is classified as a coarse aggregate (table 1, ca 1), and although it does not meet the specifications for an aggregate for concrete, it is acceptable as a surfacing material. It has been used extensively on roads in both Wabaunsee (pl. 1) and Shawnee Counties, but to fulfill the specifications for road metal, the gravel must be screened to reduce the amount of oversize material. Field observations indicate that this material makes an excellent road metal. Small springs occur at the base of these gravels.

GRAND ISLAND FORMATION

The Grand Island formation was named in 1931 by Lugn, who described it (1935, p. 103–104) as "the inwash-outwash equivalent of the Kansan till and the early Kansan inter-till sands and gravels of eastern Nebraska." Frye and Leonard (1952, p. 86) list the Grand Island and Sappa as members in the Meade formation. The type section is the Platte River bluffs east of Hamilton bridge and in the Platte River valley southeast of Grand Island in Hall County, Nebr. (Lugn, 1935, p. 106–107).

The Grand Island formation includes (in this report) the outwash gravels of the Kansan glacier, and those gravels that are equivalent in age to the Kansan glacial stage but which were not directly associated with the ice sheet. The formation crops out in the northern and southeastern parts of the county.

The bulk of the sediments that can be clearly related to the Kansan glacial stage are the deposits of glacial outwash in the northern part of the county. The largest deposit is in sec. 7, T. 11 S., R. 12 E.; similar deposits are in sec. 16, T. 11 S., R. 12 E. Only small and scattered deposits remain to indicate the course of small outwash streams that flowed south in secs. 14, 15, and 22, T. 11 S., R. 10 E., and in Paw Paw Creek valley, before draining into Mill Creek. Other sediments, probably Kansan in age, are in secs. 9, 16, and 22, T. 14 S., R. 12 E.; secs. 35, and 36, T. 11 S., R. 11 E; sec. 33, T 12 S., R. 13 E; secs. 5 and 6, T. 13 S., R. 13 E; and in sec. 7, T.15 S., R. 12 E. The deposits listed here are shown on plate 2 and represent but a few that are probably of Kansan age. Other deposits that may be of Kansan age, not shown on plate 2 as part of the Grand Island formation but shown as part of the Sanborn formation, are present along almost all of the major streams and their tributaries.

The glacial outwash consists of fine to coarse sand, red-brown silt, various kinds of small rounded erratics, many clay balls, and fragments of limestone and chert. These deposits commonly overlie glacial till, but may be incorporated in it. Studies of other features could not be made because the larger deposits have been stripped for use as road metal.

The gravel deposits southeast of Eskridge consist of locally derived fragments of limestone, chert, and shale mixed with light-gray clay. The particles range in size from granule to cobble, and almost all are subrounded. Fusulinids and brachiopods, derived from local limestone and shale units, are incorporated in the gravels. The gravel is overlain by the Sappa formation.

The deposits of gravel along the north side of Mission Creek in sec. 33, T. 12 S., R. 13 E., and secs. 5 and 6, T. 13 S., R. 13 E., consist mainly of fragments of limestone. These deposits, which lie about 50 feet above the present stream bed, are probably Kansan in age (pl. 1). The outwash deposits average 6 feet in thickness. The Kansan gravels in the nonglaciated areas average about 3 feet in thickness.

An outwash deposit was sampled for a construction material (pl. 2, Qgi; and table 1, ca 2, and lg 3 and 4). Of the material in ca 2, 32.68 percent passed the No. 200 mesh sieve. Its use is, therefore, limited to road metal unless it receives further treatment. It has been used as surface material on light-traffic roads. The gravel southeast of Eskridge was not sampled because its small quantity and high clay content make it unsuitable as a construction material. Seeps are common at the base of these gravel deposits.

SAPPA FORMATION

The name Sappa formation was applied by Condra, Reed and Gordon (1947, p. 12 and 22) to deposits of late Kansan age. The type section of the formation is in the abandoned volcanic-ash mine of the Cudahy Packing Co. near Orleans in Sappa Township of Harlan County, Nebr. (Frye and Leonard, 1952, p. 87.) In Wabaunsee County, the deposits recognized as late Kansan in age and referred to as the Sappa formation crop out southeast of Eskridge. (See Qsa, pl. 2.) The Sappa is probably more extensive than is shown on plate 2, but its exact extent cannot be determined readily because it is covered by younger deposits.

An excellent exposure of this formation is in the SE¼ sec. 22, T. 14 S., R. 12 E. The Sappa consists of gray clay and gravelly clay and is mostly colluvium and alluvium. Locally a buried soil is present in its upper part. The upper part of the soil is a tough plastic blocky dark-gray to gray-brown clay that grades downward to a light gray-brown clay. Calcium carbonate is more abundant in the upper part, but it impregnates almost all of the soil, and extends down into the clay as fracture and as tubular fillings. The many tubular fillings are probably the result of decomposition and replacement of plant roots that formerly extended to this depth. V-shaped fractures that resemble frost wedges have developed in the upper part of the soil. They are also filled with clay impregnated by calcium carbonate. (See pl. 19B.)

The mollusks and ostracodes common in this buried soil have been dated as Kansan in age by Frye and Leonard (1952, p. 155). The mollusks listed in the Wabaunsee County exposure by Frye and Leonard (p. 159) are:

Vertigo ovata Say
Retinella electrina (Gould)
Physa anatina Lea
Lymnaea parva Lea
Hawaiia minuscula (Binney)
Deroceras aenigma Leonard
Carychuim perexiguum Baker
Planorbula vulcanata vulcanata Leonard
Oxyloma navarrei Leonard
Zonitoides arboreus Say
Vertigo gouldi (Binney)
Succinea avara Say
Stenotrema leai leai (Binney)
Pisidium compressum Prime
Lymnaea palustris (Müller)
Lymnaea reflexa Say
Lymnaea bulimoides Lea
Lymnaea caperata (Say)
Gyraulus similaris (Baker)
Euconulus fulvus (Müller)
Discus cronkhitei (Newcomb)
Aplexa hypnorum (Linne)

Ostracodes are also in the deposits but the genera have not been identified. Other exposures with a similar fauna are present in stream cuts in the SE¼ sec. 16, and NE¼SE¼ sec. 9, T. 14 S., R. 12 E. The buried soil of the Sappa formation is a relatively impervious clay. Therefore, when encountered in any type of excavation seeps are likely to be present at its top surface.

SANBORN FORMATION

The Sanborn formation was named by Elias (1931, p. 163) to include a loess containing some gravel and sand at the base. For many years the Sanborn formation was used to include all the Pleistocene units in northwestern Kansas. In 1947, Frye and Fent (p. 41–42) established three members in the formation, these are, in ascending order, the Loveland, the Peoria and the Bignell. In 1952, Frye and Leonard (p. 293) added the Crete member as the lowest member of the formation. The Nebraska Geological Survey (Condra, Reed, and Gordon, 1947, p. 12–13) lists these units as formations. The type locality of the Sanborn formation is in a canyon on the south side of the Arikaree River in the SW¼SE¼ sec. 17, T. 1 S., R. 41 W., Cheyenne County, Kans. (Frye and Leonard, 1952, p. 109).

The subdivisions of the Sanborn formation used by the Kansas Geological Survey are mappable in Wabaunsee County, but it was not deemed feasible to do so in the period of time allotted to this investigation. Therefore, the Sanborn formation as mapped includes materials deposited by wind, slopewash, and streams, and through the action of soil or mantle creep. The age of these deposits ranges from Illinoian to Recent. Some of the deposits of gravel included in the Sanborn formation are probably older than Illinoian age.

The formation is present on the crests of interstream areas, and along the margins of the terraces of the principal streams and in the valleys of their tributaries. It is also found on limestone benches at various levels above the streams.

In Wabaunsee County the deposits of the Sanborn formation that are believed to be early Illinoian in age (Crete) are dated primarily on their topographic position above the present stream bed. These deposits, which are present in the NE¼NW¼ sec. 22, T. 11 S., R. 12 E., and NE¼SE¼ sec. 26, T. 11 S., R. 12 E., are 30 to 40 feet above the present stream bed of Mill Creek. The presence of glacial erratics in these gravels limits their age to Kansan or post-Kansan. They are topographically lower than, but not overlain by, Kansan deposits in this area, and are higher than the Wisconsin deposits in the terraces along Mill Creek. It is assumed therefore that these deposits are Illinoian in age. In the SE¼ sec. 16, T. 14 S., R. 12 E., deposits of gravel (Crete) overlie the Sappa and underlie the Loveland. Other deposits of gravel that are probably Illinoian in age were lumped with the younger gravels because their age could not be determined definitely.

The gravels vary considerably in lithologic characteristics. The deposit in the NE¼NW¼ sec. 22, T. 11 S., R. 12 E., consists mainly of subangular fragments of chert intermixed with cobbles and smaller erratics. A firmly cemented conglomerate is near the base. Red-brown silty clay is a binder for the gravel particles. The material in the NE¼SE¼ sec. 26, T. 11 S., R. 12 E., consists of erratics and locally derived well-rounded to angular fragments of limestone and shale. Clay and fine sand are intermixed with the gravel; the clay acts as a binder and cement for zones in which crossbedding is well displayed. The deposit in the SE¼SE¼ sec. 16, T. 14 S., R. 12 E., consists of subangular fragments (from cobble to granule in size) of local limestone and chert in a gray-brown clay matrix. Similar deposits of chert gravel are present in the lower part of the Sanborn formation adjacent to the trib-

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utaries of Mill Creek. The gravel is generally concentrated on the western and northern slopes of Mill Creek, on the west slopes of Illinois Creek and Marais des Cygnes River, and in the upper regions of Middle Branch, Mill, and Spring Creeks. These gravel deposits range from 3 to 12 feet in thickness.

Loess of at least two ages (Illinoian–Loveland, and Wisconsin–Peoria) blanketed most of this area. Today only small remnants of these deposits remain. The thickest and most widespread deposits of loess are about 4 miles east by northeast of Eskridge; about 3 miles southeast of Alta Vista; 5 miles southeast of Keene; and about 3 miles east of Maple Hill. A thin loess of the Loveland is exposed in all these areas except the one east of Maple Hill. The Sangamon soil covers most of the Loveland loess. Another facies of late Illinoian deposition is colluvium and slopewash interfingered with loess and terrace deposits. Deposits of this type are common in Wabaunsee County, especially in the area southeast of Eskridge. They consist of small fragments of limestone and chert incorporated in a generally gray to gray-brown clay matrix. These deposits are overlain by loess of the Peoria. In most exposures the Sangamon soil is a well-developed red-brown oxidized clay that becomes a darker red brown in the upper part. In most exposures the calcium carbonate has been leached out; the small amount that is present is probably secondary and derived from the overlying material. Good exposures of the Loveland are in a streambank in the SE¼ sec. 21, T. 14 S., R. 12 E., a road ditch in the NW¼NW¼ sec. 36, T. 13 S., R. 12 E., and in a streambank in the NE¼SW¼ sec. 30, T. 10 S., R. 10 E. The Loveland deposits average about 4 feet in thickness.

In Wabaunsee County loess deposits of the Peoria are thicker and more widespread than those of the Loveland. East of Eskridge and Alta Vista, loess of the Peoria mantles the high divides. Good exposures of loess of the Peoria are in the NE¼SW¼ sec. 30, T. 10 S., R. 10 E; NW¼NW¼ sec. 36, T. 13 S., R. 12 E; SW¼SE¼NE¼ sec. 15, T. 11 S., R. 13 E; and in the SE¼ sec. 10, T. 13 S., R. 13 E. These deposits consist of tan-gray to gray blocky clay and silt that are locally iron stained. The upper part of the Peoria, which contains a modern soil, is leached of calcium carbonate. Where the deposit is thin, it is clayey and very plastic. The deposits of loess generally stand at 90° in a stream or road cut and average about 10 feet in thickness.

Material of the Sanborn moved by slopewash and mantle creep is on the slopes of almost all of the interstream areas, along the margins of terraces of the major streams, and in the valleys of their tributaries. It also is found on limestone benches at various levels above the streams. This material consists of a heterogeneous mixture of silt, clay, and granule to boulder-size fragments of local limestone and shale. Its thickness varies greatly, but it averages about 12 feet.

Most of the more recent stream-deposited material of the Sanborn formation is in the upper reaches of the tributaries of the principal streams where it is interfingered with colluvium. It consists of gray to red-brown silt and clay with lenses of angular to subangular chert and limestone particles, and ranges from a few inches to about 15 feet in thickness.

Five samples of gravel (table 1, cg 1, cg 6, cg 9, lg 2, and lg 6) from the Sanborn formation were tested. Results of tests of cg 1 show that the material is sound and that its abrasion loss is low. The sieve analyses show that the gravel (cg 1) is relatively coarse, and that it contains a high percentage of wash (material passing a No. 200 sieve). The mineral count of the coarse fraction of cg 8 shows all the particles to be chert, and that they do not exceed pebble size. The wash material is red-brown silt and clay, and is but a small percentage of the total sample. Lg 2 contains glacial erratics and particles of limestone, chert, and shale. The fraction of shale and finer materials is small; the bulk of this deposit consists of coarse gravel. Cg 6 and lg 6 are composed of fragments of limestone and chert—some of silt and clay size.

The deposit of gravel (Crete) in the NE¼NW¼ sec. 22, T. 11 S., R. 12 E., has been used locally for road metal (fig. 5).

Possible sources of mineral filler in the Sanborn formation are in the SE¼ sec. 10, T. 13 S., R. 13 E., and in the SW¼SE¼NE¼ sec. 15, T. 11 S., R. 13 E. At these locations the deposits, although not sampled, appear to contain a small amount of clay minerals and may be acceptable for use as a mineral filler.

Deposits of Sanborn clay and silt are considered by Frye, Plummer, Runnels and Hladik (1949, p. 80) to be most suitable for use in manufacturing a relatively coarse low-cost ceramic aggregate. Plummer and Hladik (1948, p. 94) report that tests of ceramic-slag aggregate by the Road Materials Laboratory of the Kansas Highway Commission indicate that the material is a superior aggregate. Its low density (and consequently small "dead load") means that it can be used without excessive reinforcement. In regard to its use as railroad ballast Plummer and Hladik (1948, p. 99, and table 5) list physical test data on four ceramic-slag samples of the Sanborn formation in Kansas and state that "Physical tests indicate that ceramic slag will exceed the minimum requirements by a considerable margin." The data indicates that certain deposits of the Sanborn formation will, when fired to a ceramic slag, be suitable as a concrete aggregate, as road metal, as mineral filler, and as aggregate for bituminous mats.

Seeps are common at the base of the gravels, at the upper contact of the buried Sangamon soil, and at the contact between unconsolidated and consolidated sediments.

TERRACE DEPOSITS

Terrace deposits of Quaternary age are in the valleys of most of the streams. (See table 2 and pl. 2.) Two well-defined terrace levels are mapped along the Kansas River. The older (higher) terrace is Illinoian in age and very likely correlates with the Buck Creek terrace east of Lawrence, Kans., as defined by Davis and Carlson (1952, p. 213). This terrace is shown on plate 2 by the symbol Qt–1. The more extensive modern (lower) Newman terrace is shown on plate 2 by the symbol of Qt–2. It is aggraded during severe floods. Terrace deposits along streams other than the Kansas River and Mill Creek are shown as Qt on plate 2. On the south side of the Kansas River the terrace deposits are as much as 4 miles wide. The Mill Creek terrace is not more than 1 mile wide, and those along other streams are not more than 0.5 mile wide.

Near Wabaunsee and north of Maple Hill, the older (Buck Creek) terrace contains sediments of Illinoian and Wisconsin age; elsewhere along the Kansas River, the exposures of the sediments of this terrace were not adequate for study. The gravel (Crete?) beneath the younger sediments consists of quartz sand and gravel and particles of limestone and chert. Small glacial erratics are common in this deposit. The silt overlying the gravel (Loveland) is generally tan brown, but grades to red brown in the upper part. It contains some fragments of limestone and chert, and, in the lower part, a thin lens of fine gravel. The upper reddish zone is probably the Sangamon soil. The overlying loess, described on page 108 is tan gray to tan and has a modern soil in its upper part.

The younger terrace consists mainly of silt and clay particles, with some lenses of chert sand and limestone gravel in the lower part. The silts and clays are generally gray to tan brown, and grade downward into gray brown. The terrace materials stand in a vertical bank; columnar jointing is common and small mollusks and pelecypods, probably of Wisconsin age, are abundant in the lower zone of the terrace along Mill Creek.

The younger terrace ranges in elevation above the stream bed from a few feet along the small streams to 60 or more feet along the Kansas River. The older terrace (Buck Creek) is about 60 feet above the stream bed at Wabaunsee, and about 50 feet above it north of Maple Hill. Along the Kansas River the Newman terrace is 10 to 15 feet above the present stream bed. South of Wamego the terrace deposits are about 50 feet thick. The 1951 flood of the Kansas River scoured into bedrock beneath the bridges built on this terrace (S. E. Horner, oral communication).

Three samples of terrace deposits were tested for a construction material. (See table 1 and pl. 2, lg 5 and cg 8.) Lg 5 is a limestone gravel; Cg 8 is a chert gravel. In both of the samples the material is coarse and contains about 7 percent wash. It consists of fragments of limestone and chert with some clay- and silt-size particles. The gravel has a low abrasion loss and appears to be sound.

Material in the sample (table 1, mf 1) obtained from the Mill Creek terrace southeast of Alma did not meet the requirements for mineral filler because of the high coefficient of cementation. Other terrace deposits also appear to contain a prohibitive amount of clay. However, the clayey deposits have been used as fill material in Wabaunsee County. The clay content appears to be sufficient to permit easy compaction, but not so high as to retain moisture and to cause soft spots or slippage.

TRAVERTINE

Three deposits of travertine formed by the precipitation of calcium carbonate from spring water were found in Wabaunsee County. (See table 2 and pl. 2.) The largest deposit is in the SW¼ sec. 12, T. 12 S., R. 10 E; the others are in the NE¼ sec. 21, T. 12 S., R. 10 E., and in the center of the SE¼ sec. 4, T. 14 S., R. 11 E. They are mapped on plate 2 as Qtr.

The material is a gray to light-gray soft and porous calcium carbonate. The deposit resembles a decomposed limestone, has steeply inclined bedding planes, and contains many imprints of leaves and twigs. Adjacent to the largest deposit, a small spring flows from the base of the Neva limestone member of the Grenola limestone which probably was the source of the material. The deposit in sec. 4, T. 14 S., R. 11 E., is near a spring at the base of the Cottonwood. The spring that formed the other deposit of travertine is inactive.

The largest deposit of travertine is about 12 feet thick; the other deposits are less than 6 feet thick. The deposits of travertine are too small to be a source of construction materials.

ALLUVIUM

Sediment deposited by a stream on its present flood plain is known as alluvium (table 2). The alluvium along the Kansas

River ranges in width from a narrow strip near Wamego to a maximum of 1.5 miles; it averages about 0.5 mile in width. The flood plain of Mill Creek extends from Maple Hill to a point 1 mile southwest of Volland. The part of Mill Creek extending from Maple Hill to the Kansas River is deeply incised in its terrace deposits and the alluvium is restricted to the stream channel. Small areas of alluvium were mapped along Mission Creek from a point near Keene eastward to the county line, along Dragoon Creek near Harveyville, and along the southern part of the Marais des Cygnes River. The alluvium along the smaller streams averages about 0.25 mile in width. These deposits are generally extensive on the inner curve of meanders.

Alluvium deposited in the channel of the Kansas River consists mostly of particles of sand and gravel size. The material deposited above normal water level is fine sand and silt with some lentils of coarse gravel. The sand consists mainly of quartz, but contains feldspar, acid igneous rocks, and a small amount of chalcedony. The silt is mixed with clay, and is tan brown to gray brown. The gravel lenses contain subrounded and rounded pebbles of local limestone and chert. Small amounts of clay, fine sand, and silt are present in the gravel lenses. Sand bars are common near the inner bank of a meander and they consist of fine to coarse sand mixed with some local material of gravel size.

The alluvium of the other streams consists of gray-brown silt and clay, but commonly contain thin lenses of chert and limestone gravel in the lower part. In some of the stream beds there are bars of limestone and chert gravel. The gravel particles range in size from granules to boulders, but those of pebble size are the most abundant.

Although accurate determinations of the thickness of the alluvium in the various streams could not be made, it is estimated that the thickness of Illinoian to Recent terrace deposits of the Kansas River is about 100 feet; of Mill Creek, 50 feet; of Mission Creek, about 30 feet; of Dragoon Creek, about 30 feet; and of the Marais des Cygnes River, about 25 feet.

Two samples of mixed aggregate (ma 1 and 2) were collected from alluvial deposits of Quaternary age. These samples are from the Kansas River at Wamego, Kans., (pl. 2); the test data are given on table 1. The material consists of granitic and siliceous particles of sand and gravel. Two samples of ma 1 were taken from the Kansas River at the same location. None of the samples tested were accepted by the State Highway Commission as a mixed aggregate for concrete. This material is acceptable as an aggregate for bituminous surface course, for cover material, and for surfacing. Most of the samples of alluvium from the Kansas River contain a large amount of chert or chalcedony.

A large quantity of mixed aggregate can be pumped from the alluvium at many places along the Kansas River. The alluvium along other streams in the county consists mainly of clay and silt.

Two samples of fine aggregate were obtained from the Kansas River. This material consists of fine particles of granitic sand. Fa 1, as shown on table 1, is acceptable only for sand and gravel for road surfacing; fa 2 was accepted by the State Highway Commission as a fine aggregate for concrete.

Test data for a sample of chert gravel, cg 7, are given in table 1. This material came from a creek bed and is commonly known as "creek gravel." (Because of the map scale, it was necessary to map this unit as terrace.) The count of the coarse fraction shows that almost all particles are chert and that there is only a trace of limestone. In comparison with other gravels this material is unusually coarse, although it contains a small amount of "wash." The abrasion loss is low according to Los Angeles test. There are similar deposits along Mill Creek from Alma to Alta Vista, Middle Branch Creek, Illinois Creek, and Spring Creek. The valleys of Horse and Rock Creeks contain small quantities of chert gravel.

The one sample of limestone gravel collected from the alluvium in Wabaunsee County (table 1, lg 1; and pl. 2) was from Mill Creek south of Maple Hill. It contains a little chert, but consists mainly of limestone fragments. The State Highway Commission (1945 specifications) accepted this material as a coarse aggregate for concrete, and as an aggregate for bituminous surface cover, bituminous concrete and sheet asphalt surfaces, cover material, and surfacing.

ECONOMIC GEOLOGY

SUMMARY OF CONSTRUCTION-MATERIAL RESOURCES

GEOLOGIC SOURCES

AGGREGATE FOR CONCRETE

Aggregate for concrete is classified as fine aggregate, mixed aggregate, and coarse aggregate in table 1 and on plate 2. In this report the distinction is arbitrarily based on the amount of the material retained on a standard No. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. The material is classified as a coarse aggregate if the coarse fraction is 15 percent or more by weight of whole sample; as a mixed aggregate if the coarse fraction is between 5 and 14 percent; as a fine aggregate if the coarse fraction is less than 5 percent. The three aggregates will be considered together because they are generally obtained by grading material to specifications by sweetening or screening.

The materials reported in this and other classifications are exposed at the surface or have soft or consolidated overburden sufficiently thin (less than 6 feet) to be economically developed.

The following stratigraphic units are actual or potential sources of aggregate for concrete:

Alluvium. Only the fine aggregate of the Kansas River sand and gravel (fa 2) was accepted for aggregate for concrete.

Sanborn formation. Clay and silt of the Sanborn, when fired to a ceramic-slag aggregate, may meet the requirements of an aggregate for concrete.

Limestones of the Permian and Pennsylvanian systems. Several limestones of the Permian and Pennsylvanian systems have been accepted solely for use as the coarse fraction in aggregate for concrete. The limestones sampled and tested are shown in table 1, and are: ls 21, Funston limestone; ls 22, Threemile limestone member of the Wreford limestone; ls 24, near the top of the Neva limestone member of the Grenola limestone; ls 25 and 26, Cottonwood limestone member of the Beattie limestone; ls 28, top of the Threemile limestone member of the Wreford limestone; and ls 38, 39, and 41, biostrome in the Bennett shale member of the Red Eagle limestone. The limestones rejected as coarse aggregate for concrete were ls 9 and 17, Cottonwood limestone member of the Beattie limestone; ls 24, Neva limestone member of the Grenola limestone; ls 27, Cottonwood limestone member of the Beattie limestone; ls 29, Fort Riley limestone member of the Barneston limestone; ls 31, Florence limestone member of the Barneston limestone; and ls 23, Five Point limestone member of the Janesville shale.

The Neva limestone member of the Grenola limestone consists of many beds of limestone, which are generally separated by shale. The test data indicated that each bed of limestone should be tested to determine its suitability for specific uses. Ls 24 shows that the top bed of the Neva is not acceptable for any construction use, whereas the bed of limestone beneath it is acceptable for many uses. The Cottonwood limestone member of the Beattie limestone is a thick bed of limestone whose test characteristics are generally assumed to be constant throughout its outcrop area. It was sampled, however, at 7 different places in Wabaunsee County and 3 of the 7 samples were rejected for use as construction stone.

The other 4 samples were accepted for many construction purposes, including coarse aggregate for concrete.

CHERT GRAVEL

Chert gravel defined in this report, is an unconsolidated sediment composed of angular to subangular gravel-size fragments of chert derived by the weathering and erosion of beds of cherty limestone. This material is generally incorporated in a matrix of silt-size particles that may also contain subrounded to rounded gravel-size fragments of local limestone, and a few erratic pebbles, cobbles, or boulders. The matrix may contain a small amount of fine sand and clay.

Chert gravel is used extensively in eastern Kansas as metal on light-traffic roads.

Alluvium. Test data for a sample of chert gravel, cg 7, are given in table 1. Similar deposits of chert gravel are in the valleys of Mill, Middle Branch, Illinois, Spring, Horse and Rock Creeks.

Sanborn formation. Three samples of chert gravel (cg 1, cg 6, and cg 9) were obtained from the Sanborn formation. (See table 1, and pl. 2.) Similar deposits lie adjacent to the tributaries of Mill Creek, and are generally concentrated on the western and northern slopes of Mill Creek; on the west slope of Illinois Creek and Marais des Cygnes River; and in the upper regions of Middle Branch, Mill, and Spring Creeks. Gravel deposits are in the basal part of the Sanborn formation near Horse and Rock Creeks.

Older gravels. Four samples of pre-Kansan chert gravels were collected for laboratory testing. (See cg 2, 3, 4, and 5 in table 1, and on pl. 2.) The samples consist mainly of chert. This material was accepted by the Road Materials Laboratory of the State Highway Commission of Kansas as material for calcareous binder and base course and as secondary metal on light-traffic roads. There are similar deposits in a strip 1 mile wide that extends from Alma to St. Marys, and adjacent to the valleys of Rock Creek, Horse Creek, and the Marais des Cygnes River.

LIMESTONE GRAVEL

Limestone gravel is defined as a sedimentary material of which more than 50 percent of the fragments are limestone. In Wabaunsee County, limestone gravel has been used as a secondary-road metal. The deposits shown on plate 1 contain a small amount of chert and a few erratics, but consist mainly of limestone fragments. The matrix contains some sand, silt, and clay size particles.

Alluvium. Test data for a sample of limestone gravel, lg 1, are given in table 1. This material is in gravel bars along Mill Creek south of Maple Hill where it has been used as a light-traffic road metal (pl. 8). It was accepted by the Road Materials Laboratory of the Kansas Highway Commission as a coarse aggregate for concrete, for cover material, and for surfacing. Similar gravel is found along Mission and Dragoon Creeks.

Terrace deposits. Test data on a sample of limestone gravel from terrace deposits are given on table 1 (lg 5). This material contains fragments of limestone and chert. It has been used on secondary roads in the county. Similar deposits are present along Mill Creek and most of its larger tributaries, and along the Marais des Cygnes River, and Rock Creek, and Horse Creek.

Sanborn formation. Test data for the samples of limestone gravel in the Sanborn formation (lg 2 and 6) are shown in table 1. lg 2 is a coarse gravel and contains fragments of erratics; lg 6 contains fragments of chert. Material from these deposits has not been exploited for any type of aggregate. Similar deposits of limestone gravel are along the lower part of Illinois Creek, the west side of the Marais des Cygnes River, and along Dragoon Creek and its tributaries.

Grand Island formation. Data for two deposits of limestone gravel of Kansan age are shown in table 1 (lg 3 and 4). Material from one of these deposits has been used as a road metal on secondary roads nearby. These deposits consist of coarse gravel with some fragments of erratics and shale. Deposits of limestone gravel of the same age are along the north side of Mission Creek.

MINERAL FILLER

Material composed mainly of silt-size mineral particles (50 percent or more of the material passing the No. 200 sieve) is classified in this report as mineral filler. Mineral filler material may have only a trace of sticks or other organic debris, but a small amount of fine sand or clay is permissable. W. E. Gibson of the Road Materials Laboratory of the State Highway Commission of Kansas states (oral communication) that material will qualify for mineral filler only if laboratory tests indicate a low coefficient of cementation.

Terrace deposits. The terrace deposits are not a possible source of mineral filler because of the excessive clay content.

Sanborn formation. The data on a sample obtained from the Peoria silt member, mf 1, are shown on table 1. The coefficient of cementation of this sample was too high to permit its use as a construction material. Deposits of loess about 3.5 miles east of Maple Hill and 5 miles southeast of Keene may have a sufficiently low clay content to permit their use as a mineral filler. The other loess deposits in the county contains a high percentage of clay size particles.

RIPRAP

Riprap, as defined in this report, is any material suitable for protecting earthen fills from erosion. The material should have a specific gravity of 2 or higher and must be relatively sound and free from cracks and other structural defects or impurities that would cause it to disintegrate through erosion, slaking, or freeze-and-thaw. The blocks should have approximately rectangular faces 7 inches or more in width.

Quaternary system. Some of the erratics in boulder dumps and other glacial deposits are suitable for use as riprap; quartzite, the most abundant erratic, is the best rock for that purpose. Quartzite boulders occur as field stones that range up to 6 feet or more in diameter (see pl. 19A), and their specific gravity is about 2.6. The areas in which these boulders are most numerous are mapped on plate 2. The largest concentration is in secs. 1 and 2, T. 11 S., R. 10 E. Boulders of all kinds have been used as wash check, but many of them, other than quartzite, disintegrate rapidly.

Permian system. Many limestones of the Permian system have been accepted for use as riprap. (See table 1 and pl. 2.) Ledges of acceptable rock are in the Cottonwood limestone member of the Beattie limestone (ls 10); Eiss limestone member of the Bader limestone (ls 19); Funston limestone (ls 21); Five Point limestone member of the Janesville shale (ls 23); Fort Riley limestone member of the Barneston limestone (ls 34); Red Eagle limestone (ls 40 and 41); and the Neva limestone member of the Grenola limestone (ls 43).

The upper part of the Neva limestone member (ls 15) is acceptable as stone for riprap on the basis of most of its physical tests. It is, however, platy, and does not meet the size requirement. The Cottonwood, as discussed previously, shows some variation in test characteristics but generally fulfills the requirements for riprap. The Five Point limestone member of the Janesville shale meets some of the requirements, but it has a low specific gravity (2.05) and the Los Angeles abrasion test indicates a 46 percent loss. The thick limestone beds of the Funston and Threemile have a very low specific gravity and a high percentage of loss in the Los Angeles abrasion test. The Neva limestone member of the Grenola limestone (ls 43), which has been accepted for use as riprap by the State Highway Commission, was used on the upstream face of the dam at Lake Wabaunsee. The Cottonwood limestone member of the Beattie limestone and the Threemile limestone member of the Wreford limestone also were used as riprap on the dam and in the spillway at Lake Wabaunsee. Only the upper 5 feet, the noncherty zone, of the Threemile limestone member was used. An inspection of this limestone indicates that it disintegrates from repeated freezing and thawing, and that many of the blocks have completely eroded after 12 years of service. The Rock Island Railroad has made extensive use of the Cottonwood limestone member as riprap along stream banks.

Pennsylvanian system. Of the limestones in the Pennsylvanian system that crop out in Wabaunsee County (table 2), only the Tarkio limestone member of the Zeandale limestone (table 1, ls 1 and 2) is considered adequate for riprap. It has been installed as riprap along the Kansas River, and also has been used in the county as riprap in spillways and on the upstream faces of dams. Field observation indicates that it is entirely suitable; laboratory tests show that it is sound, has a relatively high specific gravity, and is wear-resistant.

The Maple Hill limestone member of the Zeandale limestone (ls 3), Grayhorse (ls 12), and Brownville limestone members of the Wood Siding formation (ls 16) qualify as riprap on the basis of laboratory tests. The Maple Hill and Grayhorse limestone members are thin (only slightly more than 1 foot thick). They cannot, therefore, be quarried economically for riprap, but they might be used as wash check. The Brownville (ls 16) has been accepted on the basis of minimum laboratory test requirements, but field observation indicates that the limestone disintegrates rapidly.

STRUCTURAL STONE

Structural stone, as defined in this report, is any hard dense rock material of adequate bearing strength that can be quarried and cut to desired size and shape. Material classified as structural stone is acceptable for use in the construction of buildings, bridge piers and abutments, and retaining walls. Pleasing appearance is a requirement for building stone that is not important in other uses of the same rock.

Glacial erratics. Glacial erratics, in sizes ranging from pebbles to boulders, have been used in fireplaces, fences, retaining walls, porch supports, and foundations. Variation in color makes these erratics an attractive building stone.

Limestones of the Permian and Pennsylvanian systems. Many of the limestones cropping out in the county have been used as structural stone. Their use, however, has been governed principally by accessibility. Some structural stone has been brought into the county from other areas, and an appreciable quantity has been shipped out of the county. The following limestones have been used as structural stone:

Fort Riley limestone member of the Barneston limestone.
Crouse limestone.
Cottonwood limestone member of the Beattie limestone.
Neva limestone member of the Grenola limestone.
Five point limestone member of the Janesville shale.
Aspinwall limestone member of the Onaga shale.
Grayhorse limestone member of the Wood Siding formation.

Limestone of the Cottonwood and Neva has been widely used as a structural stone in Wabaunsee County and along the outcrop belt in the northern half of the state. The Red Eagle limestone south of Eskridge and the Tarkio limestone member of the Zeandale limestone have not been used as a structural stone in Wabaunsee County, but test data (table 1) indicate that they would be acceptable for this use. The chocolate-brown color that the Tarkio develops upon weathering is displeasing.

ROAD METAL

Road metal, known also as surfacing material, base-course material, crushed stone, and aggregate, is defined in this report as any material that may be applied to a road to improve the performance characteristics of that road. Many geologic materials fulfill this requirement; the list of such material will differ from one area to another.

Sources of aggregate for concrete (see p. 113). Mixed aggregate from alluvial deposits along the Kansas River has been used in large quantities as road metal in Wabaunsee County. It has been used extensively on the State highways, and some of the county roads are surfaced with a mixture of this material and crushed stone. Field observation indicates that combining mixed aggregate and crushed rock is successful. Rutting, washing, and washboarding, which developed on a road where mixed aggregate is used alone, are almost eliminated. Mixed aggregate was also used in the bituminous-mat placed on the streets in Alma. In table 1, ma 2, and fa 1 and 2 qualify as aggregate for bituminous-mat construction.

Chert gravel. Chert gravel from the older gravels, the Grand Island formation, the Sanborn formation, terrace deposits, and creek gravel have been used in large quantities as surface material for light-traffic roads. The performance of these gravels is generally good. Field observation indicates that the older chert gravels are best for road metal because they contain a clay binder and the particles of chert are slightly rounded and weathered. Creek gravel appears to be the least desirable because of its inaccessibility and the wide range in size of the constituent particles. Commercial quantities of older chert gravels can be obtained from the pre-Kansan Mill Creek channel which extends from Alma to St. Marys. Creek gravel and older gravels can be obtained from the southern part of the Mill Creek watershed.

Limestone gravel. Limestone gravel is used as a road metal on light-traffic roads and is obtained from alluvium, terrace deposits, Sanborn formation, and the Grand Island formation.

Glacial gravels. Glacial outwash (Grand Island formation) and glacial ice-contact deposits are used as surfacing material on light-traffic roads. Glacial ice-contact deposits have been extensively used in both Wabaunsee and Shawnee Counties, but to fulfill the specifications for road metal, the gravel must be screened to reduce the amount of oversize material. Field observation indicates that this material makes an excellent road metal.

Crushed rock. The limestones of the Permian and Pennsylvanian systems were discussed in the sections on riprap and structural stone. Limestone of the Fort Riley, Cottonwood, and Red Eagle has been used extensively as crushed stone for road metal. Other limestones in this county that have been used for this purpose are: Aspinwall, Threemile, Neva, Florence, and the Americus. All these limestones appear to be suitable for use on light-traffic roads.

Roca shale. One small quarry in the Roca shale is the source of shale used to surface a land-access road. The Roca shale at this locality contains a high percentage of silt, is very calcareous, and forms a self-bonding type of macadam. Other and similar shales in the Permian and Pennsylvanian systems also might be acceptable for this use.

CALCAREOUS BINDER

To be classified as calcareous binder, the material must be composed essentially of calcium carbonate and must be soft, and easily pulverized. Two geologic formations mapped on plate 2 as potential sources of calcareous binder are the Threemile limestone member of the Wreford limestone, and the Funston limestone.

Threemile limestone member of the Wreford limestone. The biostrome facies of the Threemile is a potential source of calcareous binder. This facies is in the NW¼NE¼ sec. 35, T. 13 S., R. 9 E. It is a soft massive bed of limestone about 32 feet thick.

Funston limestone. The biostrome facies of the Funston limestone is also a potential source of calcareous binder. It is in the NE¼ sec. 24, T, 13 S., R. 9 E., and extends northwest through secs. 11, 12, and 13, T. 12 S., R. 9 E. In most of this outcrop area it is a soft massive oolitic limestone about 22 feet thick.

SUBGRADE AND EMBANKMENT MATERIAL

This definition of subgrade and embankment material is adapted from the specifications compiled for the American Association of State Highway officials (1947, p. 37–38). Geologic materials which may be suitable for highway construction are:

Fine-granular unconsolidated sediments, including soil, of which 50 percent or more pass through a No. 200 sieve.

Coarse-granular unconsolidated sediments and broken or crushed consolidated rocks, of which at least 65 percent by weight is retained on a No. 200 sieve.

Broken or crushed rock.

All materials listed above are available in Wabaunsee County for the construction of subgrades and embankments. They may be obtained during excavation along the alinement of the structure or from areas nearby. The geologic formations from which these materials can be produced are:

Fine-granular sediments. The Sanborn formation and terrace deposits contain almost unlimited quantities of clayey silt. Glacial till consists mostly of clay, although it has a small amount of silt in some places.

Coarse-granular sediments. The alluvium in the valley of the Kansas River contains sand and gravel, and that of Mill Creek contains limestone and chert gravel. The gravels are in the basal part of the terrace deposits of these two streams and their tributaries. In most places the gravel is covered by 10 feet or more of silt and clay.

Broken or crushed rock. Most limestones of the Pennsylvanian and Permian systems are durable. The shales of the Pennsylvanian and Permian systems vary in their physical characteristics. The silty and calcareous shale parts of the Hughes Creek, Johnson, and Florena have been used in the contruction of embankments. Silty shales that may have sandy or clayey zones, but which are probably acceptable for this use, are given in the following list: (For details see discussion of each shale unit and its measured sections.)

Permian system
- Chase group
  - Oketo shale member of the Barneston limestone.
  - Matfield shale.
  - Havensville shale member of the Wreford limestone.

Permian system—Continued
- Council Grove group
  - Speiser shale.
  - Blue Rapids shale.
  - Easly Creek shale.
  - Stearns shale.
  - Florena shale member of the Beattie limestone.
  - Eskridge shale.
  - Roca shale.
  - Johnson shale.
  - Hughes Creek shale member of the Foraker limestone.
- Admire group
  - Hamlin shale member of the Janesville shale.
  - West Branch shale member of the Janesville shale.
  - Towle shale member of the Onaga shale.

Pennsylvanian system
- Wabaunsee group
  - French Creek shale member of the Root shale.
  - Dry shale member of the Stotler limestone.
  - Pillsbury shale.
  - Wamego shale member of the Zeandale limestone.
  - Willard shale.

The shales which are mainly clay and are, therefore, probably unacceptable as construction materials are as follows:

Permian system
- Chase group
  - Holmesville shale member of Doyle shale.
  - Havensville shale member of Wreford limestone.
- Council Grove group
  - Hooser shale member of the Bader limestone.
  - Bennett shale member of the Red Eagle limestone.
- Admire group
  - Hawxby shale member of the Onaga shale.

Pennsylvania system
- Wabaunsee group
  - Pony Creek shale member of the Wood Siding formation.
  - Friedrich shale member of the Root shale.
  - Harveyville shale member of the Emporia limestone.
  - Auburn shale.

COAL

Thin beds of coal crop out in Wabaunsee County, but none are of sufficient thickness to be of economic value; the thick beds of coal are at considerable depth. Almost all data on coal presented here was obtained from the publications cited.

In Wabaunsee County coal was first mined in 1887 from a shaft in two beds in sec. 11, T. 12 S., R. 10 E. A 40-inch bed was mined at the 1,680 foot level, and a 24-inch bed at the 1,708 foot level. These beds of coal are in the Cherokee group of the Pennsylvanian system. No data is available on the production, but information gathered from local inhabitants and the archives of the Alma newspaper indicates that this mining operation was not extensive and lasted only a few months.

In the early 1920's two 40-foot shafts were opened in the SW¼-NE¼ sec. 8, T. 14 S., R. 13 E., on a bed of coal from 17 to 34 inches thick in the West Branch shale member of the Janesville shale. The coal, which was used locally, has a high ash content, burns sootless, and has no block seams. The mines were closed mainly because of flooding; today, a windmill pumps water from one of the abandoned shafts (Schoewe, 1951, p. 60–62).

Schoewe lists the proved reserves of this coal bed as 80,000 tons; Abernathy, Jewett, and Schoewe (1947, p. 15, 18) list the potential reserves at 156 million tons. This bed of coal is probably correlative with one of the thin beds noted elsewhere in the West Branch. The beds of coal common in this shale in other part of the county are not more than 0.5 foot thick. The 17 to 34 inches of coal probably represents a local thickening of a bed.

The "Lorton" coal bed (in the upper part of the French Creek shale member of the Root shale) is 0.6 to 0.9 foot thick over most of the county. In the SW¼ sec. 28, T. 12 S., R. 13 E., this bed of coal was mined for local use (Crane, 1898, p. 137, Whitla, 1940, p. 61, and Schoewe, 1946, p. 133, and 137). The quantity mined is negligible and because of the thinness of the bed it is not considered a potential reserve.

PETROLEUM

Petroleum in economic quantities was first discovered in Wabaunsee County in 1949. Since that time, additional pools have been discovered. Almost all data on petroleum presented here were obtained from the publications cited.

One of the earliest exploratory wells in Wabaunsee County was drilled in 1892, to a depth of 2,006 feet. Between 1892 and 1949, 27 additional wells were drilled in the county. All except one were essentially dry holes. The only producing well during this period was one in sec. 9, T. 12 S., R. 10 E., producing 44,000 cubic feet of helium gas. In April 1949, the first producing oil well in the county was drilled by the Carter Oil Company. From 1949 to February 1, 1951, 65 wells were drilled and 4 more pools were discovered (Smith and Anders, 1951, p. 17). In Wabaunsee County the 6 pools that have been or are producing gas or oil are Alma, Davis Ranch, Davis Ranch East, Mill Creek, Newbury, and Woodbury. Their total production at the end of 1950 was 402,874 barrels of oil (Ver Wiebe and others, 1951, p. 167), and 44,000 cubic feet of gas.

Alma gas pool. In 1929 a producing helium gas well was drilled in the NW¼SE¼SE¼ sec. 9, T. 12 S., R. 10 E. According to Ockerman (1935, p. 71) this well produced 44,000 cubic feet of helium gas from a sandstone unit at 266 to 276 feet. No attempt has been made to develop this field.

Davis Ranch pool. The Davis Ranch pool, discovered in April, 1949 by the Carter Oil Company, inspired extensive exploration programs throughout the county. The first producing well (Carter Oil Company No. 1 Davis) is in the SW¼SE¼SW¼ sec. 33, T. 13 S., R. 10 E. A complete report on the geology of this pool was made by Smith and Anders (1951, p. 13–52). They reported that 18 of the 21 holes drilled in this pool by February 1951, were producers, and that the oil-bearing horizon is the Viola formation, at a depth of 3,201 feet, in all wells except one that produces from the undifferentiated limestone and dolomite beds of Silurian and Devonian age. The total production of this pool to the end of 1950 was listed as 385,911 barrels of oil (Ver Wiebe and others, 1951, p. 167).

Davis Ranch East pool. The one producing well on this pool which is on the downthrown side of a fault block that separates it from the Davis Ranch pool is in the SW¼SW¼SW¼ sec. 34, T. 13 S., R. 10 E. This well produced 7,599 barrels of oil from the Viola formation at a depth of 3,305 to 3,314 feet before it was abandoned in 1950 (Ver Wiebe and others, 1951, p. 125).

Mill Creek pool. The Mill Creek pool was discovered in 1950 in sec. 2, T. 12 S., R. 10 E., by the Skelly Oil Company. Its production is from the Viola formation at a depth of 2,923 feet. In 1950 the total production of this pool was 6,905 barrels of oil. At the end of 1951, 4 wells had been drilled of which 3 were producers (Ver Wiebe and others, 1951, p. 167).

Newbury pool. The Newbury pool was discovered in 1950 in sec. 11, T. 11 S., R. 11 E., by the Skelly Oil Company. The only well producing at the end of 1950 was from the Viola formation at a depth of 2,901 feet. Its production during 1950 was 2,459 barrels of oil (Ver Wiebe and others, 1951, p. 167).

Woodbury pool. In 1950 the Woodbury pool was discovered in the SE¼NW¼NE¼ sec 11, T. 15 S., R. 10 E., by the Carter Oil Company. Only one well is producing from this pool, which is in the Viola formation at a depth of about 3,335 feet. No data on production is available.

AGRICULTURE LIME

Although lime for use on acidic soil has been produced in small quantities in Wabaunsee County, most lime for agricultural use has been imported from southeastern Kansas. Agriculture lime in Kansas is generally a byproduct from a quarry that is producing crushed rock for road surfacing.

In regard to specifications for agriculture lime, Myers, Clapp, and Davidson (1937, p. 3–4) state:

"Good quality crushed limestone should have a calcium carbonate equivalent (acid correcting power) between 90 and 100 percent. * * * The purity of the sample should always be considered when purchasing or using lime. If two samples of equal fineness, one having a purity of 100 percent and the other of 75 percent, are being considered, it should be kept in mind that 1,500 pounds of the former material is equivalent to 2,000 pounds of the latter. A greater quantity of 75 percent lime must be purchased, thereby increasing the cost of hauling and applying; hence the 75 percent material would actually be worth less to the farmer than three-fourths as much of the 100 percent sample."

Crushed limestone of the following specifications as to fineness is recommended as best meeting the desired end: 100 percent to pass through a 10-mesh sieve or 40 percent to pass through a 100-mesh sieve.

In Wabaunsee County agriculture lime has been obtained from two quarries—one in the biostrome of the Bennett shale member of the Red Eagle limestone in the NE¼NW¼ sec. 31, T. 14 S., R. 12 E., and one in the Cottonwood limestone member of the Beattie limestone in the SE¼ sec. 33, T. 13 S., R. 11 E. (See p. 61 and 74.) The $CaCO_3$ content of the limestone in the biostrome of the Bennett is 82.9 percent; that of the Cottonwood is 85.7 percent. The fineness of the material can be controlled by crushing.

The Fort Riley limestone member of the Barneston limestone, northeast of Alta Vista, reportedly has a $CaCO_3$ content of about 90 percent.

Other limestones in the county, will probably meet the requirements of agriculture lime, but no test data are available.

STRATIGRAPHIC SECTIONS

Each geologic formation or member that crops out in Wabaunsee County, Kans., is represented here by at least one measured section. The sections were measured by Melville R. Mudge and Robert H. Burton.

1. *Section of a Quaternary terrace deposit in a streambank in the SW¼SE¼NW¼ sec. 23, T. 12 S., R. 10 E.*

	Feet
Soil, silty, dark-gray to black; grades into underlying silt	2.8
Silt, clayey, gray-brown; stands vertically, has crude columnar joints, and the lower 8 feet has a bedded appearance; contains many carbon stains, and roots penetrate nearly to the base; small pelecypods and gastropods common	14.5

	Feet
Silt, clayey, gray-brown to tan, thin-bedded to crossbedded; contains a lens of fine gravel in the upper 8 feet, thick gravel lenses in the lower 7 feet, rounded to subangular particles of limestone and chert, and commonly has limonite- and carbon-stained areas; small white thin-shelled pelecypods and gastropods common	15.4
Thickness exposed	32.7

Base covered by water.

2. *Section of a Quaternary terrace deposit in a streambank in the NE¼SW¼ sec. 30, T. 10 S., R. 10 E.*

	Feet
Sanborn formation:	
Peoria silt member:	
Soil, silty, dark-gray; stands vertically; grades into underlying silt	5.1
Silt, clayey, tan-gray; weathers tan; stands vertically; contains limonite-stained areas, slightly leached	6.2
Loveland silt member:	
Silt, clayey, red-brown; stands vertically; carbon and iron stains common; pipettes and root fragments present; a few scattered fragments of limestone; thin lenses of fine gravel in lower part which are composed predominantly of particles of quartz and limonite, and small erratics	11.8
Crete sand and gravel member:	
Gravel, silt, and fine sand; lenses of sand and gravel with silt interbedded; gravel consists mainly of quartz; some angular chert and rounded limestone fragments, and erratics; a lens of sand and glacial erratics near the base is underlain by fine sand; some clay balls	4.0
Thickness exposed of Sanborn formation	27.1

Base covered.

3. *Section of the Sanborn formation down into the Grand Island formation in a streambank in the SE¼SW¼ sec. 22, T. 14 S., R. 12 E.*

Soil, silty, noncalcareous, dark-gray, blocky to granular; 1.5 feet thick.

	Feet
Sanborn formation.	
Loveland silt member:	
Clay, calcareous, tan mottled with gray-brown, blocky, limonite-stained; numerous calcareous nodules	7.6
Unconformity.	
Sappa formation:	
Caliche zone, very calcareous, light-gray; lenticular; thin blue-gray clay lentils common; some limestone fragments; limonite nodules common; minute white-shelled pelecypods and gastropods abundant	0–2.5
Clay, noncalcareous, dark-gray, blocky; mottled with brown; some calcareous nodules in lower part	1.2
Clay, calcareous, tan-gray; calcareous nodules abundant; some limonite and carbon stains	1.3

	Feet
Grand Island formation:	
Clay, calcareous, tan-gray to gray-brown; many calcareous nodules; limestone fragments abundant in lower part	1.7
Thickness exposed	11.8–14.3

Base covered.

4. *Section of the Sanborn formation (Loveland and Peoria silt members) in a road cut in the NW¼NW¼ sec. 36, T. 13 S., R. 12 E.*

	Feet
Sanborn formation:	
Peoria silt member:	
Clay, silty, tan-gray to gray, blocky, very plastic; iron stains abundant; modern soil developed in the upper 2.5 feet	4.9
Loveland silt member:	
Clay, silty, red-brown, blocky, very plastic, iron-stained, (represents the Sangamon soil that is developed on the Loveland) color changes to dark brown in upper part	1.8
Thickness exposed of Sanborn formation	6.2

Base covered.

5. *Section from the Sanborn formation (Loveland silt member into the Grand Island formation in a streambank in the SE¼SE¼ sec. 16, T. 14 S., R. 12 E.*

	Feet
Sanborn formation:	
Loveland silt member:	
Clay, red-brown, blocky, very plastic; some limestone fragments	5.0±
Crete sand and gravel member:	
Gravel, clayey; gray-brown clay matrix; fragments of semi-angular cobble- to granule-size limestone and chert; some carbon and iron stains	2.6
Unconformity.	
Sappa formation:	
Clay, silty, gray-green to tan-brown, blocky; leached; $CaCO_3$ deposited in lower part; some limestone fragments; mollusks rare	5.2
Grand Island formation:	
Gravel, tan-brown clay matrix; semiangular chert and limestone fragments from cobble- to granule-size; some clay balls; fragments of Permian brachiopods and fusulinids in gravel	2.7
Unconformity.	
Foraker limestone (Permian): Hughes Creek shale member.	
Thickness exposed	15.5

Base covered.

6. *Section of the Barneston limestone in an old quarry in the SE¼NE¼ sec. 35, T. 13 S., R. 8 E.*

Soil, silty, dark-gray; about 1 foot thick.
Barneston limestone:

Fort Riley limestone member:	*Feet*
Limestone, hard, tan, massive; weathers gray and blocky; porous near top; some limonite stains; brachiopods, crinoid columnals, and echinoid spines; limestone known as "rimrock" and forms prominent hillside bench	3.2
Shale, very calcareous, tan, massive to platy; some limonite streaks; contains pelecypods	2.6
Limestone, soft, gray, massive; weathers blue gray; contains some small calcite crystals, brachiopods, bryozoans, crinoid columnals, and echinoid spines	2.5
Thickness exposed	8.3
Florence limestone member:	
Limestone, clayey, dolomitic, gray, massive; weathers blue gray and shaly; chert lens in middle of lower part; brachiopods, crinoid columnals and echinoid spines present	10.9
Limestone, hard, tan-gray, massive; weathers tan; contains 2 chert lenses and some chert nodules; crinoid columnals, echinoid spines, bryozoans, and brachiopods present	3.4
Limestone, hard, dense, dark-gray, massive; weathers blocky	.2
Limestone, clayey, soft, tan, massive; weathers shaly; some iron stains; brachiopods, echinoid spines, and bryozoans present	1.3
Limestone, hard, gray, massive; weathers tan gray; numerous chert lenses and nodules; some iron stains; numerous calcium carbonate streaks; brachiopods, echinoid spines, crinoid columnals and bryozoans	16.9
Thickness exposed	32.7
Total thickness of Barneston limestone exposed	41.0

Base covered.

7. *Section from the Fort Riley limestone member of the Barneston limestone into the Blue Springs shale member of the Matfield shale in a streambank in the SW¼NW¼NE¼ sec. 19, T. 13 S., R. 9 E.*

Soil, silty, gray; weathered limestone about 1 foot thick.
Barneston limestone:

Fort Riley limestone member:	*Feet*
Limestone, hard, dense, gray; weathers tan gray and blocky contains some chert nodules, brachiopods, and echinoid spines. Thickness exposed	1.5

	Feet
Barneston limestone—Continued	
Oketo shale member:	
Shale, silty, calcareous, tan gray, thin-bedded to blocky; weathers tan; crinoid columnals present	2.2
Shale, silty, very calcareous, gray, blocky; weathers tan gray; small limonite stains common; echinoid spines present	1.1
Thickness	3.3
Florence limestone member:	
Limestone, hard, dark-gray, blocky; one chert band in middle part, chert nodules common throughout; some iron stains; contains crinoid columnals, brachiopods, and echinoid spines	1.8
Limestone, clayey, dolomitic, gray to tan, massive; weathers gray and in irregular blocks; some chert nodules near base; brachiopod fragments in thin zones near top; contains brachiopods, and echinoid spines	3.4
Limestone, hard, gray to dark-gray, massive; many chert lenses and nodules; contains echinoid spines, crinoid columnals, and bryozoans	3.5
Limestone, hard, gray to dark gray; weathers gray to tan; massive part weathers blocky; many chert lenses and nodules; limestone most massive near top; contains brachiopods, crinoid columnals, and echinoid spines	23.4
Limestone, medium-hard, dense, clayey, gray, massive; weathers light gray, conchoidal fracture; many chert nodules in upper part; contains crinoid columnals, brachiopods, bryozoans, and echinoid spines	3.5
Shale, silty, calcareous, greenish-black, thin-bedded to blocky, lenticular; seepage zone; contains pelecypods	.2
Limestone, soft, clayey, gray to light-gray, speckled; conchoidal fracture; iron stained	1.8
Thickness	38.0
Total thickness of Barneston limestone exposed	42.4
Matfield shale:	
Blue Springs shale member:	
Shale, silty, calcareous, gray-green to light-green, thin-bedded to blocky; iron stains on fracture planes	6.9
Shale, silty, calcareous, thin-bedded, gray-green to maroon mottled with gray-green; becomes purple and green at the base	1.6
Shale, very calcareous, blocky; grades downward from gray green to lilac to gray green	2.0
Shale, silty, calcareous, gray-green; weathers light green, blocky; some limonite stains	.1
Shale, silty, calcareous, gray, blocky; weathers gray green	.1
Shale, silty, calcareous; grades downward from maroon to gray green	1.6
Shale, silty, calcareous, gray-green, blocky; weathers light green	.9

	Feet
Matfield shale—Continued	
Blue Springs shale member—Continued	
Shale, silty, very calcareous, blocky; maroon with a purple tint at the base	1.2
Shale, silty, very calcareous, gray-green, thin-bedded to blocky; weathers light green	.7
Shale, silty, very calcareous, maroon, blocky	.5
Shale, silty, very calcareous, gray-green, blocky; with two purple bands	.5
Shale, silty, calcareous, maroon, thin-bedded to blocky; weathers light maroon with a purple tint in the upper part	.5
Shale, silty, very calcareous, purple, blocky, lenticular	.3
Shale, calcareous, gray-green, nodular to thin-bedded; weathers light green, numerous purple-stained bands; some iron stains	1.3
Shale, silty, very calcareous, blocky, purple to maroon in upper part grading down into gray green	1.5
Shale, silty, calcareous, red-brown, thin-bedded; weathers light green to tan with some gray lenses, some maroon stains	.2
Shale, very silty, calcareous, tan to green, purple stained, blocky, lenticular; iron stains on bedding planes; contains some small clay balls which weather lighter than the matrix	.8
Shale, very calcareous, light-green, blocky, lenticular; weathers nodular	1.2
Shale, very calcareous, tan-gray, blocky, porous; weathers tan	.8
Shale, silty, calcareous, gray, thin-bedded; weathers light gray; some limonite stains	.3
Shale, clayey, noncalcareous, tan-gray, blocky	.3
Thickness exposed	23.3

Base covered.

8. *Section of the Matfield shale in a road cut in the SE¼SE¼ sec. 27, T. 13 S., R. 9 E.*

Base of Florence limestone member of the Barneston limestone.

	Feet
Matfield shale:	
Blue Springs shale member:	
Shale, silty, calcareous, green, thin-bedded; weathers light green; calcium carbonate on fracture planes	10.2
Covered interval	16.9
Shale, silty, calcareous, green, blocky; some cone-in-cone structure	1.3
Shale, calcareous, maroon, blocky; clayey with some silt; some cone-in-cone structure	1.0
Shale, clayey, calcareous, gray-green, thin-bedded; weathers green; calcareous nodules in lower part; some limonite stains	1.4
Thickness	30.8

	Feet
Matfield shale—Continued	
Kinney limestone member:	
(Upper limestone absent).	
Shale, silty, calcareous, tan-gray, thin-bedded, limonite stained; some calcareous nodules; brachiopods abundant	11.9
Limestone, hard, red-brown; weathers tan; irregular clay inclusions; some iron stains; microfossils very abundant	1.1
Limestone, hard, tan-gray; weathers tan and blocky; limonite nodules and inclusions present; contains brachiopods and small crinoid columnals	1.5
Limestone, clayey, soft, tan; weathers tan gray; contains brachiopods and pelecypods	.6
Thickness	15.1
Wymore shale member:	
Shale, silty, calcareous, tan, thin-bedded to platy; many very calcareous lenses; some limonite stains	5.6
Shale, silty, very calcareous, tan, blocky	1.7
Shale, clayey, calcareous, tan-gray, thin-bedded; weathers tan; heavily limonite stained at the base	.7
Shale, silty, calcareous, green, blocky	1.4
Shale, silty, calcareous, gray-green, blocky; weathers light green; iron stains on bedding and fracture planes	2.7
Shale, silty, calcareous, gray-green, thin-bedded to blocky	1.1
Shale, silty, calcareous, maroon, blocky	2.1
Shale, clayey, noncalcareous, dark-gray, blocky; weathers gray green; calcareous nodules in lower part	1.4
Shale, silty, calcareous, maroon, blocky	2.6
Thickness exposed	19.3
Total thickness of exposed Matfield shale	65.2

Base covered.

9. *Section from the Wreford limestone down into the Speiser shale in a road cut in the SW¼NW¼ sec. 10, T. 14 S., R. 10 E.*

Soil, silty, clayey, gray-brown, granular; some limestone and chert fragments about 2 feet thick.

	Feet
Wreford limestone:	
Schroyer limestone member:	
Limestone, medium-hard, gray, massive; weathers tan and blocky; some iron stains; many thick chert lenses, which weather blocky and in small chips, cover most of the exposures; contains brachiopods and crinoid columnals	5.7
Limestone, hard, dense, gray, massive; weathers tan gray and blocky to thin-bedded; fossil fragments abundant	1.2
Thickness exposed	6.9

	Feet
Wreford limestone—Continued	
Havensville shale member:	
Shale, calcareous, thin-bedded to blocky; tan-gray; clayey with some silt; weathers tan; some limonite stains; calcareous plates in upper part	8.8
Limestone, medium-hard, gray; porous, massive; weathers light gray and platy; clay balls common; fossil fragments abundant	2.8
Shale, clayey, calcareous, tan-gray, blocky; weathers tan; some limonite stains; some calcareous nodules in the upper part	4.3
Thickness	15.9
Threemile limestone member:	
Limestone, medium-hard, tan-gray, massive; weathers gray and platy; two chert lenses present; iron stains common; some fossils	1.9
Chert, dense, hard, light-gray to gray; weathers blocky and in irregular chips; conchoidal fracture; some iron stains; some fossil fragments	.3
Limestone, medium-hard, light-gray; weathers blocky; cavernous and porous in middle part; contains some chert nodules, iron stains, and fossil fragments	6.8
Chert, dense, hard, light-gray; weathers blocky; some iron stains	.1
Limestone, soft, tan; weathers tan gray and blocky; iron stains; some fossil fragments	1.2
Chert, dense, hard, light-gray to gray; mottled with dark gray, weathers light gray and into small blocks and chips; conchoidal fracture; some iron stains and fossil fragments	.5
Limestone, medium-hard, tan-gray, massive; weathers gray, blocky, and irregular; some limonite-stained areas	.8
Chert, dense, hard, gray mottled with dark gray; weathers light gray to gray; conchoidal fracture; some iron stains; some fossils on upper surface	.5
Limestone, medium-hard, tan-gray; weathers gray and into irregular plates and blocks; some fossil fragments	.3
Shale, silty, calcareous, tan-gray, thin-bedded; mottled with dark gray; weathers tan; some iron stains, and fossil fragments	.8
Limestone, medium-hard, gray, massive; weathers tan-gray and blocky; two thick chert lenses present, some fossil fragments	1.6
Thickness	14.8
Total thickness of exposed Wreford limestone	37.6
Speiser shale:	
Shale, silty, calcareous, tan-gray, thin-bedded; dark-gray areas; weather tan; becomes very calcareous in lower part; fossiliferous	3.3
Shale, silty, calcareous, tan-gray, blocky; weathers tan	1.1

	Feet
Speiser shale—Continued	
Shale, clayey, calcareous, gray-green, thin-bedded to blocky; iron stains abundant on fracture planes; lower part more resistant to weathering	2.2
Shale, clayey, slightly calcareous, gray-green; some silt; weathers light green; blocky; iron stains on some fracture planes	3.9
Shale, clayey, calcareous, maroon, blocky; mottled with light maroon and gray-green; some iron stains	5.7
Thickness exposed	16.2

Base covered.

10. *Section of the Wreford limestone in a road cut in the SW¼NW¼ sec. 10, T. 13 S., R. 9 E.*

Soil, silty, black; contains chert fragments; about 1.5 feet thick.

Wreford limestone:

	Feet
Schroyer limestone member:	
Limestone and chert lenses, alternating; slumped and eroded	±3.0
Chert, hard, dense, gray, blocky, lenticular; weathers gray orange	.5
Limestone, medium-hard, tan, blocky and porous, lenticular, iron-stained; weathers gray; contains crinoid columnals, echinoid spines, and brachiopod fragments	.3
Chert, hard, dense, gray, lenticular; weathers gray orange and blocky	.3
Limestone. hard, tan, thin-bedded; weathers tan gray; many calcium carbonate nodules and a few chert nodules; brachiopods and echinoid spines	1.0
Limestone, medium-hard, tan, blocky; weathers light gray; lenticular chert bed in middle, some chert nodules at the base; iron stained; brachiopods and crinoid columnals	.5
Limestone, hard, tan brown; weathers porous; many calcite-lined cavities	1.0
Limestone, soft, tan-brown, cavernous; weathers tan and irregular	.9
Limestone, hard, tan-brown, porous, lenticular; weathers tan	.4
Thickness exposed	7.9
Havensville shale member:	
Shale, silty, calcareous, gray-green, thin-bedded; weathers light gray; black specks present throughout	1.4
Limestone, hard, tan, massive; weathers platy; contains brachiopods, echinoid spines, and crinoid columnals	1.8
Shale, clayey, calcareous, gray-green; some silt; weathers light gray green; thin-bedded; calcium carbonate stains on fracture planes	2.9
Covered interval	2.5
Shale, clayey, noncalcareous, gray-green, thin-bedded to blocky; weathers light gray; limonite stains on bedding planes; small calcareous nodules in upper part	9.8
Thickness	18.4

Wreford limestone—Continued	Feet
Threemile limestone member:	
Limestone, medium-hard, light-gray massive; weathers tan gray; massive 0.5 foot chert lens in middle, chert nodules throughout	2.4
Limestone, medium-hard, light-gray, massive; weathers tan gray; porous in middle; limonite stains in some zones; contains echinoid spines and brachiopod fragments	1.9
Chert, hard, dense, gray, lenticular; weathers tan to gray	.2
Limestone, soft, light-gray, lenticular; weathers tan gray; Brachiopod fragments	.4
Chert, hard, dense, dark gray, blocky, lenticular; weathers gray to tan	.2
Limestone, hard, dense, gray, lenticular; weathers tan gray and to irregular blocks	.5
Chert, hard, dark-gray to tan, blocky, lenticular, iron-stained	.4
Limestone, hard, gray, lenticular; weathers tan gray and blocky; some chert nodules, crinoid columnals, bryozoans and echinoid spines and brachiopods	.5
Shale, silty, very calcareous, tan-gray; weathers tan; thin-bedded to massive in upper part; contains brachiopods, crinoid columnals and bryozoans	.5
Limestone, hard, light-gray; weathers tan gray; some chert nodules, crinoid columnals, and echinoid spines	.7
Chert, hard, dense, gray, lenticular; weathers gray to tan; some bryozoan, echinoid spines and crinoid columnals	.4
Thickness exposed	8.1
Total thickness of exposed Wreford limestone	34.4

Base covered.

11. *Section of the Wreford limestone in a streambank in the SW¼SE¼ sec. 26, T. 13 S., R. 9 E.*

Wreford limestone:	Feet
Schroyer limestone member; badly weathered	5±
Havensville shale member:	
Shale, silty, calcareous, tan-gray to tan, thin-bedded; thin limestone lens near top. Thickness exposed	9.8
Threemile limestone member:	
Limestone, soft, light-gray, massive, porous and cavernous; weathers gray and blocky; limonite stains in pores; contains bryozoans, brachiopod fragments, gastropods, microfossils and algae; forms a prominent hillside bench	23.4
Chert, hard, dense, light-gray to gray, blocky	.2
Limestone, soft, tan; many limonite-stained areas	1.4
Chert, tan to gray; nodular; very lenticular	.2
Limestone, soft, tan gray, massive, porous; weathers blocky	1.8
Chert, gray, limonite-stained; weathers light gray to gray, and to small irregular blocks	.1
Limestone, soft, tan; weathers platy	1.1

Wreford limestone—Continued	Feet
Threemile limestone member—Continued	
Chert, gray to dark-gray; blocky, lenticular	0.3
Limestone, soft, light-gray to gray, limonite-stained; weathers blocky; contains chert nodules	1.1
Chert, gray to dark-gray, blocky, limonite-stained	.5
Limestone, medium-hard, dense, gray, massive; weathers light gray and shaly	1.8
Limestone, hard, crystalline, gray; weathers light gray; a thin chert lens in middle; microfossils abundant	.4
Chert, dark-gray, lenticular; weathers in large blocks	.6
Thickness exposed	32.9
Total thickness of exposed Wreford limestone	47.7

Base covered.

12. *Section from the Threemile limestone member of the Wreford limestone down into the Blue Rapids shale in a road cut in the SW¼SW¼ sec. 31, T. 13 S., R. 11 E.*

Soil, silty, dark-gray; chert and limestone fragments; about 1 foot thick.

Wreford limestone:	
Threemile limestone member:	Feet
Limestone, hard, white, massive; weathers tan-gray and blocky	1.9
Chert, light-gray to dark-gray, lenticular, iron-stained; weathers tan-gray and blocky; bryozoans and fossil fragments abundant on top surface	.3
Limestone, medium-hard, light-gray; weathers tan gray and blocky; contains crinoid columnals, bryozoans, and brachiopod fragments	.8
Chert, tan-gray to dark-gray, lenticular; weathers to irregular blocks; bryozoans, brachiopod fragments on top surface	.3
Limestone, hard, tan-gray, lenticular	.2
Chert, tan-gray to dark-gray, lenticular; weathers to irregular blocks; brachiopod fragments on top surface	.3
Limestone, hard, tan-gray, lenticular; weathers tan; some chert nodules; contains crinoid columnals, bryozoans, and brachiopods	.3
Shale, silty, very calcareous, gray-brown, thin-bedded; weathers tan; contains brachiopods and crinoid columnals	.6
Limestone, hard, dense, tan-gray; weathers tan, and platy; some crinoid columnals	.2
Chert, gray to dark-gray, lenticular; weathers to small blocks	.3
Limestone, medium-hard, tan-gray, lenticular; weathers tan and blocky; contains chert nodules, crinoid columnals and echinoid spines	.4
Chert, tan to dark-gray, massive; weathers blocky; some limestone; iron-stained; bryozoans, crinoid columnals and echinoid spines on top surface	.6

	Feet
Wreford limestone—Continued	
Threemile limestone member—Continued	
Limestone, hard, tan-gray, massive, lenticular; weathers tan and blocky; contains crinoid columnals and brachiopod fragments	0.6
Total thickness of exposed Wreford limestone	6.8
Speiser shale:	
Shale, silty, calcareous, gray-brown, thin-bedded to platy; weathers tan gray; brachiopods abundant, crinoid columnals common	2.5
Limestone, hard, dense, tan gray; weathers tan and blocky; echinoid spines present	.8
Shale, silty, calcareous, tan-gray, thin-bedded, lenticular; weathers tan	.1
Limestone, soft, tan-gray, blocky to thin-bedded; weathers tan	.2
Shale, silty, slightly calcareous, gray-green, blocky; weathers light green; contains limonite streaks and calcareous nodules	2.8
Shale, slightly silty, blocky; calcareous to very calcareous in middle part; maroon, mottled with green in upper and middle parts	8.7
Shale, silty, calcareous, thin-bedded, very light green; mottled with light maroon in middle; weathers nearly white; wavy calcareous bed at top	2.6
Total thickness	17.7
Funston limestone:	
Limestone, soft, tan-gray, porous; weathers tan, and blocky; 3 limestone beds separated by 2 very thin shales	0.8
Shale, silty, calcareous, tan, thin-bedded	.1
Limestone, soft, tan, massive, finely porous; weathers tan gray and blocky	2.5
Shale, silty, gray-brown, blocky to thin-bedded; noncalcareous except a very calcareous zone near top; weathers tan gray; iron stains on bedding and fracture planes	4.9
Shale, silty, calcareous, gray-brown to dark-gray, thin-bedded; weathers tan gray to gray; iron stains on fracture planes	5.9
Shale, silty, calcareous, tan-gray, thin-bedded to platy; weathers tan; very calcareous in lower part; contains pelecypods, brachiopods, and bryozoans	2.2
Total thickness	16.4
Blue Rapids shale:	
Shale, silty, calcareous, tan-gray, thin-bedded to platy; weathers tan; alternating thick and thin beds	1.4
Shale, clayey, calcareous, dark-gray, thin-bedded; weathers gray to gray green; iron stains on fracture planes	.2
Shale, silty, calcareous, tan-gray, thin-bedded to platy; weathers tan	1.6
Thickness exposed	3.2

Base covered.

13. *Section from the upper part of the Threemile limestone member of the Wreford limestone down into the middle part of the Speiser shale in a road cut in the NW¼NE¼NE¼ sec. 1, T. 14 S., R. 11 E.*

	Feet
Wreford limestone:	
Threemile limestone member:	
Limestone, medium-hard, partly dense, tan to light-gray, massive, porous, weathers blocky; contains many chert nodules and lentils; echinoid spines, crinoid columnals, bryozoans and fossil fragments present; soft fossiliferous zone in upper part	15.6
Shale, silty, calcareous, tan, thin-bedded	2.0
Limestone, hard, light-gray, massive; weathers blocky; complete and fragmentary crinoid columnals, echinoid spines, and bryozoans present	2.4
Limestone, tan; weathers blocky; contains two chert lenses	1.6
Shale, silty, calcareous, tan-gray, thin-bedded	.7
Limestone, hard, tan-gray; weathers tan and blocky; chert nodules abundant; some fossil fragments	3.9
Total thickness of exposed Wreford limestone	26.2
Speiser shale:	
Shale, silty, calcareous, gray, thin-bedded; many iron stains; brachiopods and pelecypods	3.0
Limestone, medium-hard, partly dense, gray; weathers blocky to platy; lime and siliceous nodules in lower part that are rounded and as much as one-fourth inch in diameter; some limonite nodules	.8
Shale, clayey, very calcareous, gray; weathers nodular	1.6
Shale, silty, slightly calcareous, gray-green, blocky; mottled with purple in lower part	4.1
Thickness exposed	9.5
Base covered.	

14. *Section of the Threemile limestone member of the Wreford limestone down into the Blue Rapids shale in a road cut in the NE¼SW¼ sec. 12, T. 12 S., R. 9 E.*

	Feet
Wreford limestone:	
Threemile limestone member:	
Chert and limestone, weathered; mixed with dark-gray silty soil. Thickness exposed	5.0+
Speiser shale:	
Limestone, hard, gray to tan-gray; weathers blocky; fusulinids common; fossil fragments abundant	0.9
Shale, clayey, calcareous, gray-green, blocky; some calcium carbonate nodules	5.9
Total thickness	6.8

Funston limestone:	*Feet*
Limestone, hard to medium-hard, dark to light-gray, massive, oolitic; some dense areas; weathers blocky; some limonite nodules; bedding appearance on weathered surface	4.8
Shale, silty, very calcareous, tan, thin-bedded; contains many calcareous lenses	2.5
Limestone, medium-hard to soft, light-gray, massive, porous; weathers tan gray and blocky; very oolitic with zones having a crossbedded appearance; some dense gray zones; some pelecypods	3.1
Shale, silty, calcareous, tan, thin-bedded; some calcium carbonate nodules	.3
Limestone, medium-hard, light-gray, massive, porous, oolitic; weathers gray and blocky; weathered surface has crossbedded appearance; some small gastropods and pelecypods	3.6
Limestone, medium-hard, gray, massive; weathers tan and blocky; two thin shale partings; pelecypods	.5
Limestone, medium-hard, tan-gray; weathers tan and blocky; some pelecypods	1.1
Shale, clayey, slightly calcareous, gray to tan-gray, thin-bedded to blocky; weathers tan	5.1
Limestone, medium-hard, gray; weathers tan gray, blocky, and shaly; contains many fossil fragments (algae?)	1.1
Limestone, hard, slightly crystalline, gray; weathers tan and blocky; weathered surface has a bedding appearance; fossil fragments abundant; some microfossils	.6
Shale, silty, calcareous, tan, thin-bedded	.1
Limestone, hard, dense, gray; weathers tan and blocky; subconchoidal fracture; some iron stains	.5
Total thickness	23.3

Blue Rapids shale:	
Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; iron stains on bedding planes; some calcium carbonate plates. Thickness exposed	1.8

Base covered.

15. *Section from the Threemile limestone member of the Wreford limestone down into the Crouse limestone in a road cut in the SW¼SE¼ sec. 9, T. 12 S., R. 9 E.*

Soil, silty, gray to dark-gray; about 1.5 feet thick.

Wreford limestone:

Threemile limestone member:	*Feet*
Limestone, hard, gray, massive; weathers tan gray and blocky; thick chert lens near the top; some limonite stains; contains crinoid columnals, echinoid spines, and many brachiopod fragments	1.5
Shale, silty, calcareous, gray-green, thin-bedded; weathers gray; contains brachiopods, bryozoans, and crinoid columnals	.6
Limestone, hard, dense, gray, massive, limonite stained; weathers tan and blocky; contains two thick chert lenses, echinoid spines, crinoid columnals, and brachiopods	1.7
Thickness exposed	3.8

Speiser shale:	Feet
Shale, silty, calcareous, tan to gray, thin-bedded to blocky; weathers tan; iron stains on fracture planes; crinoid columnals and brachiopods	3.2
Limestone, hard, gray; weathers tan gray and to small chips; pelecypods and brachiopods	.6
Shale, silty, calcareous, gray-green, blocky to thin-bedded; weathers light green; iron stains and calcium carbonate streaks in the lower part	4.3
Shale, silty, calcareous, gray-brown, blocky; weathers light green; contains many limonite and calcium carbonate stained areas	2.1
Shale, silty, slightly calcareous, dark-green and maroon, blocky, limonite stained; weathers light green	.9
Shale, silty, calcareous, dark-green, thin-bedded, iron stained; weathers light green	.7
Total thickness	11.8

Funston limestone:	
Limestone, clayey, medium-hard, gray; weathers tan gray and to small irregular blocks and plates; contains a thin shale parting near the middle; iron stained; pelecypods	1.6
Limestone, hard, white; weathers tan gray and platy; very thin lenticular shale near base	.5
Limestone, soft, white, massive; weathers tan gray and to irregular blocks; slightly porous near top; some algae	2.7
Limestone, soft, tan, platy; weathers tan gray	.1
Limestone, hard, dense, light-gray, massive; weathers tan gray and to plates or blocks; algae in basal part	1.6
Limestone, hard, gray, massive, porous in middle, iron-stained; weathers light gray; contains crinoid columnals and brachiopod fragments	2.7
Shale, clayey, slightly calcareous, gray to light-gray, thin-bedded; some calcareous nodules	5.3
Shale, silty, calcareous, tan gray, thin-bedded; contains many fossil fragments	1.1
Total thickness	15.6

Blue Rapids shale:	
Shale, clayey, noncalcareous, gray-green to tan-gray, blocky to thin-bedded; some silt; iron stains on bedding planes; thin calcareous lentils in upper part	7.3
Shale, clayey, slightly calcareous; maroon, blocky; mottled with some purple	3.6
Covered interval	1.4
Shale, clayey, slightly calcareous, gray-green, thin-bedded to blocky; thin calcareous lentils scattered throughout	9.3
Total thickness	21.6

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	Feet
Crouse limestone:	
Limestone, hard, partly dense, gray to tan-gray, massive, slightly porous; weathers blocky in basal part and platy in the upper part; clayey in the upper part; some iron stains; thin shale lens near middle. Thickness exposed	13.4
Base covered.	

16. *Section from the Threemile limestone member of the Wreford limestone down to the Cottonwood limestone member of the Beattie limestone in a road cut in the SW¼SE¼ sec. 13, T. 12 S., R. 10 E.*

	Feet
Wreford limestone:	
Threemile limestone member:	
Chert and soil; weathered	0–25
Speiser shale:	
Limestone, medium-hard, tan, massive; weathers tan gray and blocky; some iron stains; algae, minute fossil fragments abundant; some microfossils	1.6
Shale, clayey, calcareous, thin-bedded; tan-gray; mottled with dark gray; weathers tan; limonite stains on some bedding planes; calcareous lens in upper part	4.2
Shale, calcareous, light-gray-green, thin-bedded to blocky; clayey with some silt; weathers tan gray; calcareous lenses near the top and the middle; iron stains on fracture planes; shale mottled with limonite stains	5.3
Shale, silty, calcareous, light-gray; thin-bedded; has violet tint, and is mottled with gray green; iron stains on bedding planes	2.7
Total exposed	13.8
Funston limestone:	
Limestone, medium-hard, light-gray, massive; weathers tan and blocky; rough porous surface; some microfossils in the upper part; forms a hillside bench	2.4
Shale, clayey, calcareous, tan-gray, blocky to thin-bedded; thin calcareous lens in the upper part	1.8
Limestone, hard, dense, gray, massive; weathers tan and to two ledges; algal nodules on the upper surface, some pelecypods	.3
Shale, silty, calcareous, gray to light gray-green, thin-bedded; weathers tan gray; some iron stains on bedding planes; calcareous nodules in the upper part	5.7
Covered interval (weathered limestone and shale)	8.4
Limestone, medium-hard, gray, massive iron-stained; clayey in some zones; weathers tan gray and platy; contains pelecypods and other fossil fragments	2.4
Total thickness	21.0
Blue Rapids shale:	
Shale, silty, calcareous, light gray-green; weathers tan gray; thin-bedded becoming blocky at the base; iron stains on bedding planes	4.8

	Feet
Blue Rapids shale—Continued	
Shale, clayey with some silt, noncalcareous, blocky; maroon with purple mottling near the top; some iron stains on fracture planes	1.7
Shale, clayey with some silt, noncalcareous, blocky; gray green mottled with purple near the top; calcareous nodules in the upper part	1.1
Shale, clayey, calcareous, tan to tan-gray, thin-bedded; some calcareous nodules; partly covered	4.1
Shale, clayey, calcareous, gray-green, blocky; some calcareous nodules	1.3
Covered interval	3.5
Total thickness	16.5
Crouse limestone:	
Limestone, hard, dense to somewhat crystalline, gray, massive to platy, slightly porous; weathers tan gray and platy, imparting algal appearance; limonite-stained areas in the lower part	2.0
Limestone, hard, crystalline, dark-gray, thin-bedded; weathers tan to gray and platy	.5
Limestone, gray, massive; weathers tan gray and platy; contains thin lenticular shale partings	1.5
Shale, silty, calcareous, tan, thin-bedded to platy; iron stains on bedding planes	.4
Limestone, hard, dense, tan-gray, massive; weathers tan; heavily limonite stained in middle part	1.7
Shale, very calcareous, tan, thin-bedded to platy, iron-stained	.2
Limestone, crystalline, red-brown; weathers tan brown, blocky, and more rapidly in middle part; contains pelecypods and minute fossil fragments	.4
Shale, silty, calcareous, blocky to thin-bedded; tan gray becoming darker in the lower part, weathers tan; partly covered	6.7
Limestone, hard, somewhat clayey, tan-gray; massive; weathers tan; thin shale parting near middle; some limonite specks; microfossils are in uppermost part; pelecypods, brachiopods and bryozoans	2.5
Total thickness	15.9
Easly Creek shale:	
Shale, silty, calcareous, light-green, blocky; iron stains on fracture planes	.6
Shale, silty, calcareous, dark-gray-green; blocky to thin-bedded; weathers light green; iron stains on bedding planes	2.3
Shale, clayey, calcareous, gray-green to tan, thin-bedded; a maroon tint in the lower part; iron stains on fracture and bedding planes	2.8
Shale, clayey, calcareous, gray-green, thin-bedded; weathers light green; iron stains on fracture planes	.9
Shale, silty, calcareous, dark-gray, blocky, lenticular; weathers gray	.1
Shale, silty, very calcareous; blocky; gray green grading down into maroon	1.6

Easly Creek shale—Continued	*Feet*
Shale, silty, calcareous, gray-green; weathers light green; thin-bedded with a thin lenticular blocky lens in lower part; iron stains on bedding planes	1.0
Limestone, hard, clayey, gray, slightly iron stained; weathers tan; minute secondary calcite crystals on weathered surface	.2
Shale, silty, calcareous, gray-green, thin-bedded	.4
Shale, silty, very calcareous, maroon, thin-bedded to blocky	1.9
Shale, clayey, slightly silty, calcareous, gray-green, thin-bedded to blocky; weathers light green; iron stains on fracture planes	.7
Shale, silty, calcareous, maroon, blocky	.8
Shale, silty, calcareous, gray-green, blocky; weathers light green	.7
Total thickness	14.0
Bader limestone:	
Middleburg limestone member:	
Limestone, clayey, soft, red-brown, wavy, very porous, lenticular; upper part thin-bedded; blocky in the lower part; limonite stained and streaked	1.3
Shale, very calcareous, light-green, blocky, wavy and lenticular, porous; weathers tan; limonite streaks	.9
Shale, silty, calcareous, tan-gray, thin-bedded to blocky; weathers tan	.8
Limestone, clayey, wavy, porous, gray brown; weathers red brown; hard in lower part; limonite stained near top	.4
Shale, clayey, very calcareous, light-gray; thin-bedded becoming platy in upper part	.4
Shale, silty, calcareous, thin-bedded; olive drab mottled with gray; weathers tan gray	.4
Shale, silty, calcareous, dark-gray, thin-bedded to fissile; weathers gray	1.6
Limestone, hard, tan-gray; weathers tan, massive; weathers platy in the upper part; contains crinoid columnals, bryozoans, pelecypods, and microfossils	2.8
Shale, silty, calcareous, tan-gray, thin-bedded to blocky; some carbon stains	.9
Limestone, hard; gray brown, weathers tan; lenticular; some carbon specks	.2
Thickness	9.7
Hooser shale member:	
Shale, silty, noncalcareous, olive-drab; weathers gray; thin-bedded to blocky	.9
Shale, silty, calcareous, tan-gray, thin-bedded; weathers light gray	2.0
Shale, clayey, calcareous, dark-gray, thin-bedded to fissile; carbon and limonite stains in upper part	.9
Shale, very calcareous, soft, tan, blocky, lenticular, iron-stained; contains brachiopods and pelecypods	.8
Shale, silty, calcareous, gray-green, blocky; some calcareous nodules	.3
Thickness	4.9

	Feet
Bader limestone—Continued	
Eiss limestone member:	
Limestone, hard, partly dense; massive; gray with purple tint; weathers gray and to irregular porous blocks; cavernous in center; limonite inclusions; contains pelecypods	1.7
Limestone, medium-hard, tan-gray, iron-stained; weathers tan and blocky with numerous thin shale partings; pelecypods abundant and brachiopods common	1.1
Shale, silty, slightly calcareous, dark-gray, blocky to thin-bedded; weathers blue gray to tan; a few secondary calcite inclusions; limonite stains on fracture planes; brachiopods and pelecypods in upper 0.5 foot	4.1
Shale, very calcareous, dark-gray, thin-bedded to platy; weathers blue gray to tan; contains brachiopods, pelecypods, bryozoans and crinoid columnals	3.5
Limestone, clayey, tan-gray; weathers tan; upper part weathers to small chips; iron stained in some zones; some brachiopod fragments	.4
Thickness:	10.8
Total thickness of Bader limestone	25.5
Stearns shale:	
Shale, silty, calcareous, olive-drab, thin-bedded; weathers light gray; some limonite stains	2.9
Shale, calcareous, dark-gray to olive-drab, thin-bedded; weathers dark gray; clayey with some silt	1.0
Shale, silty, calcareous, gray-green; weathers light gray green; blocky; carbon stains on some fracture planes; heavily limonite stained in upper part	2.7
(11.2 feet exposed, full interval to top of Cottonwood limestone member of the Beattie limestone is 24.5 feet.)	
Limestone, soft, tan, cavernous and porous, lenticular	.4
Limestone, hard, dense, clayey, gray, lenticular; weathers tan gray	.4
Shale, silty, calcareous, dark-gray to gray, blocky; weathers light gray green; very calcareous zone near the top	3.3
Shale, calcareous, gray-brown, thin-bedded to blocky; some limonite specks weathers tan gray; clayey with some silt	.5
Covered interval	13.3

Beattie limestone: Top of Cottonwood limestone member.

17. *Section from the upper part of the Speiser shale down to the base of the Crouse limestone in a road cut in the NE¼NE¼ sec. 19, T. 13 S., R. 12 E.*

	Feet
Speiser shale:	
Shale, silty, calcareous, gray-green to tan-gray, thin-bedded to blocky; calcium carbonate nodules abundant in the upper part. Thickness exposed	11.3

	Feet
Funston limestone:	
Limestone, hard, gray; weathers blocky; thin shale partings; fossil fragments	3.1
Shale, silty, calcareous, tan-gray, thin-bedded; grades up into gray green; iron stains on bedding planes	13.0
Limestone, hard, gray; weathers blocky; fossil fragments abundant; contains gastropods, pelecypods and brachiopods	1.1
Shale, silty, calcareous, gray, thin-bedded; weathers tan gray	4.3
Limestone, hard, gray; weathers platy; fossil fragments, ostracodes and gastropods abundant in certain zones; pelecypods common	.6
Total thickness	22.1
Blue Rapids shale:	
Shale, tan gray, thin-bedded; clayey with some silt	2.1
Shale, silty, calcareous, gray-green, thin-bedded	2.0
Shale, silty, calcareous, light-purple, blocky to thin-bedded	2.9
Shale, silty, calcareous, gray-green, thin-bedded	.9
Shale, clayey, noncalcareous, maroon, purple, and gray green, blocky	2.8
Shale, silty, calcareous, tan to gray, thin-bedded; gray green in upper part	9.5
Total thickness	20.2
Crouse limestone:	
Limestone, moderately hard, dense, gray-brown; thin shale partings; weathers blocky to platy; porous in upper part; minute fossil fragments abundant in certain zones in lower part	4.3
Shale, clayey, calcareous, gray, thin-bedded; weathers tan gray	7.1
Limestone, gray; weathers shaly to blocky; some fossil fragments; lower part not exposed	.7
Thickness exposed	12.1

Base covered.

18. *Section of the Funston limestone in a road cut in the SW¼NW¼ sec. 10, T. 15 S., R. 10 E.*

Speiser shale: Basal part; about 10 feet thick.

	Feet
Funston limestone:	
Limestone, hard, crystalline, gray; weathers tan gray and blocky; contains microfossils, gastropods, and pelecypods	1.4
Shale, very calcareous, light-gray, platy; weathers tan	.5
Limestone, hard, tan-gray; weathers tan and platy; some microfossils	.4
Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; thin, clayey limestone in middle part	1.5
Limestone, hard, tan-gray; weathers gray and blocky; fractures nearly at right angles; limonite stains; very oolitic	1.2
Shale, calcareous, tan-gray, thin-bedded; weathers tan	.1
Limestone, soft, tan-gray, massive; weathers gray; weathered surface gives crossbedded appearance; some limonite specks; very oolitic	2.4

Funston limestone—Continued	*Feet*
Shale, silty, very calcareous, tan, platy; lenticular; some limonite specks; some microfossils	0.2
Limestone, hard, tan; weathers tan gray; limonite specks abundant	1.4
Shale, calcareous, tan, thin-bedded	.1
Limestone, soft, tan; weathers tan gray; algae abundant	.9
Shale, very calcareous, tan-gray, thin-bedded to platy, lenticular, weathers tan	.1
Limestone, hard, tan; weathers tan gray; algae in upper part	1.0
Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan gray	.1
Limestone, hard, tan; weathers tan gray and to elongated blocks; some algae	1.0
Shale, noncalcareous, dark-gray, fissile; clayey with some silt; limonite stains on some bedding planes	2.1
Shale, very calcareous, gray; weathers tan gray; platy; some limonite stains	.4
Limestone, clayey, medium-hard, gray, massive; weathers tan gray; weathers platy in upper part; some algae and brachiopods	1.8
Shale, slightly calcareous, gray to gray-green, platy to blocky; silty in the lower part, clayey in the upper part, some limonite stains	6.2
Limestone, dense, hard, somewhat crystalline, tan-gray, massive; weathers gray; some microfossils and brachiopod fragments	1.5
Thickness exposed	24.3

Base covered.

19. *Section from the Funston limestone down into the Easly Creek shale in a road cut in the NE¼SE¼ sec. 21, T. 13 S., R. 11 E.*

Funston limestone:	*Feet*
Limestone, tan to gray; soft in lower part, hard in upper part; massive in upper part; weathers in rectangular blocks 1.2 feet thick; lower part is porous and contains algae	5.7
Shale, clayey, noncalcareous, gray to dark-gray; thin-bedded	7.4
Limestone, medium-hard, tan-gray; weathers blocky to nodular. Fossil fragments abundant; crinoid columnals, bryozoans and pelecypods common	1.2
Shale, silty, calcareous, tan-gray, thin-bedded	3.9
Limestone, medium-hard, tan-gray, massive; weathers blocky to shaly; fossil fragments abundant; microfossils, and pelecypods common	1.0
Thickness exposed	19.2

Blue Rapids shale:	
Shale, clayey, calcareous, gray to tan-gray, thin-bedded to blocky; purple tint in lower part; cavernous zone 4.0 feet from base	11.3
Limestone, medium-hard, gray, platy to shaly	.8
Shale, silty, calcareous, tan to gray, thin-bedded; becomes blocky in upper part	2.8
Total thickness	14.9

Crouse limestone:	*Feet*
Limestone, medium-hard, tan; massive in lower and upper parts, platy in middle part	7.6
Shale, clayey, calcareous, gray to tan-gray; thin-bedded to blocky	8.1
Limestone, medium-hard, gray, massive; weathers blocky to shaly; fossil fragments abundant; bryozoans and pelecypods common	2.3
Total thickness	18.0
Easly Creek shale:	
Shale, silty, calcareous, gray-green with a purple tint, thin-bedded	5.7
Shale, silty, calcareous, blocky; maroon becoming purple in the upper part	2.2
Shale, silty, calcareous, thin-bedded; gray green with purple and maroon lenses	3.4
Thickness exposed	11.3
Base covered.	

20. *Section of the biostrome in the Funston limestone in a stream and road cut in the NW¼NE¼ sec. 24, T. 13 S., R. 9 E.*

Soil, silty, gray; contains chert fragments; about 2 feet thick.	
Funston limestone:	*Feet*
Limestone, soft, light-gray, massive; porous, very oolitic; weathers gray; tends to weather platy in center and to develop a crossbedded appearance; some algae and fossil fragments	11.3
Limestone, soft; light-gray, massive, porous, very oolitic; weathers gray and blocky; weathered surface has crossbedded appearance; algae and gastropods common	11.3
Shale, silty, very calcareous, gray, thin-bedded to platy; weathers light gray; contains brachiopods, echinoid spines, and pelecypods	1.3
Limestone, soft, gray, massive; weathers shaly; contains pelecypods, brachiopods, and algae (?)	.9
Thickness exposed	24.8
Blue Rapids shale:	
Shale, silty, noncalcareous, dark-gray; weathers gray and blocky. Thickness exposed	1.2
Base covered.	

21. *Section of part of the biostrome in the Funston limestone in a road cut in the SE¼SE¼ sec. 7, T. 12 S., R. 10 E.*

Funston limestone (top covered):	*Feet*
Limestone, conglomeratic, gray with green tint; less conglomeratic material in lower part; rounded to angular fragments of limestone and claystone up to ½ inch, but mainly 1/32 inch in diameter; carbon specks in lower part	1.7

Funston limestone (top covered)—Continued	*Feet*
Conglomerate, limestone and claystone, angular; coarse fraction 2 inches in diameter; contains brachiopods	0.2
Shale, very calcareous, tan; weathers platy	2.3
Limestone, impure, medium-hard, oolitic, gray, massive, weathers blocky; some iron nodules; upper part contains fossil fragments that are somewhat coarser than those in the lower part	6.3
Conglomerate; limestone nodules in a lime matrix; angular to subangular; maximum diameter is ½ inch	.2
Limestone, medium-hard, tan-gray; iron stains in small cavities	.4
Shale, very calcareous, tan; weathers platy	.9
Limestone, medium-hard, conglomeratic, tan to tan-gray, blocky; porous with calcite lined cavities; angular to subangular fragments of lime; some flat and elongated; maximum diameter is 1 inch; some iron stains on surface; iron specks disseminated throughout ledge	.6
Shale, silty, calcareous, tan-gray, thin-bedded	2.0
Limestone, medium-hard, conglomeratic, gray; fragments up to ¼ inch in diameter	.3
Thickness exposed	14.9

Base covered.

22. *Section of the biostrome in the Funston limestone in a road ditch in the center of the SE¼ sec. 13, T. 13 S., R. 9 E.*

Funston limestone top covered:	*Feet*
Limestone, medium-hard, tan-gray, massive; weathers blocky; oolitic in upper 3 feet	3.6
Shale, silty, calcareous, tan-gray, thin-bedded; calcareous plates abundant	2.8
Limestone, hard, gray; weathers platy; contains pelecypods	.3
Shale, silty, calcareous, tan-gray, thin-bedded; many calcareous lentils in lower part	7.7
Limestone, hard, partly dense, conglomeratic, gray; weathers blocky; clay balls up to 2 inches in diameter, rounded to angular, irregular in shape; contains gastropods	.7
Shale, silty, calcareous, gray, thin-bedded; contains fossil fragments	1.7
Limestone, hard, gray; massive in the upper part, platy in the lower part, with shale partings; fragments of bryozoa are abundant in massive part	5.3
Limestone, hard; conglomeratic, tan-gray; weathers blocky; limonite and clay balls up to ¼ inch in diameter, rounded to semiangular; contains pelecypods	.9
Shale, silty, calcareous, gray-green, thin-bedded	2.6
Shale, clayey, very calcareous, gray; weathers shaly	.9
Thickness exposed	26.5

Base covered.

23. *Section from the upper part of the Crouse limestone down into the lower part of the Easly Creek shale in a road cut in the SW¼SE¼, sec. 36, T. 13 S., R. 10 E.*

	Feet
Crouse limestone:	
Limestone, hard, gray to tan-gray; massive in the upper and middle parts, platy in the lower part; porous in the upper part; contains microfossils (?) in upper part; ostracodes in middle part	8.9
Limestone, hard, partly dense, gray to tan-gray; weathers blocky; some fossil fragments	.9
Shale, clayey, calcareous, gray, thin-bedded; many iron stains	4.5
Shale, silty, very calcareous, gray, thin-bedded; bryozoans very abundant, brachiopods and crinoid columnals common	2.5
Limestone, medium-hard, gray; weathers shaly; contains pelecypods, bryozoans and crinoid columnals	1.4
Thickness exposed	18.2
Easly Creek shale:	
Shale, clayey, calcareous, gray-green, blocky	0.8
Limestone, soft, sandy, gray, shaly, nodular; dense in upper part	1.4
Shale, silty, calcareous, gray with a gray-green tint, thin-bedded	.8
Shale, silty, calcareous, maroon, blocky to thin-bedded; mottled with gray green	1.8
Shale, silty, calcareous, gray-green, thin-bedded	2.0
Shale, silty, calcareous, thin-bedded to blocky; maroon with thin purple band in upper part	1.2
Shale, silty, calcareous, blocky; gray grading down to gray green in lower part	2.7
Limestone, medium-hard, gray; weathers shaly	.2
Shale, silty, calcareous, tan, thin-bedded	.7
Shale, silty, calcareous, maroon, blocky to massive	1.8
Shale, silty, calcareous, gray-green, blocky; iron stains on fracture planes	1.2
Shale, silty, calcareous, maroon, blocky	.4
Shale, silty, calcareous, gray-green, thin-bedded	1.5
Thickness exposed	16.5

Base covered.

24. *Section from the lower part of the Crouse limestone down to the lower part of the Eiss limestone member of the Bader limestone in a road cut in the NE¼NW¼NW¼ sec. 9, T. 14 S., R. 11 E.*

	Feet
Crouse limestone:	
Shale, silty to clayey, calcareous, tan-gray, thin-bedded	5.6
Limestone, medium-hard, dark-gray; weathers shaly; contains fossil fragments, pelecypods and brachiopods	1.9
Thickness exposed	7.5

	Feet
Easly Creek shale:	
Shale, silty, calcareous, light-green to gray-green, thin-bedded; many calcareous lentils present	3.4
Shale, silty, calcareous, thin-bedded; gray with a purplish tint	1.2
Shale, silty, calcareous, thin-bedded; gray green in lower part becoming a light gray green in upper part; thin calcareous lentils in upper part	4.4
Shale, silty, calcareous, maroon, thin-bedded	.8
Shale, silty, calcareous, tan, thin-bedded; thin calcareous lentils common	.9
Total thickness	10.7
Bader limestone:	
Middleburg limestone member:	
Limestone, argillaceous, medium-hard, tan-gray; weathers shaly	0.3
Shale, silty, calcareous, tan-gray, thin-bedded	1.8
Limestone, dense, medium-hard, dark-gray; weathers blocky	.3
Shale (mostly covered), tan-gray	2.7
Limestone, medium-hard, tan-gray, massive; weathers blocky to platy; minute iron specks; contains ostracodes, bryozoans and pelecypods	2.4
Thickness	7.5
Hooser shale member:	
Shale, calcareous, tan-gray, thin-bedded; clayey with some silt	2.1
Limestone, hard, dense, gray-brown, blocky; some calcite veinlets and iron stains	.2
Shale, calcareous, blocky, gray-green; becomes light gray green in upper part; clayey with some silt, iron stains abundant in upper part	2.8
Shale, silty, calcareous, maroon, blocky	1.4
Shale, calcareous, blocky; gray green in lower part, purple in upper 1 feet; clayey with some silt	1.9
Thickness	8.4
Eiss limestone member:	
Limestone, medium-hard, partly dense, tan-gray; blocky in the upper part, platy in lower part; porous in upper part; thin shale partings in lower part; upper surface is irregular, dense and algal-like; some pelecypods	2.1
Shale, silty, calcareous, tan-gray, blocky to thin-bedded; calcium carbonate nodules abundant in upper part	7.9
Limestone, argillaceous, medium-hard, tan-gray, blocky; contains brachiopod and pelecypod fragments	2.0±
Thickness exposed	12.0±
Total thickness of exposed Bader limestone	29.0±

Base covered.

25. *Section from the lower part of the Crouse limestone down into the middle part of the Eskridge shale in a road cut in the SW¼SE¼ sec. 4, T. 12 S., R. 10 E.*

	Feet
Crouse limestone:	
Limestone, medium-hard, tan-gray; weathers platy; some limonite nodules and clay balls less than ¼ inch in diameter; fossil fragments include pelecypods. Thickness exposed	1.1
Easly Creek shale:	
Shale, silty to clayey, calcareous, gray-green to tan-gray, thin-bedded to blocky; some iron stains	9.8
Limestone, soft, clayey, tan-gray; weathers blocky	.1
Shale, silty, calcareous, blocky; gray green mottled with maroon in upper part	5.6
Total thickness	15.5
Bader limestone:	
Middleburg limestone member:	
Limestone, medium-hard, gray-brown, blocky, iron stained, fossiliferous	.2
Shale, clayey, calcareous, thin-bedded; dark gray becoming tan gray in upper part	2.8
Limestone, hard, gray-brown; weathers blocky to shaly; fossil fragments abundant, including gastropods	2.6
Thickness	5.6
Hooser shale member:	
Shale (partly covered), gray to maroon; gray green to tan in upper part. Thickness	9.4
Eiss limestone member	
Limestone, hard, gray; weathers blocky to platy; fossil fragments include pelecypods	2.1
Shale, silty, calcareous, gray-green, thin-bedded; many calcium carbonate nodules	3.0
Shale, silty, calcareous, gray, thin-bedded; limestone lentils in upper part; contains bryozoans and brachiopods	2.5
Limestone, medium-hard, gray, massive; weathers shaly; fragments of brachiopods and bryozoans present	1.9
Thickness	9.5
Total thickness of Bader limestone	24.5
Stearns shale:	
Shale, clayey, calcareous, thin-bedded; dark gray in lower part becoming gray in upper part; some calcareous lentils; some wood fragments; microfossils abundant	6.9
Shale, silty, calcareous, gray-green, blocky	1.0

	Feet
Stearns shale—Continued	
Limestone, medium-hard, gray; weathers blocky to nodular; shale lentil in lower part; upper part contains lime nodules	1.0
Shale, silty to clayey, calcareous, blocky; gray green in lower part, gray to gray green in upper part	3.8
Limestone, medium-hard, gray, blocky	.2
Shale, silty, calcareous, gray-green, blocky	.2
Total thickness	13.1
Beattie limestone:	
Morrill limestone member:	
Limestone, hard, partly dense, gray; weathers platy to blocky; algae gives bedded appearance	.5
Shale, calcareous, tan-gray, thin bedded; clayey with some silt	1.2
Shale, silty, very calcareous, tan-gray, thin-bedded to nodular; contains numerous limestone lentils	1.1
Limestone, hard, brown; weathers platy	.5
Thickness	3.3
Florena shale member:	
Shale, clayey, calcareous, gray to gray-green, thin-bedded, cavernous to nodular in upper part; contains geodes. Thickness	7.3
Cottonwood limestone member:	
Limestone, hard, tan-gray, massive, porous; weathers blocky; solution channels in upper part; some chert nodules; fusulinids very abundant in upper 1.5 feet; coral zone 2.3 feet from base; contains crinoid columnals, echinoid spines, and brachiopods. Thickness	5.8
Total thickness of Beattie limestone	16.4
Eskridge shale:	
Shale, silty, calcareous, gray-green, iron-stained; thin-bedded grading up to blocky; thin calcareous lentils in lower part	4.3
Shale, silty, calcareous; blocky; gray mottled with maroon; some gray green; maroon in upper part	1.3
Limestone, clayey, gray; weathers blocky	.5
Shale, silty, calcareous, tan-gray to light gray-green, thin-bedded; calcareous lentils in middle part	1.9
Shale, clayey, calcareous; purple with gray green lentils; calcareous lentils in upper and lower part	1.3
Shale, silty to clayey, calcareous, maroon, thin-bedded	2.4
Thickness exposed of Eskridge shale	11.7

Base covered.

26. *Section from the top of the Eiss limestone member of the Bader limestone down to the top of the Morrill limestone member of the Beattie limestone in a road cut in the NE¼NW¼NW¼ sec. 23, T. 13 S., R. 10 E.*

	Feet
Bader limestone:	
Eiss limestone member:	
Limestone, medium-hard, gray, massive; weathers blocky and porous in upper part, shaly in lower part; contains brachiopods, pelecypods, crinoid columnals (some as minute fragments), and microfossils	2.5
Shale, clayey, slightly calcareous, gray, thin-bedded; weathers tan	3.5
Limestone, medium-hard, tan-gray; weathers into irregular chips; contains fusulinids, brachiopods, pelecypods, crinoid columnals, bryozoans; minute fossil fragments common; pelecypods abundant	.5
Shale, silty, calcareous, tan-gray, thin-bedded	1.1
Limestone, medium-hard, gray; weathers blocky in lower part, shaly in upper part; contains pelecypods, gastropods and other fossil fragments	2.2
Thickness exposed	9.8
Stearns shale:	
Shale, silty, calcareous, tan-gray to gray, thin-bedded; thin calcareous, lentils	3.1
Shale, clayey, calcareous, dark-gray, thin-bedded	3.7
Coal, black, lenticular, thin-bedded	.2
Shale, silty, calcareous, tan-gray, blocky; 0.5-foot ostracode zone beneath coal	3.4
Cavernous zone, tan-gray, very calcareous	.4
Shale, clayey, calcareous, tan, thin-bedded	1.9
Limestone, medium-hard, clayey, dense, gray; weathers shaly	.2
Shale, silty, calcareous, blocky, gray to tan-gray; greenish tint in gray part; some calcareous lentils	5.4
Total thickness	18.3
Beattie limestone: Top of Morrill limestone member.	

27. *Section from the base of the Hooser shale member of the Bader limestone down into the Morrill limestone member of the Beattie limestone in a road ditch in the NE¼SW¼ sec. 24, T. 13 S., R. 11 E.*

	Feet
Bader limestone:	
Base of the Hooser shale member.	
Eiss limestone member:	
Limestone, medium-hard, gray; weathers shaly to blocky; porous; pelecypods abundant	3.5
Shale, gray, thin-bedded; silty in lower part, clayey in upper part; some iron stains; crinoid columnals, pelecypods, and bryozoans in lower part	7.7
Limestone, hard, gray; weathers tan and blocky; fossil fragments of bryozoans and gastropods abundant	2.0
Total thickness of exposed Bader limestone	13.2

	Feet
Stearns shale:	
Shale, silty, calcareous; gray green mottled with gray; thin-bedded to blocky in lower part; some iron stained zones; thin calcareous plates in upper part	6.1
Limestone, soft, tan-gray, cavernous; some celestite-lined cavities	2.3
Shale, clayey, noncalcareous, gray, thin-bedded; iron stained	4.4
Total thickness	12.8
Beattie limestone:	
Morrill limestone member:	
Limestone, gray to tan; medium hard to soft in lower part; platy in upper part, massive and cavernous in lower part. Thickness exposed	3.3
Base covered.	

28. *Section from the Eiss limestone member of the Bader limestone down into the Cottonwood limestone member of the Beattie limestone in a road cut in the NW¼NE¼ sec. 9, T. 14 S., R. 11 E.*

Shale and limestone, weathered; about 3 feet thick.

	Feet
Bader limestone:	
Eiss limestone member	
Limestone, clayey, gray, massive; weathers nodular and blocky and tan gray; iron stains on fracture planes; brachiopods abundant, bryozoans and pelecypods common. Thickness exposed	2.3
Stearns shale:	
Shale, calcareous, blocky, gray-brown; weathers gray; clayey with some silt	1.8
Shale, silty, calcareous, olive-drab; thin-bedded; limonite stained; weathers light gray	1.0
Shale, clayey, calcareous, black to olive-drab, fissile; weathers dark gray; some limonite-stained areas	1.7
Shale, silty, calcareous, gray-green, thin-bedded; weathers gray; heavily limonite stained in upper part	.6
Limestone, clayey, dark-gray, lenticular; weathers light gray; many voids filled with calcite	.4
Shale, silty, calcareous, gray-green, thin-bedded; weathers gray	.5
Shale, silty, very calcareous, light-gray; blocky; weathers gray; iron stains on fracture planes	.6
Shale, silty, very calcareous, light-green, thin-bedded to fissile; weathers very light gray; iron stains on fracture planes	1.2
Shale, silty, calcareous, gray-green, thin-bedded to blocky; weathers green; iron stains on bedding and fracture planes	2.3
Total thickness	10.2

	Feet
Beattie limestone:	
Morrill limestone member:	
Limestone, soft, tan-gray; porous, iron-stained; weathers gray and to small nodules and irregular blocks and plates	1.8
Shale, silty, calcareous, gray, thin-bedded, lenticular	.2
Limestone, clayey, dark-gray, lenticular; weathers tan gray and shaly	.2
Shale, silty, very calcareous, dark-gray; thin-bedded to platy; weathers gray	.2
Limestone, hard, dense, dark-gray; weathers gray and blocky	.5
Shale, silty, calcareous, tan-gray; thin-bedded; weathers tan	.2
Limestone, clayey, gray; weathers tan gray and blocky; porous	1.1
Limestone, hard, dense, gray; weathers light gray; massive, weathers platy and blocky; lenticular; thin shale parting in middle part; band of algae	1.9
Limestone, soft, tan, massive; weathers cavernous; porous; some black streaks	1.4
Thickness	7.5
Florena shale member:	
Shale, silty, calcareous, tan to tan-gray; weathers tan-gray; blocky to thin-bedded; brachiopods very abundant, bryozoans common. Thickness	9.6
Cottonwood limestone member:	
Limestone, hard, tan-gray; weathers gray; massive, weathers blocky; two thin bands of chert nodules present; porous; fusulinids very abundant, echinoid spines and crinoid columnals common; forms a prominent hillside bench. Thickness exposed	6.5
Total thickness of exposed Beattie limestone	23.6

Base covered.

29. *Section from the Morrill limestone member of the Beattie limestone down into the upper part of the Eskridge shale in a road cut in the SE¼SW¼SW¼ sec. 14, T. 13 S., R. 10 E.*

	Feet
Beattie limestone:	
Morrill limestone member:	
Limestone, hard, gray; weathers blocky to platy; minute fossil fragments abundant	1.5
Limestone, medium-hard, gray, cavernous; weathers blocky; algal (?) in lower part	1.1
Thickness	2.6
Florena shale member:	
Shale, silty, calcareous, tan-gray, thin-bedded; contains brachiopods, bryozoans, trilobites, and fusulinids. Thickness	9.3

	Feet
Beattie limestone—Continued	
Cottonwood limestone member:	
Limestone, medium-hard, light-gray; weathers tan gray and blocky; solution channels in upper part; some chert nodules; fusulinids very abundant in upper 4.3 feet; echinoid spines, brachiopods, and crinoid columnals common; zone of solitary corals, 1.3 feet above base	7.5
Limestone, medium-hard, gray; weathers platy; some fossil fragments	.5
Thickness	8.0
Total thickness of Beattie limestone	19.9
Eskridge shale:	
Shale, clayey, calcareous, tan-gray; blocky. Thickness exposed	8.1
Base covered.	

30. *Section from the Beattie limestone down to the base of the Neva limestone member of the Grenola limestone in a road cut in the NE¼SW¼ sec. 12, T. 12 S., R. 10 E.*

	Feet
Beattie limestone:	
Morrill limestone member:	
Limestone, medium-hard, dense, gray; weathers blocky; porous	0.6
Shale, silty, calcareous, gray, thin-bedded; weathers tan	2.2
Limestone, medium-hard to soft; gray in the upper part; the lower part is gray brown, platy to cavernous, has calcite lined pores, and contains microfossils	3.6
Thickness	6.4
Florena shale member:	
Shale, silty, calcareous, gray to tan-gray, thin-bedded; clayey and cavernous in upper part; brachiopods and crinoid columnals in lower part; some fusulinids. Thickness	9.5
Cottonwood limestone member:	
Limestone, hard, light-gray to tan, massive; weathers blocky; 4 zones of chert nodules; fusulinids abundant in upper 1.8 feet; crinoid columnals, brachiopods; fossil fragments; corals present in a zone about 1 foot from base	4.5
Shale, very calcareous, gray, platy; some fossil fragments	.5
Limestone, medium-hard, tan-gray; weathers blocky; shale parting in middle part	.9
Thickness	5.9
Total thickness of Beattie limestone	21.8

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	Feet
Eskridge shale:	
Shale, silty, calcareous, gray-green, thin-bedded; some thin limestone lentils	13.3
Shale, calcareous, maroon, blocky; some clay	3.1
Shale, silty, calcareous, gray-green, thin-bedded; calcareous nodules abundant	11.3
Shale, purple, thin-bedded; clayey with some silt; calcareous becoming very calcareous in upper part; calcareous nodules abundant; columnal structure	2.1
Shale, silty, calcareous, gray-green, thin-bedded	.9
Limestone, clayey, impure, gray; weathers blocky	.4
Shale, silty, calcareous, gray to gray-green, thin-bedded	.9
Total thickness	32.0
Grenola limestone:	
Neva limestone member:	
Limestone, hard, tan-gray to gray; weathers blocky; dense and platy in upper part; lower part is massive, coquinoid with fossil fragments	2.9
Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; echinoid spines, fusulinids, and brachiopods	1.5
Limestone, medium-hard to soft, gray-brown; massive, porous; weathers blocky; weathers shaly in upper part; echinoid spines, crinoid columnals with fusulinids in lower part; some algae in zone 1 foot from base	7.2
Shale, silty, calcareous, gray, thin-bedded; weathers tan	1.1
Limestone, medium-hard, gray, massive; weathers tan, shaly, and in irregular chips; contains fossil fragments, crinoid columnals, brachiopods, and fusulinids	1.8
Shale, silty, calcareous, gray, thin-bedded; weathers tan; contains fusulinids, echinoid spines, crinoid columnals, and brachiopods	.8
Limestone, medium-hard, gray; massive; weathers blocky; contains fossil fragments; fusulinids, and crinoid columnals	1.5
Thickness exposed	16.8

Base covered.

31. *Section from the Cottonwood limestone member of the Beattie limestone down to the top of the Neva limestone member of the Grenola limestone in a road cut in the SW¼NW¼NW¼ sec. 36, T. 14 S., R. 11 E.*

	Feet
Beattie limestone:	
Cottonwood limestone member:	
Limestone, medium-hard, light-gray; weathers blocky; contains echinoid spines and crinoid columnals	1.4
Shale, silty, very calcareous, gray, thin-bedded	.5
Limestone, medium-hard, gray; weathers to blocky; some chert nodules	.5
Thickness exposed	2.4

	Feet
Eskridge shale:	
Shale, silty to clayey, calcareous; thin-bedded to blocky; gray to gray green with two thin maroon beds in lower part; calcareous lentils in lower part	7.8
Limestone, hard, gray; weathers platy; some microfossils	.9
Shale, silty, calcareous, gray, thin-bedded	.3
Limestone, hard, partly dense, gray; weathers blocky; iron stains on fracture planes; contains microfossils and pelecypods	.9
Shale, clayey, noncalcareous, gray, thin-bedded; carbonaceous in lower part	5.4
Coal, impure, clayey, black, thin-bedded to blocky	.3
Shale, silty, calcareous, gray, blocky	.9
Limestone, impure, clayey, gray, thin-bedded	.2
Shale, silty, calcareous, tan-gray to gray-green, blocky to thin-bedded	3.2
Shale, silty, noncalcareous, maroon, thin-bedded	1.8
Shale, clayey, noncalcareous, gray-green, blocky	1.3
Shale, silty, noncalcareous, maroon, blocky, cavernous	2.2
Shale, clayey, noncalcareous, gray, blocky	.5
Shale, silty, calcareous, gray, thin-bedded, cavernous; mottled with maroon	2.3
Shale, clayey, very calcareous, light-gray, blocky	.4
Shale, clayey to silty, calcareous, light- to dark-gray, blocky	1.4
Limestone, impure, hard, dense, gray, granular to blocky	.6
Shale, silty, calcareous, gray-green, blocky	3.1
Thickness exposed	33.5

Grenola limestone: Top of Neva limestone member.

32. *Section from the Cottonwood limestone member of the Beattie limestone down into the Neva limestone member of the Grenola limestone in the spillway at Lake Wabaunsee in the NE¼NW¼ sec. 4, T. 14 S., R. 11 E.*

	Feet
Beattie limestone:	
Cottonwood limestone member:	
Limestone, hard, tan, massive, porous; weathers tan gray and blocky; some chert nodules, fusulinids very abundant in upper 2.3 feet; zone of small solitary corals 2.5 feet from base; echinoid spines, crinoid columnals, and fossil fragments common. Thickness exposed	5.8
Eskridge shale:	
Shale (covered by colluvium)	5.2
Shale, clayey, noncalcareous, gray, thin-bedded	3.4
Limestone, hard, dense, gray; weathers platy to blocky; some pelecypods	1.1
Shale, silty, calcareous, gray-green, thin-bedded; contains calcium carbonate nodules	6.9
Limestone, hard, dense, crystalline, gray; weathers blocky; some microfossils	.4
Shale, silty, calcareous, gray-green, thin-bedded; some maroon and purple lentils in lower part	3.3

	Feet
Eskridge shale—Continued	
Shale, silty, calcareous, maroon, blocky; very calcareous zone in middle part	6.4
Shale, silty, calcareous, light-maroon and gray-green, thin-bedded to blocky	11.3
Total thickness	38.0
Grenola limestone:	
Neva limestone member:	
Limestone, medium-hard, gray; weathers blocky to shaly	.6
Shale, silty, calcareous, gray to tan-gray, thin-bedded; contains echinoid spines and brachiopods	3.6
Limestone, medium-hard, tan to tan-gray, massive, porous to cavernous; weathers blocky and in irregular plates	6.1
Shale, clayey, calcareous, gray, blocky to thin-bedded	1.3
Limestone, medium-hard, gray; weathers blocky and in irregular plates; some fusulinids	1.2
Shale, silty to clayey, calcareous, gray, thin-bedded to blocky; some brachiopods and fusulinids	1.1
Limestone, hard, gray; weathers tan and blocky; some chert nodules and fossil fragments	1.3
Thickness exposed	15.2

Base covered.

33. *Section from the Cottonwood limestone member of the Beattie limestone down into the upper part of the Roca shale in a road cut in the SE¼NE¼ sec. 27, T. 11 S., R. 10 E.*

Soil, silty, gray; some limestone fragments; about 1 foot thick.

	Feet
Beattie limestone:	
Cottonwood limestone member:	
Limestone, medium-hard, tan-gray, massive; weathers to irregular blocks; band of chert nodules in middle part; fusulinids very abundant and weather out easily, leaving a pitted surface; echinoid spines and plates common; forms hillside bench	1.9
Limestone, medium-hard, light-gray, massive; weathers tan gray and blocky; band of chert nodules 1.2 feet from the top, other chert nodules in the upper part; contains fusulinids, echinoid spines and plates, bryozoans, brachiopods. and crinoid columnals	3.0
Shale, silty, very calcareous, thin-bedded, gray; weathers tan gray; some brachiopod fragments	.1
Limestone, medium hard, gray; weathers tan gray and platy; limonite particles on unweathered surface; oolitic areas	.2
Thickness exposed	5.2
Eskridge shale:	
Shale, silty, calcareous, light-green, blocky to thin-bedded	.4
Shale, calcareous; clayey with some silt; dark green with a thin purple zone 1 foot from top, weathers light green; thin-bedded grading to blocky; more resistant in middle part	3.8

Eskridge shale—Continued	Feet
Shale, silty, calcareous; thin-bedded to blocky; purple becoming maroon in upper part; weathers maroon; more resistant to weathering than adjacent shales	1.2
Shale, calcareous, thin-bedded, gray-green; clayey with some silt; weathers light green; a few iron stains	.4
Shale, calcareous, purple, thin-bedded; silty with some clay	.4
Shale, calcareous, thin-bedded to blocky; violet; weathers pinkish violet; silty with some clay	2.6
Limestone, clayey, hard, light-gray; weathers platy; iron stains on weathered surface; contains minute white calcium carbonate particles	.5
Shale, silty, calcareous, blocky to thin-bedded, dark-green; weathers light green	.3
Shale, silty, blocky, calcareous; purple to maroon with a green zone in upper part; weathers purple	1.6
Shale, silty, blocky, slightly calcareous, olive-drab to dark gray-brown; weathers light green	2.7
Shale, thin-bedded, calcareous, maroon to purple; silty with some clay; weathers maroon	1.5
Shale, silty, calcareous, blocky; dark gray with purple stains; weathers gray; some iron stains in lower part	1.9
Shale, calcareous; dark-green to dark-gray; clayey with some silt; weathers light green; thin-bedded; iron stains on fracture planes	1.5
Shale, slightly calcareous, fissile; black to gray-green; clayey with some silt; weathers dark gray; iron stains on fracture planes	.6
Limestone, clayey, medium-hard, gray; weathers light gray and thin-bedded to blocky; iron stains on fracture planes	.8
Shale, thin-bedded to blocky; slightly calcareous, olive-drab; clayey with some silt; weathers light gray; iron stains on some fracture planes	1.4
Limestone, clayey, medium-hard, gray; weathers light gray; blocky with a thin wavy bed at the base; some iron stains	.5
Shale, silty, slightly calcareous, gray-brown, blocky to thin-bedded; weathers tan	1.5
Limestone, clayey, medium-hard, light-green, massive; weathers tan and cavernous; very lenticular and wavy; thin shale lens near the top	1.5
Shale, calcareous, blocky, lenticular, gray-green; clayey with some silt, weathers very light green	.3
Shale, clayey, noncalcareous, purple, blocky; weathers light maroon	.5
Shale, silty, very calcareous, light-green, thin-bedded; weathers very light gray	.6
Shale, silty, calcareous, pinkish-violet mottled with purple, thin-bedded; weathers light purple	.6
Shale, silty, calcareous, purple, thin-bedded to blocky; contains 2 zones of resistant material that weathers to a series of columns; iron stains on fracture planes	2.8

	Feet
Eskridge shale—Continued	
Shale, silty, calcareous, green to purple, blocky to thin-bedded; the upper part weathers to a columnar appearance; iron stains on bedding planes	1.6
Shale, slightly silty, noncalcareous, maroon, thin-bedded	.3
Shale, silty, calcareous, green, blocky to thin-bedded, lenticular; weathers light green; clayey limestone in upper part; iron stains on some of the weathered surfaces	.6
Shale, silty, calcareous, maroon; thin-bedded	.2
Limestone, clayey, medium-hard, gray, lenticular; iron stained; weathers light gray and blocky	.3
Shale, silty, calcareous, green, thin-bedded to platy; lenticular; weathers light green; some thin lenticular limestone	1.1
Total thickness	34.0
Grenola limestone:	
Neva limestone member:	
Limestone, hard, tan, massive; lenticular; weathers tan gray; lenticular algal-like zone in the upper part; brachiopod fragments	1.8
Shale, silty, very calcareous, light-green, thin-bedded; weathers tan; contains brachiopods and echinoid spines	3.6
Limestone, hard, light-gray, blocky; weathers tan and to irregular blocks; contains small calcite-filled cavities	1.5
Shale, silty, calcareous, tan, thin-bedded	.2
Limestone, hard, dense, gray-orange; weathers tan; massive to rotten at base; forms hillside bench; contains echinoid spines, bryozoans and brachiopod fragments	2.8
Limestone, hard, gray-orange, massive, blocky; thin shale parting near middle; speckled with small iron spots; secondary calcite is present on some weathered surfaces; contains echinoid spines and brachiopod fragments	1.8
Shale, silty, calcareous, gray-orange, thin-bedded; weathers cream	.7
Limestone, hard, dense, gray-orange, thin-bedded to blocky, iron-stained; weathers tan; contain small calcite crystals; some echinoid spines	1.2
Shale, silty, noncalcareous, blue-gray, thin-bedded to fissile; weathers light blue; fusulinids and brachiopods common	.8
Shale, silty, calcareous, brown, thin-bedded to fissile; weathers tan	.4
Limestone, dense, gray-orange; weathers tan; contains calcite nodules; shows tendency to fracture; contains crinoid columnals, bryozoans, and brachiopod fragments	1.3
Thickness	16.1
Salem Point shale member:	
Shale, silty, calcareous, gray-orange to blue-gray, thin-bedded; weathers tan; contains many thin calcareous lenses which weather to give the shale a platy appearance; a thin lens of limestone occurs in the middle part. Thickness	9.1

	Feet
Grenola limestone—Continued	
Burr limestone member:	
Limestone, soft, cream; weathers tan; massive to platy; ostracode zone in upper part	2.6
Shale, silty, calcareous, tan, blocky	.2
Limestone, clayey, hard, gray-brown, iron-stained; weathers tan and blocky; pelecypods common	.2
Shale, silty, calcareous, tan; thin-bedded to blocky	.4
Limestone, medium-hard, gray-orange, iron-stained; weathers tan and blocky; pelecypods abundant	.4
Thickness	3.8
Legion shale member:	
Shale, clayey, noncalcareous, black to olive-drab, fissile. Thickness	1.7
Sallyards limestone member:	
Limestone, medium-hard, clayey, gray to tan-gray; weathers tan gray, blocky, and in small chips; contains bryozoans, crinoid columnals, and fragments of other fossils. Thickness	1.3
Total thickness of Grenola limestone	32.0
Roca shale:	
Shale, clayey, calcareous, blocky; gray, with a gray-green tint; weathers gray; some silt; some calcareous nodules. Thickness exposed	5.5
Base covered.	

34. *Section from the base of the Cottonwood limestone member of the Beattie limestone down to the top of the Roca shale in a road cut in the SW¼SW¼ sec. 11, T. 12 S., R. 11 E.*

	Feet
Base of Cottonwood limestone member of the Beattie limestone.	
Eskridge shale:	
Shale, silty, calcareous, tan-gray to gray-green, thin-bedded to blocky; cavernous in middle part; very calcareous in upper part; thin calcareous lentils in lower part	17.6
Covered by colluvium	15.9
Total thickness	33.5
Grenola limestone:	
Neva limestone member:	
Limestone, medium-hard, tan to gray; porous; weathers blocky; echinoid spines	5.9
Shale, silty, calcareous, tan-gray, thin-bedded; fusulinids abundant; crinoid columnals and echinoid spines common	.8
Limestone, medium-hard, gray-brown; weathers blocky; cavernous, especially in lower part; calcite lining some of the pores; fossil fragments very abundant	1.3

Grenola limestone—Continued	
Neva limestone member—Continued	*Feet*
Shale, silty, calcareous, tan to gray, thin-bedded; numerous calcium carbonate lentils in upper parts; crinoid columnals and fusulinids abundant in upper part; brachiopod fragments common	3.3
Limestone, hard, dense, gray; weathers blocky; fusulinids, echinoid spines, and fragments	1.2
Shale, silty, calcareous, tan; thin-bedded	.7
Limestone, soft, tan; weathers shaly to blocky; minute fossils and ostracodes	.3
Thickness	13.5
Salem Point shale member:	
Shale, silty, calcareous, gray; weathers tan; thin-bedded; many calcareous plates. Thickness	7.6
Burr limestone member:	
Limestone, hard, partly dense, gray; weathers platy to blocky; ostracodes in upper part	.5
Shale, silty, calcareous, gray to tan; thin-bedded	.6
Limestone, soft, gray; weathers shaly	2.1
Shale, silty, calcareous, tan-gray; thin-bedded	1.1
Limestone, dark-gray; weathers blocky; fossil fragments; gastropods and crinoid columnals common	1.1
Shale, silty, calcareous, tan-gray; thin-bedded	.6
Limestone, hard, dark-gray; weathers blocky to shaly; crinoid columnals, brachiopod fragments, and pelecypods	.9
Thickness	6.9
Legion shale member:	
Shale, clayey, calcareous, gray; thin-bedded. Thickness	3.9
Sallyards limestone member:	
Limestone, medium-hard, gray; weathers tan gray and blocky to platy; pelecypods abundant; gastropods and small fossil fragments common. Thickness	0.9
Total thickness of Grenola limestone	32.8
Roca shale.	

35. *Section from the middle part of the Neva limestone member of the Grenola limestone down into the upper part of the Roca shale in a road cut in the NW¼SE¼ sec. 30, T. 12 S., R. 12 E.*

Grenola limestone:	
Neva limestone member:	*Feet*
Limestone, medium-hard, gray, massive; weathers blocky in lower part, platy in upper part; porous; echinoid spines, some brachiopod fragments, and corals	3.2
Shale, silty, calcareous, gray, thin-bedded; fusulinids abundant; crinoid columnals and echinoid spines common	1.0

	Feet
Grenola limestone—Continued	
Neva limestone—Continued	
Limestone, medium-hard, tan; weathers blocky; fusulinids abundant, especially in upper part; crinoid columnals, echinoid spines, and brachiopods	0.7
Shale, silty, tan-gray, thin-bedded; some clay; fusulinids abundant in upper part	3.9
Limestone, medium-hard, tan gray; weathers blocky; fossil fragments abundant; brachiopods, bryozoans crinoid columnals, and fusulinids common to rare	1.8
Thickness exposed	10.6
Salem Point shale member:	
Shale, silty, calcareous, tan-gray; thin limestone lentils in lower part. Thickness	8.9
Burr limestone member:	
Limestone, medium-hard to soft, tan to light-gray; weathers shaly to platy; pelecypods abundant in lower part; ostracodes abundant in upper 0.4 foot	1.8
Shale, silty, calcareous, tan-gray; thin-bedded	3.1
Limestone, hard, gray; weathers blocky; fossil fragments and gastropods abundant, fusulinids rare and crinoid columnals common	1.2
Shale, silty, calcareous, tan-gray; thin-bedded	.2
Limestone, medium-hard, tan; weathers blocky and in irregular chips; fossil fragments, pelecypods, and gastropods abundant	1.0
Thickness	7.3
Legion shale member:	
Shale, clayey, noncalcareous, gray; thin-bedded. Thickness	1.9
Sallyards limestone member:	
Limestone, medium-hard, gray; weathers blocky; crinoid columnals, bryozoans and brachiopods common, fossil fragments abundant. Thickness	.9
Thickness of exposed Grenola limestone	29.6
Roca shale:	
Shale, silty, calcareous, gray to tan; thin-bedded. Thickness exposed	2.8
Base covered.	

36. *Section from the Neva limestone member of the Grenola limestone down into the Howe limestone member of the Red Eagle limestone in a road cut in the SE¼SW¼NW¼ sec. 14, T. 12 S., R. 12 E.*

	Feet
Grenola limestone:	
Neva limestone member:	
Limestone, medium-hard; gray; weathers blocky and in irregular chips; algae, fusulinids, and fragments. Thickness exposed.	1.4

Grenola limestone—Continued	*Feet*
Salem Point shale member:	
Shale, silty, calcareous, olive-drab, blocky; calcareous lentils. Thickness	7.7
Burr limestone member:	
Limestone, soft, coquinoid, tan-brown; limonite stained; composed almost entirely of ostracodes and fragments of other fossils	.3
Limestone, medium-hard, gray to tan; blocky to platy	2.2
Shale, clayey, noncalcareous, dark-gray; thin-bedded to fissile; thin-shelled brachiopods common	1.6
Limestone, medium-hard, gray to tan; weathers blocky and in small chips; fossil fragments	2.1
Thickness	6.2
Legion shale member:	
Shale, clayey, calcareous, gray-brown; thin-bedded	4.5
Shale, clayey, noncalcareous, dark-gray; thin-bedded to blocky	3.2
Thickness	7.7
Sallyards limestone member:	
Limestone, medium-hard, gray; weathers blocky; crinoid columnals, gastropods, pelecypods, and fragments of these and other fossils. Thickness	.9
Thickness of exposed Grenola limestone	23.9
Roca shale:	
Shale, clayey, calcareous; tan gray mottled with purple; weathers tan; thin-bedded	5.7
Shale, clayey, calcareous; purple in the lower part grading up into gray green and olive drab; blocky; iron stains on fracture planes	5.6
Limestone, shaly, soft, conglomeratic, tan; limestone and iron nodules at least ¼ inch in diameter	.9
Shale, very limy and calcareous, light-gray, massive to blocky; iron stains on fracture planes	2.7
Shale, clayey, calcareous, tan-gray, thin-bedded; some calcareous lentils	6.8
Total thickness	21.7
Red Eagle limestone:	
Howe limestone member:	
Limestone, soft, brown; weathers blocky and porous; ostracodes very abundant in upper part. Thickness exposed	2.4
Base covered.	

37. *Section from base of the Burr limestone member of the Grenola limestone down into the Howe limestone member of the Red Eagle limestone in a road cut in the SW¼NW¼ sec. 13, T. 13 S., R. 12 E.*

Grenola limestone:
Base of Burr limestone member.
Legion shale member: *Feet*
Shale, silty, calcareous, gray-brown; thin-bedded; pelecypods 2.1
Shale, silty, calcareous, gray; thin-bedded 1.4

Thickness 3.5
Sallyards limestone member:
Limestone, medium-hard, gray; weathers blocky and in irregular chips. Thickness .9

Thickness of exposed Grenola limestone 4.4

Roca shale:
Shale, clayey, noncalcareous, gray-brown to dark-gray; thin-bedded 15.2
Shale, clayey, calcareous, gray-green to purple; blocky; calcium carbonate nodules abundant 5.6
Shale, gray to tan; cavernous to platy 2.1
Shale, silty, calcareous, gray to tan-gray, thin-bedded; calcareous plates abundant in upper part 7.8

Total thickness 30.7

Red Eagle limestone:
Howe limestone member:
Limestone, brown to tan-brown, medium-hard; weathers nodular and porous. Thickness exposed .6
Base covered.

38. *Section from the Sallyards limestone member of the Grenola limestone down into the base of the Foraker limestone in a road cut in the SW¼NW¼NW¼ sec. 9, T. 12 S., R. 12 E.*

Grenola limestone:
Sallyards limestone member: *Feet*
Limestone, medium-hard; gray with minute brown specks; weathers blocky; iron stains abundant; small gastropods abundant; fossil fragments. Thickness exposed 0.5

Roca shale:
Shale, clayey, calcareous, gray-green to tan-gray; some purple in middle part; blocky; many thin calcareous lenses. Total thickness 22.6

	Feet
Red Eagle limestone:	
Howe limestone member:	
Limestone, soft, brown to tan-brown, blocky, porous; some celestite(?)-lined cavities and pore spaces; ostracodes abundant in upper part. Thickness	2.4
Bennett shale member:	
Shale; covered by colluvium. Thickness	9.2
Glenrock limestone member:	
Limestone, medium-hard, gray-brown; weathers blocky; limonite nodules common; fusulinids and pelecypods. Thickness	.9
Total thickness of Red Eagle limestone	12.5
Johnson shale:	
Shale (mostly covered), clayey, calcareous, gray-green to gray; thin-bedded to blocky; clayey limestone lenses abundant. Total thickness	24.9
Foraker limestone:	
Long Creek limestone member:	
Limestone, soft, tan-brown; weathers platy; cavernous with some celestite. Thickness	5.8
Hughes Creek shale member:	
Limestone, medium-hard, gray; weathers in irregular plates; fusulinids very abundant	1.5
Shale, silty, calcareous, tan-gray, thin-bedded; iron stained; fusulinids abundant	1.1
Shale (covered with colluvium)	9.3
Limestone, medium-hard, gray; weathers in irregular plates; fossil fragments	.5
Shale, silty, calcareous, tan-gray; thin-bedded	1.3
Limestone, soft to medium-hard, gray; weathers in irregular plates; fossil fragments	.9
Shale, clayey to silty, calcareous, gray to tan-gray, thin-bedded; fusulinids abundant; brachiopods and bryozoans common	4.5
Limestone, medium-hard, gray-brown; weathers blocky; some iron stains; fossil fragments abundant; fusulinids and brachiopods common	.5
Shale, clayey, calcareous, gray, thin-bedded; limonite stains abundant	1.4
Limestone, medium-hard, gray to tan-gray; weathers blocky and in irregular plates; fossil fragments	.8
Shale (mostly covered), clayey, calcareous, gray, thin-bedded to blocky; some iron stains	13.8
Thickness	35.6
Americus limestone member:	
Limestone, hard, dark blue-gray; weathers blocky; crinoid columnals abundant; fusulinids and brachiopod fragments common	1.1

Foraker limestone—Continued

	Feet
Americus limestone member—Continued	
Shale, silty, calcareous, tan-gray; thin-bedded	0.5
Limestone, medium-hard; tan to tan gray; weathers blocky and in small irregular chips; minute fossil fragments abundant in lower part; brachiopods and crinoid columnals common	1.0
Thickness	2.6
Total thickness of Foraker limestone	44.0

Base covered.

39. *Section from the Sallyards limestone member of the Grenola limestone down to the top of the Americus limestone member of the Foraker limestone in a streambank in the SW¼NE¼ sec. 11 T. 12 S., R. 10 E.*

	Feet
Grenola limestone:	
Sallyards limestone member:	
Limestone, medium-hard, tan-gray, blocky; weathers shaly in lower part; pelecypods. Thickness exposed	1.6
Roca shale:	
Shale, silty to clayey, calcareous, gray-brown; thin-bedded	1.6
Limestone, hard, brittle, clayey, dense, tan-gray; weathers blocky	.6
Shale, clayey, calcareous; gray green in lower part, olive drab to tan gray in upper part; thin very calcareous zones in middle part	8.7
Shale, very calcareous, light-gray to white; blocky and in irregular plates	5.6
Shale, silty, calcareous, maroon; thin-bedded	.9
Shale, silty to clayey, calcareous, gray-green; some mudstone lenses	7.5
Total thickness	24.9
Red Eagle limestone:	
Howe limestone member:	
Limestone, soft to medium-hard, tan-brown; weathers gray and blocky; crystalline. Thickness	.7
Bennett shale member:	
Shale, silty, calcareous; olive drab mottled with some gray; weathers tan; blocky to thin-bedded; crinoid columnals, brachiopods, echinoid spines, and fusulinids	5.1
Shale, silty, very calcareous, tan-brown, massive; weathers tan and blocky; fossil fragments	1.6
Shale, clayey, calcareous, dark-gray; weathers olive drab; wood fragments and carbon stains in lower part; some iron stains	4.7
Thickness	11.4
Glenrock limestone member (missing).	
Total thickness of Red Eagle limestone	12.1

	Feet
Johnson shale:	
Shale, calcareous, tan-brown, massive to thin-bedded; clayey at the base, silty in the upper part; very calcareous near base; weathers tan; calcareous plates on surface; some iron stains on bedding planes	5.5
Shale (mostly covered by slump), clayey, calcareous, gray to gray-green; thin-bedded to blocky; very calcareous bed in middle part; some iron stains	14.3
Total thickness	19.8
Foraker limestone:	
Long Creek limestone member:	
Limestone, medium-hard, tan-brown to yellow-brown, some gray brown; massive; weathers shaly and in irregular blocks; porous, pitted; some solution channels; some celestite and iron stains	.6
Shale, silty, calcareous, gray-green; blocky	.5
Limestone, medium-hard, tan-brown, massive; earthy in upper part; weathers gray brown and unevenly on surface; calcite and celestite crystals in pitted surface; solution channels	.7
Shale, silty, noncalcareous; gray green at the base, tan brown in the upper part; weathers tan; blocky in the upper part, becomes thin-bedded in lower part	.5
Limestone, soft, dolomitic, tan; mottled with gray in middle part; massive; weathers blocky to platy	3.2
Limestone, soft, tan-brown, massive; weathers tan and blocky; pitted; speckled with brown stains; fossil fragments in basal part	1.4
Shale, silty, calcareous, tan-gray to gray, thin-bedded; wood fragments	.3
Limestone, soft, tan to yellow-brown, massive; weathers blocky; some iron stains; porous; pelecypod zone in middle part	.7
Thickness	7.9
Hughes Creek shale member:	
Limestone, clayey, gray, massive; weathers tan-gray, shaly, and in irregular blocks; fusulinids very abundant	2.1
Shale (mostly covered), gray	10.4
Limestone, medium-hard, gray; weathers blocky; brachiopods and fusulinids	.9
Shale, clayey, calcareous, gray; some silt; weathers fissile	1.4
Limestone, medium-hard, gray; weathers blocky	.7
Shale, clayey, calcareous, gray, thin-bedded	9.1
Limestone, medium-hard, gray; weathers shaly in the upper part	1.1
Shale, silty, calcareous, gray, thin-bedded	3.5
Shale, gray; fossil fragments	1.7
Shale, silty, gray, thin-bedded; very fossiliferous	9.5
Thickness	40.4

	Feet
Foraker limestone—Continued	
Americus limestone member: Top.	
Thickness of exposed Foraker limestone	48.3
Base covered.	

40. *Section from the Roca shale down into the Johnson shale in a streambank in the center sec. 36, T. 14 S., R. 11 E.*

	Feet
Soil and colluvium; about 6 feet thick.	
Roca shale:	
Limestone, hard, tan; weathers tan gray and shaly; porous; some microfossils	0.5
Shale, silty, very calcareous, gray-green; weathers light gray; blocky to thin-bedded; some limonite nodules and stains	3.7
Thickness exposed	4.2
Red Eagle limestone:	
Howe limestone member:	
Limestone, soft, tan; weathers gray; massive; weathers blocky; porous; 0.3-foot chert lens in upper part; some microfossils, including ostracodes. Thickness	3.4
Bennett shale member:	
Shale, silty, calcareous, gray-brown; weathers tan; thin-bedded; iron stained	.5
Shale, clayey, slightly calcareous, dark-gray, thin-bedded to fissile; contains brachiopods	2.3
Thickness	2.8
Glenrock limestone member:	
Limestone, hard, tan-gray, massive, iron-stained; weathers blocky; small fusulinids abundant; echinoid spines and brachiopods common. Thickness	1.2
Total thickness of Red Eagle limestone	7.4
Johnson shale:	
Shale, clayey, slightly calcareous, dark-gray; weathers gray; blocky, becoming thin-bedded at the base; some iron stains. Thickness exposed	3.2
Base covered.	

41. *Section of the Red Eagle limestone in a road cut in the NE¼NE¼ sec. 12, T. 15 S., R. 11 E.*

	Feet
Red Eagle limestone:	
Bennett shale member:	
Limestone (biostrome facies), medium-hard, light-gray to tan, massive; weathers tan gray and blocky; many styolites; some celestite-filled pores about 4 feet from the top; iron stains; brachiopods, corals, algae, crinoid columnals, and echinoid spines; forms prominent hillside bench	13.2

Red Eagle limestone—Continued

	Feet
Bennett shale member—Continued	
Limestone, medium-hard, tan-brown; weathers gray, blocky in the lower part but shaly near the top; chitinous brachiopod fragments very abundant in lower part; fusulinids, crinoid columnals, and echinoid spines	0.7
Shale, clayey, calcareous, tan-gray to dark-gray, thin-bedded to fissile, carbonaceous	3.9
Thickness exposed	17.8
Glenrock limestone member:	
Limestone, hard, tan-gray; weathers blocky; fusulinids very abundant; crinoid columnals	.9
Thickness of exposed Red Eagle limestone	18.7

Base covered.

42. *Section from the Howe limestone member of the Red Eagle limestone down into the Hamlin shale member of the Janesville shale in two road cuts in the SW¼SW¼ sec. 30, T. 11 S., R. 12 E.*

Soil, about 4 feet thick.

Red Eagle limestone:

	Feet
Howe limestone member:	
Weathered limestone	0.6
Limestone, soft, tan, blocky to thin-bedded; porous; wavy; ostracodes abundant	.8
Limestone, soft, gray-orange; weathers tan; lenticular, wavy; contains ostracodes, brachiopods, and pelecypods	1.3
Limestone, slightly dolomitic, red-brown; weathers gray orange; massive; lenticular	1.5
Thickness exposed	4.2
Bennett shale member:	
Shale, silty, calcareous, gray-brown; weathers tan; thin-bedded; limonite stains on some areas; echinoid spines abundant; brachiopods and bryozoans common	2.6
Limestone, clayey, gray-orange; weathers tan and platy; lenticular; brachiopods and crinoid columnals	.5
Shale, silty, calcareous, olive-drab to dark gray-brown; in some places almost black; weathers tan to blue gray; thin-bedded to fissile; chitinous brachiopods abundant	2.9
Thickness	6.0
Glenrock limestone member:	
Limestone, hard, tan, massive; weathers blocky; limonite stained at top; many minute plant fragments or microfossils; fusulinids abundant; brachiopods and pelecypods. Thickness	2.0
Thickness of exposed Red Eagle limestone	12.2

	Feet
Johnson shale:	
Shale, silty, calcareous, tan, thin-bedded	0.5
Shale, silty, calcareous; olive drab mottled with black; weathers tan to blue gray; thin-bedded to fissile; blocky in the middle part	5.8
Shale, very calcareous, tan, platy to blocky; iron stains on fracture planes; wavy folding	2.1
Shale, gray-orange, thin-bedded; considerable secondary calcite; weathers tan	.5
Limestone, medium-hard, gray; weathers blocky; iron stains on fracture planes	.1
Shale, silty, calcareous, gray-brown, blocky; weathers tan	1.0
Shale, silty, very calcareous, gray-brown; weathers tan and is light gray-yellow in basal part; platy to blocky; resistant to weathering	.8
Shale, silty, calcareous, olive-drab, thin-bedded to blocky; weathers tan gray	1.3
Shale, silty, calcareous, yellow-green, thin-bedded to blocky; weathers tan	.8
Shale, calcareous, gray-green, thin-bedded to blocky; grades down to green, mottled with purple in middle part	4.5
Shale, very calcareous, gray; weathers tan gray; generally thin-bedded; massive in basal part; some calcareous lenses and iron stains; wavy folding	2.5
Shale, silty, calcareous, olive-drab to green, thin-bedded to blocky, iron-stained; calcium carbonate nodules in the lower part	6.7
Total thickness	26.6
Foraker limestone:	
Long Creek limestone member:	
Limestone, soft, dolomitic, red-brown, massive; weathers gray orange; small calcite-lined cavities throughout; thick masses of white to tan celestite occur in upper part; pelecypods abundant in middle part. Thickness	4.6
Hughes Creek shale member:	
Limestone, clayey, soft, dark-gray, blocky, irregular; weathers blue gray; many brown specks	3.0
Shale, clayey, noncalcareous; olive-drab to black; some silt; weathers blue gray; thin-bedded to fissile	4.5
Shale, silty, calcareous, dark-gray; weathers blue gray; thin-bedded to blocky; fusulinids abundant; brachiopods, crinoid columnals, bryozoans, and echinoid spines and plates common	1.8
Limestone, soft, clayey, blue-gray; weathers tan and platy in upper part; fusulinids abundant; brachiopods and bryozoans common	1.0
Shale, silty, noncalcareous, black to dark blue-gray; weathers blue gray; fissile; thin-shelled brachiopods common	2.3
Limestone, soft, clayey, gray; weathers tan and platy; massive; fusulinids, echinoid spines, and brachiopod fragments	.8
Shale, silty, calcareous, olive-drab; weathers tan; thin-bedded to blocky in the lower part	.7

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	Feet
Foraker limestone—Continued	
Hughes Creek shale member—Continued	
Shale, silty, noncalcareous, black, fissile; weathers blue gray	0.7
Shale, silty, very calcareous, dark-gray, thin-bedded to platy; weathers light blue gray; brachiopods, bryozoans, and echinoid spines	2.9
Limestone, clayey, dark-gray, massive; weathers gray and blocky	.2
Shale, silty, calcareous, black, fissile; weathers blue gray; brachiopods abundant	.1
Limestone, hard, tan, blocky	.5
Shale, silty, calcareous, dark blue-gray, fissile; weathers blue gray; contains fusulinids and brachiopods	.5
Limestone, dense, blue-gray; weathers tan and platy in upper part; brachiopod fragments and echinoid spines	.9
Shale, silty, calcareous, dark blue-gray, thin-bedded to fissile; weathers gray	5.0
Shale, silty, very calcareous, gray, thin-bedded to platy; weathers tan gray; more resistant to weathering than shales above and below; brachiopods abundant; pelecypods common	2.8
Shale, silty, calcareous; thin-bedded to blocky; gray brown mottled with dark gray; weathers tan; some brachiopods	7.0
Shale, silty, calcareous, gray, thin-bedded; weathers light gray; crinoid columnals present	.6
Thickness	35.3
Americus limestone member:	
Limestone, hard, gray to tan-gray; weathers tan gray and blocky; complete and fragmentary brachiopods, crinoid columnals, and echinoid spines	1.2
Shale, silty, calcareous, gray, thin-bedded; weathers tan gray	.2
Limestone, medium-hard, tan; weathers tan gray, and blocky; some microfossils	1.0
Limestone, medium-hard, tan; weathers to irregular beds; some iron stains on fracture planes; microfossils	1.4
Shale, silty, calcareous, gray; some clay; weathers tan gray; blocky; some iron stains	.7
Limestone, hard, partly dense, gray; weathers tan gray and blocky; porous in part; limonite stained; algal band in middle part	.7
Thickness	5.2
Total thickness of Foraker limestone	45.1
Janesville shale:	
Hamlin shale member:	
Sandstone (calcarenite), fine-grained; calcareous fragments; ostracodes	.5
Shale, silty, calcareous, thin-bedded to blocky, gray to gray-green; some clay; weathers tan gray; some limonite stains on bedding planes; calcareous plates and nodules on weathered surface	15.9
Thickness exposed	16.4

Base covered.

43. *Section from the base of the Johnson shale down into the middle part of the Hamlin shale member of the Janesville shale in a road cut in the SW¼SE¼SE¼ sec. 27, T. 11 S., R. 11 E.*

	Feet
Base of Johnson shale.	
Foraker limestone:	
Long Creek limestone member:	
Limestone, medium-hard, slightly dolomitic, tan brown; weathers blocky to porous; some shale partings; some celestite; pelecypods in lower part. Thickness exposed	5.6
Hughes Creek shale member:	
Shale, very calcareous, gray, fusulinids very abundant; some brachiopods	3.6
Shale, silty, calcareous, gray, thin-bedded; thin micaceous lentils in upper part; brachiopods, crinoid columnals, echinoid spines, and bryozoans common; fusulinids very abundant	6.1
Limestone, medium-hard, gray; weathers shaly to blocky; contains fusulinids, crinoid columnals and fragments of fossils	1.1
Shale, clayey, calcareous, very dark gray, thin-bedded; carbonaceous zones; iron-stained zone in middle part	2.2
Limestone, soft, granular, gray-brown; weathers shaly; fossil fragments and microfossils abundant; fusulinids common	.7
Shale, silty, calcareous, micaceous, gray, thin-bedded; sandstone lentils in middle part; crinoid columnals, fusulinids, and brachiopods	8.1
Limestone, medium-hard, dark-gray; weathers blocky; fossil fragments abundant; fusulinids common	.4
Shale, silty, calcareous, gray, thin-bedded	.7
Limestone, medium-hard, dark-gray; weathers blocky; minute fossil fragments abundant	.4
Shale, silty, calcareous, dark-gray, thin-bedded; some calcareous plates; crinoid columnals, brachiopods, fusulinids, and bryozoans	15.6
Thickness	38.9
Americus limestone member:	
Limestone, hard, dark-gray; weathers blocky; crinoid columnals and fusulinids common; fossil fragments abundant	1.0
Shale, clayey, noncalcareous, gray, thin-bedded; limonite stains in lower part	.8
Limestone, hard, gray-brown to gray, massive; weathers in irregular chips and plates in lower part, blocky in upper part; fossil fragments, microfossils, and ostracodes abundant; thin band of gray algae in the lower 0.6 foot	1.8
Thickness	3.6
Thickness of exposed Foraker limestone	48.1

	Feet
Janesville shale:	
Hamlin shale member:	
Shale, silty, calcareous, gray, thin-bedded	0.8
Shale, silty, very calcareous, gray, blocky; limonite stains in upper part	3.5
Shale, silty, calcareous, gray-green, blocky	7.4
Shale, silty, calcareous, dark-gray, thin-bedded	.6
Shale, clayey, calcareous, gray-green, thin-bedded; weathers tan gray	7.0
Shale, clayey, calcareous, maroon, thin-bedded; some silt	2.5
Shale, clayey, noncalcareous, gray, thin-bedded; numerous limonite stains	9.1
Thickness exposed	30.9

Base covered.

44. *Section from the lower part of the Johnson shale down to the base of the Foraker limestone in a road cut in SW¼NW¼ sec. 3, T. 13 S., R. 12 E.*

	Feet
Johnson shale:	
Shale, silty to clayey, calcareous, gray-green, thin-bedded; irregular limestone beds in upper part that are light gray, soft, and platy to blocky. Thickness exposed	5.3
Foraker limestone:	
Long Creek limestone member:	
Limestone, soft, dolomitic, tan to tan-brown; weathers cavernous; much calcite and celestite crystals in pores. Thickness	6.4
Hughes Creek shale member:	
Shale, silty, calcareous, dark-gray, thin-bedded	.5
Limestone, medium-hard, tan-brown; weathers blocky; pelecypods abundant; brachiopods and fusulinids common	.5
Shale, silty, calcareous, gray, thin-bedded	.7
Limestone, shaly, gray; composed almost entirely of fusulinids	2.7
Shale, silty, calcareous, gray, thin-bedded; fusulinids abundant; brachiopods common	10.4
Limestone, hard, gray; weathers blocky; fossil fragments abundant; fusulinids, crinoid columnals, corals, and trilobites common to rare	.8
Shale, clayey, calcareous, dark-gray, thin-bedded to fissile	.7
Limestone, hard, dark-gray; weathers blocky to shaly; fossil fragments and fusulinids	.4
Shale, silty, very calcareous, gray, thin-bedded; fusulinids abundant, brachiopods common	5.4
Limestone, medium-hard, gray; weathers blocky; fossil fragments and fusulinids	.5
Shale, silty, calcareous, gray, thin-bedded; brachiopods and fusulinids	.7
Limestone, hard, gray; weathers tan and from blocks to irregular plates; thin shale parting in upper part; fossil fragments of fusulinids and bryozoans	1.1
Shale, silty, calcareous, gray, thin-bedded; brachiopods, crinoid columnals, and bryozoans	13.4
Thickness	37.8

	Feet
Foraker limestone—Continued	
Americus limestone member:	
Limestone, hard, dark-gray; weathers blocky	1.6
Shale, silty, calcareous, gray; weathers blocky	.8
Limestone, medium-hard, tan-brown, partly dense; weathers in irregular blocks and chips; gray in upper part; microfossils abundant and dark-gray algal masses in lower part	2.0
Thickness	4.4
Total thickness of Foraker limestone	48.6
Base covered.	

45. *Section from the base of the Long Creek limestone member of the Foraker limestone down into the Hamlin shale member of the Janesville shale in a borrow pit in the center of sec. 33, T. 10 S., R. 10 E.*

	Feet
Foraker limestone:	
Long Creek limestone member: Base.	
Hughes Creek shale member:	
Shale, silty, calcareous, gray to tan-gray; thin-bedded to blocky; fossil fragments abundant in lower part; fusulinids very abundant	5.1
Limestone, medium-hard, gray; weathers shaly to blocky; fossil fragments	.8
Shale, silty, calcareous, thin-bedded; tan gray in upper part, dark gray in lower part; brachiopods	1.6
Limestone, medium-hard, tan-gray, blocky, iron-stained; fossil fragments	1.1
Shale, silty, calcareous, gray, thin-bedded to blocky; weathers tan gray	5.1
Shale, very calcareous, gray; weathers tan gray; thin-bedded becoming blocky in upper part; iron stains abundant in lower part; fossils very abundant	3.4
Limestone, medium-hard, clayey, gray, blocky	.2
Shale, silty, calcareous, very dark gray, thin-bedded	.5
Limestone, medium-hard, gray, blocky; fossil fragments	.5
shale, silty, calcareous, tan-gray, thin-bedded, very fossiliferous	.5
Limestone, medium-hard, gray, blocky; weathers tan; fossil fragments abundant in lower part; brachiopods	.8
Shale, clayey, calcareous, gray, blocky; weathers olive drab; brachiopods in upper part	2.9
Limestone, argillaceous, gray to tan-gray, blocky to shaly, iron-stained; brachiopods abundant in lower part	1.5
Shale, clayey, calcareous, gray, blocky; some silt; thin fossiliferous zones in upper part; lower part fossiliferous	8.8
Thickness	32.8
Americus limestone member:	
Limestone, hard, dark-gray, blocky; crinoid columnals and pelecypods abundant	.9

Foraker limestone—Continued	
Americus limestone member—Continued	*Feet*
Shale, silty, calcareous, gray, thin-bedded	0.2
Limestone, medium-hard, gray; weathers blocky in upper part and in irregular plates in lower part; iron stains abundant; banded algae in lower 0.3 foot; microfossils abundant	1.7
Thickness	2.8
Thickness of exposed Foraker limestone	35.6
Janesville shale:	
Hamlin shale member:	
Sandstone; (calcarenite) composed of grains of limestone and ostracodes	.2
Shale, silty, calcareous, thin-bedded to blocky; gray green grading up into gray; calcareous lenses in the upper part	12.7
Thickness exposed	12.9

Base covered.

46. *Section from the Hughes Creek shale member of the Foraker limestone down into the Hamlin shale member of the Janesville, inclusive in a road cut in the SW¼NW¼ sec. 1, T. 15 S., R. 12 E.*

Soil, silty, dark gray; a maximum of 4 feet thick.

Foraker limestone:	
Hughes Creek shale member:	*Feet*
Shale, silty, calcareous, dark-gray, thin-bedded; weathers tan; very fossiliferous; fossils include brachiopods, pelecypods, bryozoans, and crinoid columnals. Thickness exposed	5.7
Americus limestone member:	
Limestone, hard, dark-gray, massive; weathers gray and blocky; fusulinids abundant; brachiopods and crinoid columnals common	1.2
Shale, clayey, noncalcareous, gray to gray-green, thin-bedded; weathers tan to gray; some limonite stains	1.7
Limestone, soft, gray to dark-gray; weathers shaly; crinoid columnals and echinoid spines	.5
Shale, silty, very calcareous, gray to dark-gray, thin-bedded	.6
Limestone, hard, partly dense, massive, gray; weathers tan gray and from blocky to platy; large massive algae gives wavy bedded appearance; brachiopod fragments	.7
Thickness	4.7
Thickness of exposed Foraker limestone	10.4

Janesville shale:

Hamlin shale member:

	Feet
Sandstone, (calcarenite) tan; composed of minute limestone fragments	0.4
Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; calcareous lens in lower part	2.8
Shale, silty, calcareous, gray-green, thin-bedded	2.9
Thickness exposed	6.1

Base covered.

47. *Section from the Hughes Creek shale member of the Foraker limestone into the Hamlin shale member of the Janesville shale is in a road cut in the SW¼SE¼ sec. 12, T. 12 S., R. 11 E.*

Soil, silty, brown; about 3.5 feet thick.

Foraker limestone:

Hughes Creek shale member:

	Feet
Shale, gray, thin-bedded; calcareous becoming very calcareous at base; weathers tan; brachiopods, fusulinids, and crinoid columnals	1.1

Americus limestone member:

Limestone, hard, dark-gray; weathers gray to tan; fractures at right angles; crinoid columnals, brachiopods, bryozoans, fusulinids, pelecypods, and corals	1.3
Shale, silty, slightly calcareous, dark-gray, thin-bedded; weathers tan gray	.7
Limestone, hard, tan-gray; weathers tan and to irregular fragments; some brachiopod fragments	.7
Limestone, hard, dense, tan-gray; weathers gray and platy; many minute specks	1.1
Limestone, hard, tan-gray; weathers tan and to irregular fragments; some iron stains; thick algal band near middle	.7
Thickness	4.5
Thickness of exposed Foraker limestone	5.6

Janesville shale:

Hamlin shale member:

Limestone, soft, red-brown, thin-bedded; weathers tan; badly weathered; microfossils common	.5
Shale, silty, calcareous, gray-green, thin-bedded, lenticular; weathers gray	.6
Limestone, hard, tan-gray; weathers tan and to rounded edges; algae	1.0
Shale, silty, calcareous, gray-green, thin-bedded; lenticular; weathers light gray green	.8
Limestone, soft, tan-yellow, lenticular; weathers tan; cavernous; algal traces	.9
Shale, silty, calcareous, green to gray, thin-bedded; weathers light green. Thickness exposed	10.8

Base covered.

48. *Section from the base of the Americus limestone member of the Foraker limestone down into the middle part of the West Branch shale member of the Janesville shale in a road cut in the SE¼NE¼ sec. 3, T. 13 S., R. 12 E.*

Base of the Americus limestone member of the Foraker limestone.
Janesville shale:

	Feet
Hamlin shale member:	
Shale, silty, calcareous, thin-bedded; tan gray mottled with maroon in upper part; many calcareous plates	14.4
Shale, clayey, noncalcareous, gray, thin-bedded; sandy in upper part; some sandstone lentils in upper part	13.6
Coal, impure, black, thin-bedded	.3
Sandstone and sandy shale, micaceous, tan, thin-bedded to massive; some limonite plates; plant fragments common	15.6
Thickness exposed	43.9
Five Point limestone member:	
Limestone, medium-hard, light-gray, platy	1.8
Shale, silty, calcareous, tan to gray, thin-bedded; iron stains common	1.1
Limestone, medium-hard, gray, blocky; weathers tan gray; fossil fragments abundant; brachiopods, corals, and crinoid columnals	1.2
Shale, silty, calcareous, gray to tan-gray, thin-bedded; contains brachiopods and crinoid columnals	.9
Siltstone, dark-brown; weathers blocky	.3
Shale, silty, calcareous, tan-gray to gray, thin-bedded; contains brachiopods and crinoid columnals	.7
Limestone, hard, gray-brown, blocky; fossil fragments; brachiopods and fusulinids	.4
Thickness	6.4
West Branch shale member:	
Shale, silty, noncalcareous, tan-brown, thin-bedded; many carbon stains and one thin carbonaceous zone	.5
Coal, impure, black, thin-bedded	.2
Shale, clayey, noncalcareous, gray, thin-bedded; many iron-stained zones	4.9
Limestone, medium-hard, dark-gray; weathers in irregular chips; contains fossil fragments; cephalopods, gastropods, and pelecypods	1.2
Sandstone and sandy shale, micaceous, thin-bedded; gray in upper part, tan in lower part; carbon stains and plant fragments abundant	6.8
Thickness exposed	13.6
Thickness of exposed Janesville shale	63.9

Base covered.

49. *Section from the Americus limestone member of the Foraker limestone down into the Falls City limestone in a road cut in the SE¼SW¼SW¼ sec. 19, T. 11 S., R. 12 E.*

	Feet
Foraker limestone:	
Americus limestone member:	
Limestone, hard, gray, massive; weathers blocky; dark-gray algal band. Thickness exposed	0.4
Janesville shale:	
Hamlin shale member:	
Shale, clayey, thin-bedded; calcareous; some silt; tan gray in the lower part, gray green in upper part; calcareous plates abundant; impure clayey limestone lens in lower part	17.3
Shale, clayey, calcareous, thin-bedded; gray green in the lower part, grading up into maroon	5.7
Limestone, hard, clayey, brittle, tan-brown to brown, iron-stained; weathers blocky	.3
Sandstone and sandy shale, micaceous, tan to tan-gray; thin-bedded with a 0.6 foot massive bed in the middle part and a 1.6 foot massive bed at base; leaf and wood fragments common; iron stains and carbon stains abundant	5.9
Shale, clayey, noncalcareous, gray, thin-bedded	7.9
Limestone, impure, clayey, tan to gray; some iron stains	.4
Shale, clayey, calcareous; some silt; gray to gray green mottled with maroon in upper part; iron stains abundant in upper part	7.1
Thickness	44.6
Five Point limestone member:	
Limestone, medium-hard, clayey, gray; weathers platy and with conchoidal fracture	1.1
Shale, silty, calcareous, tan to tan-brown, thin-bedded; fossils in upper part, include fragments, and crinoid columnals, and brachiopods	2.2
Limestone, medium-hard, gray; weathers blocky; fossil fragments abundant	.4
Thickness	3.7
West Branch shale member:	
Shale, clayey, slightly calcareous, gray, thin-bedded	1.8
Coal, impure, black, thin-bedded to blocky	.3
Shale, clayey, noncalcareous, gray, thin-bedded; some iron stains and plates	2.5
Limestone, medium-hard, gray; weathers nodular and shaly; fossil fragments, bryozoans, and crinoid columnals	1.3
Shale, clayey, noncalcareous, tan-gray, thin-bedded; iron stains abundant	2.9
Coal, impure, black, thin-bedded; wood fragments in lower part	.2

Janesville shale—Continued	
West Branch shale member—Continued	*Feet*
Shale, silty, noncalcareous, tan-gray to olive-drab, thin-bedded; some iron stains	3.4
Shale, clayey, calcareous, gray-green, blocky; iron stains on fracture planes	5.6
Limestone, soft to medium-hard, tan to tan-brown; weathers cavernous and blocky; iron stains abundant; some fossil fragments	2.7
Shale, clayey, calcareous, gray, thin-bedded; some iron stains	4.9
Thickness	25.6
Total thickness of Janesville shale	73.9
Falls City limestone:	
Limestone, clayey, tan to gray; thin shale parting; weathers blocky; pelecypods abundant; some fossil fragments, gastropods and bryozoans	.7
Shale, clayey, calcareous, gray, blocky; some silt; calcareous zones in middle	5.6
Thickness exposed	6.3

Base covered.

50. *Section from the Five Point limestone member down into the West Branch shale member of the Janesville shale in a road cut in the NW¼NW¼ sec. 14, T. 13 S., R. 12 E.*

Soil, silty, gray-brown; 0.4 feet thick.

Janesville shale:	
Five Point limestone member:	*Feet*
Limestone, soft, coquinoid, red-brown; oatmeal texture; weathers gray; massive layers, weather blocky and in large boulders; forms a prominent hillside bench; small fusulinids and crinoid columnals; brachiopod fragments very abundant	4.6
Shale, silty, calcareous, blocky; gray brown to light gray in upper part; weathers tan	.6
Limestone, hard, tan-gray; weathers tan and blocky; platy in lower part; crinoid columnals, echinoid spines, brachiopods, bryozoans, and gastropods	.7
Shale, silty, calcareous, thin-bedded, gray; weathers light gray; brachiopods, crinoid columnals and corals	1.0
Limestone, hard, gray; weathers tan and blocky; brachiopods, bryozoans, and crinoid columnals	.3
Thickness	7.2
West Branch shale member:	
Shale, silty, calcareous, gray, thin-bedded; weathers light gray; limonite stained in lower part, carbon stains on some of the bedding planes	.5
Coal, impure, black, thin-bedded, lenticular	.1
Shale, silty, slightly calcareous, light-gray to yellow, thin-bedded; iron and carbon stains on bedding planes	2.4

	Feet
Janesville shale—Continued	
West Branch shale member—Continued	
Limestone, clayey, soft, gray-brown; weathers tan and to small chips; some brachiopods	0.5
Shale, silty, calcareous, gray brown; weathers tan; thin-bedded	1.4
Shale, gray to tan gray, thin-bedded; sandy in lower part, silty in upper part; thin crossbedded sandstone lens in lower part	11.2
Thickness exposed	16.1
Thickness of exposed Janesville shale	23.3

Base covered.

51. *Section of the Five Point limestone member and the West Branch shale member of the Janesville shale in a road cut in the NE¼SE¼ sec. 23, T. 14 S., R. 12 E.*

Soil, silty, gray; about 1.5 feet thick.

	Feet
Janesville shale:	
Five Point limestone member:	
Limestone, hard, dense, gray, massive; weathers tan gray and platy and forms four ledges	3.5
Shale, silty, calcareous, tan-gray, thin-bedded, lenticular	.1
Limestone, hard, dense, light-gray; weathers tan and platy	1.0
Shale, silty, calcareous, tan, thin-bedded lenticular	.1
Limestone, medium-hard, tan-gray, lenticular, limonite stained; weathers blocky	1.0
Shale, silty, calcareous, gray, thin-bedded; weathers tan gray	.1
Limestone, soft, tan, lenticular; weathers shaly; speckled with black; crinoid columnals, echinoid spines, and brachiopod fragments	.2
Shale, clayey, noncalcareous, olive-drab, fissile; weathers gray	1.3
Limestone, clayey, gray; weathers tan gray and shaly; brachiopods, small fusulinids, bryozoans, and crinoid columnals	.4
Thickness exposed	7.7
West Branch shale member:	
Shale, silty, calcareous, gray, thin-bedded; weathers tan; limonite stains at base; crinoid columnals and brachiopods	.9
Coal, impure, black, thin-bedded	.1
Shale, silty, calcareous, tan-gray, thin-bedded to blocky, limonite-stained	1.5
Siltstone, tan-gray; some mica; weathers gray; massive to platy at the top	1.1
Shale, slightly sandy, tan to tan-gray, thin-bedded to blocky; carbon stains and a thin siltstone in the middle; some limonite stains	7.0
Thickness exposed	10.6
Thickness of exposed Janesville shale	18.3

Base covered.

52. *Section from the base of the Five Point limestone member of the Janesville shale into the Towle shale member of the Onaga shale in a road cut in the SE¼SE¼ sec. 10, T. 13 S., R. 13 E.*

	Feet
Janesville shale:	
Base of Five Point limestone member.	
West Branch shale member:	
Shale, clayey, slightly calcareous, gray to orange, thin-bedded to blocky, limonite-stained; some silt	1.7
Coal, impure, black, thin-bedded	.1
Shale, slightly sandy, slightly calcareous, orange to gray, thin-bedded; many limonite plates on weathered surface	4.7
Shale, silty, calcareous, tan, thin-bedded; heavily limonite stained; weathers red brown; contains some thin limonite lenses	.4
Limestone, clayey, medium-hard, tan-gray, massive to nodular; weathers tan; contains brachiopods, pelecypods, bryozoans, and crinoid columnals	2.0
Shale, slightly sandy, noncalcareous, gray-brown, thin-bedded to blocky; weathers tan; some mica	2.4
Coal, impure, black, thin-bedded	.2
Shale, clayey, noncalcareous, gray, thin-bedded; many thin coal lenses; carbon stains on bedding planes	1.3
Covered interval (colluvium)	5.6
Limestone, silty, soft, tan, thin-bedded; weathers to thin plates; cavernous	4.0
Shale, clayey, calcareous, dark gray; some silt; weathers gray; blocky	2.6
Shale, clayey, olive-drab; some silt; very calcareous in upper part; weathers tan gray; blocky; irregular calcareous nodules cover the surface	4.6
Thickness	29.6
Falls City limestone:	
Limestone, hard, slightly crystalline, gray-brown; weathers tan and blocky; fragments of bryozoans, pelecypods, and brachiopods	.3
Shale, clayey, slightly calcareous, tan, thin-bedded	.4
Limestone, hard, dense, gray, platy to blocky, lenticular; weathers tan; pelecypods, brachiopods, bryozoans, gastropods, and crinoid columnals	.8
Shale, clayey, noncalcareous; gray-brown; thin-bedded to blocky; weathers tan; some limonite stains; contains a thin very fossiliferous limestone 3 feet from the top with pelecypods, bryozoans, brachiopods, and crinoid columnals; some silt	10.6
Limestone, dense, hard, tan-gray; weathers tan and blocky; pelecypods very abundant; gastropods common	.5
Shale, silty, calcareous, blocky; olive-drab; weathers tan; contains many thin lenticular limestones which show on weathered surfaces	4.4
Limestone, hard, gray-brown; weathers tan and blocky; pelecypods very abundant; gastropods abundant	.4
Thickness	17.4

	Feet
Onaga shale:	
Hawxby shale member:	
Shale, clayey, calcareous, olive-drab, thin-bedded; weathers gray; some silt; contains many thin calcareous lenses and nodules	3.4
Limestone (not well exposed), tan, massive; hard in the upper part, soft in the lower part; limonite nodules and brown and tan specks common	2.5
Limestone, medium-hard, tan-brown; weathers platy in upper part, blocky in lower part; limonite streaks; speckled with minute brown and tan stains	1.0
Shale, silty, calcareous, tan, thin-bedded; contains small calcium carbonate nodules	4.1
Shale, very calcareous, tan, thin-bedded to platy; weathers tan gray	1.1
Thickness	12.1
Aspinwall limestone member:	
Limestone, clayey, gray-brown; weathers tan; blocky; lenticular; some iron streaks	.4
Shale, silty, calcareous, gray-brown, weathers tan; thin-bedded to blocky; two thin clayey limestones in the upper part; iron stains on some of the bedding planes	3.4
Limestone, medium hard, red brown; weathers tan and blocky; numerous limonite nodules; brachiopods and pelecypods	.3
Shale, clayey, noncalcareous, gray brown, weathers tan; thin-bedded to blocky	.4
Limestone, medium-hard, gray-brown, weathers tan; lenticular; some brachiopod fragments	.1
Shale, clayey, noncalcareous, olive-drab, thin-bedded to fissile; weathers gray	.6
Limestone, soft, gray-brown, weathers tan and shaly; heavily limonite stained; contains brachiopods and pelecypods	.2
Thickness	5.4
Towle shale member:	
Shale, silty, noncalcareous, gray-brown, weathers blue gray to tan; thin-bedded; iron and carbon stains on some bedding planes; many limonite-stained areas; limonite flakes on the surface	8.7
Sandstone, hard, dense, blue-gray, thick-bedded; weathers brown; some mica	.9
Shale, noncalcareous, thin-bedded, gray-brown; slightly sandy and contains some mica; weathers tan; contains tan calcium carbonate nodules	5.8
Shale, silty, noncalcareous, blue-gray, weathers light blue gray; thin-bedded	3.0
Thickness exposed	18.4
Thickness of exposed Onaga shale	35.9

Base covered.

53. *Section of the Aspinwall limestone member of the Onaga shale is in a stream cut in the SW¼NW¼NW¼ sec. 36, T. 11 S., R. 11 E.*

	Feet
Onaga shale:	
Aspinwall limestone member:	
Limestone, medium-hard, gray, iron-stained; weathers blocky to nodular	1.4
Shale, silty, very calcareous, gray, massive to nodular	1.1
Limestone, hard, gray-brown, limonite-stained; weathers blocky; many limonite specks; clay balls abundant, angular to rounded, as much as 2 inches in diameter; shale parting in middle	3.1
Shale, silty, calcareous, tan-gray to gray, thin-bedded	3.9
Limestone, medium-hard, gray; many brown specks; platy	1.6
Thickness exposed	11.1
Base covered:	

54. *Section of the Aspinwall limestone member of the Onaga shale down into the Plumb shale member of the Wood Siding formation in a road cut in the NW¼SW¼ sec. 1, T. 12 S., R. 12 E.*

	Feet
Onaga shale:	
Aspinwall limestone member:	
Limestone, hard, dense, porous, brittle, gray-brown; weathers blocky; limestone fragments as large as 2 inches in diameter; upper surface has algal appearance. Thickness exposed	2.1
Towle shale member:	
Shale (partly exposed), clayey, calcareous; maroon in the lower part, gray green in upper part; blocky. Thickness	11.3
Thickness of exposed Onaga shale	13.4
Wood Siding formation:	
Brownville limestone member:	
Limestone (poorly exposed), medium-hard; tan gray with a greenish tint; weathers blocky to nodular; shale parting in upper part; brachiopods. Thickness	2.4
Pony Creek shale member:	
Shale (covered by colluvium). Thickness	8.2
Grayhorse limestone member:	
Limestone, medium-hard, conglomeratic, gray-brown; weathers blocky; limonite nodules and clay balls abundant, as much as one-fourth inch in diameter; angular to rounded; fossil fragments. Thickness	.7
Plumb shale member:	
Shale, clayey, calcareous, gray, thin-bedded; limonite-stained; calcareous lentils common	1.9
Limestone, medium-hard, brown, platy; pelecypods abundant	.1
Shale, silty, calcareous, tan-gray, thin-bedded	.2
Coal, impure, black, thin-bedded to blocky	.2

	Feet
Wood Siding formation—Continued	
Plumb shale member—Continued	
Shale, silty, calcareous, tan-gray, thin-bedded, iron-stained; sandy in lower part	3.0
Sandstone, micaceous, fine-grained, noncalcareous, tan, massive, crossbedded; limonite nodules and stains abundant; wood and leaf fragments common	11.3
Thickness exposed	16.7
Thickness of exposed Wood Siding formation	28.0
Base covered.	

55. *Section from the Aspinwall limestone member of the Onaga shale down into the Plumb shale member of the Wood Siding formation in a road cut in the SW¼SW¼ sec. 28, T. 11 S., R. 12 E.*

	Feet
Onaga shale:	
Aspinwall limestone member:	
Limestone, hard, partly dense, brittle, tan-brown; weathers blocky; limestone inclusions very abundant, at least 2 inches in diameter, and subangular to angular; bedded appearance	1.7
Shale, silty to clayey, calcareous, tan-gray, thin-bedded; many calcium carbonate nodules	1.9
Limestone, medium-hard; tan brown with a grayish tint; weathers blocky; many small iron specks in zones give a bedded appearance; fossil fragments in brown zones	2.3
Shale, silty, calcareous, micaceous, tan, thin-bedded	.3
Limestone, medium-hard, conglomeratic, gray-brown; limestone and limonite nodules as much as ¼-inch in diameter, subangular	.2
Thickness exposed	6.4
Towle shale member:	
Shale, clayey, calcareous, gray-brown, thin-bedded; some iron stains	4.6
Conglomerate, gray-brown; limestone and limonite nodules as much as ¼-inch in diameter, subrounded to rounded; pelecypods	.2
Shale, clayey, noncalcareous, gray, thin-bedded, iron-stained; some silt	2.1
Total thickness	6.9
Thickness of exposed Onaga shale	13.3
Wood Siding formation:	
Brownville limestone member:	
Limestone, medium-hard, partly dense; gray brown with a gray green tint; weathers blocky to nodular; brachiopods abundant; sharks teeth, bryozoans and gastropods common. Thickness	2.7

Wood Siding formation—Continued	
Pony Creek shale member:	*Feet*
Shale, silty to sandy, noncalcareous, micaceous, thin-bedded; gray in lower part, tan gray in upper part; some lentils of sandstone; upper 0.7 foot contains brachiopods and crinoid columnals	8.2
Limestone, medium-hard, dark-gray, thin-bedded; fossil fragments abundant	0.2
Shale, clayey, slightly calcareous, gray, thin-bedded	1.2
Thickness	9.6
Grayhorse limestone member:	
Limestone, medium-hard; tan brown with brown iron specks; weathers blocky; fossil fragments; pelecypods, brachiopods and crinoid columnals. Thickness	0.5
Plumb shale member:	
Shale, silty, calcareous, tan-gray, thin-bedded	1.8
Thickness of exposed Wood Siding formation	14.6
Base covered.	

56. *Section from the Aspinwall limestone member of the Onaga shale down into the channel of the Plumb shale member of the Wood Siding formation in a road cut in the SE¼SW¼ sec. 26, T. 11 S., R. 12 E.*

Soil, silty, gray to black; about 2 feet thick.	
Onaga shale:	
Aspinwall limestone member:	
Limestone (badly weathered)	1.8
Limestone, dense, medium-hard, gray-brown; weathers brown and to irregular blocks; contains white calcium carbonate nodules which give a conglomeratic appearance in some places	1.4
Shale, silty, calcareous, light-gray; weathers tan; thin-bedded	.2
Limestone, medium-hard, gray-brown; weathers brown and to irregular blocks; lenticular; contains many calcareous nodules which weather lighter than the matrix; a few iron nodules	.9
Shale, silty, calcareous, gray; weathers gray green; blocky; limonite stains on fracture and bedding planes	1.2
Shale, silty, calcareous, red-brown; weathers light gray with a pinkish tint; thin-bedded to blocky; iron stains on bedding planes; veins of calcium carbonate along fractures	2.8
Limestone, medium-hard, light-gray; weathers thin-bedded; iron stains on weathered surface; contains many limonite specks	.4
Shale, silty, calcareous, gray-green, thin-bedded; iron stains on bedding planes	.2
Limestone, clayey, gray-green, iron-stained; weathers light gray; blocky to platy in the lower part	.6
Thickness exposed	9.0

	Feet
Onaga shale—Continued	
Towle shale member:	
Shale, silty, calcareous, olive-drab, thin-bedded to blocky; weathers gray; two thin lenticular limy zones in basal part; limonite nodules	4.9
Shale, silty, calcareous, dark-gray, blocky; weathers gray	1.1
Shale, silty, calcareous, maroon, thin-bedded to fissile; mottled with gray; weathers maroon; nodular in the upper part; limonite nodules	4.9
Thickness	10.4
Thickness of exposed Onaga shale	19.4
Wood Siding formation:	
Brownville limestone member:	
Limestone, soft, gray-brown; weathers brown and to small irregular blocks; stained maroon from the overlying shale; limonite nodules common; brachiopods, pelecypods, and gastropods	.9
Shale, silty, calcareous, yellow-green, thin-bedded, maroon-stained; weathers tan	.1
Limestone, soft, maroon-stained; gray brown with a yellow-green tint; weathers brown and blocky; contains brachiopods, bryozoans, and crinoid columnals	1.4
Thickness	2.4
Pony Creek shale member:	
Shale, clayey, noncalcareous; thin-bedded to blocky; dark gray with maroon stains on bedding and fracture planes; weathers gray; some silt; brachiopods abundant near top	1.9
Shale, clayey, noncalcareous, micaceous; gray brown in the upper part grading downward into dark gray; weathers light gray; thin-bedded to fissile; carbon stains on some of the bedding planes; limonite stains on uppermost part	5.2
Shale, rust-brown; consists mainly of iron oxide and iron sulfide and calcium carbonate	.1
Shale, silty, very calcareous, dark-gray; weathers gray; thin-bedded and nodular	.2
Shales and limestones; alternating thick shales and thin limestones; shale, clayey, noncalcareous, dark-gray to tan; weathers tan; fissile; thin lenticular limestones are hard, gray brown, and weather tan; iron stained; contains some small iron sulfide nodules	3.4
Thickness	10.8
Grayhorse limestone member:	
Limestone, hard, tan-gray; weathers tan and into chips; joint cracks show a filling of iron-stained micaceous shale; microfossils abundant. Thickness	0.3

468594—59——13

	Feet
Wood Siding formation—Continued	
Plumb shale member:	
Shale, calcareous, red-brown; thin-bedded, iron-stained; two thin clayey limestones; weathers tan; contains nodules of calcium carbonate and limonite	0.4
(Possible unconformity)	
Shale, silty, slightly calcareous, gray-brown, blocky; weathers blue gray; contains some limonite nodules	5.5
Shale, clayey, noncalcareous, gray, blocky, heavily limonite stained; weathers dark gray	.9
Limestone, hard, dense, dark-gray, very lenticular; weathers gray; conchoidal fracture; limonite stains on weathered surface	.3
Shale, silty, calcareous, gray, thin-bedded, limonite-stained; weathers light gray; contains small calcareous nodules and minute gypsum crystals	1.3
Shale, arenaceous, micaceous, gray, limonite-stained; thin-bedded, dark gray at base; weathers blue gray; contains carbon specks, sandstone lenses, and some fossil fragments	3.0
Thickness exposed	11.4
Thickness of exposed Wood Siding formation	24.9

Base covered.

57. *Section from the Aspinwall limestone member of the Onaga shale down into the channel of the Plumb shale member of the Wood Siding formation in a road cut in the NW¼ sec. 8, T. 12 S., R. 13 E.*

	Feet
Onaga shale:	
Aspinwall limestone member:	
Limestone, fine-grained, hard, tan gray to gray; weathers blocky and in irregular chips; speckled with limonite. Thickness	0.9
Towle shale member:	
Shale (mostly covered with slump); maroon near the base, gray green to tan and mottled with maroon in the upper part. Thickness	9.0
Thickness of exposed Onaga shale	9.9
Wood Siding formation:	
Brownville limestone member:	
Limestone, medium-hard, gray; gray-green tint; weathers gray and blocky to nodular; brachiopods abundant; crinoid columnals, bryozoans and fusulinids common. Thickness	2.6
Pony Creek shale member:	
Shale, sandy, micaceous, clayey and calcareous; light gray green mottled with maroon in upper part; thin-bedded; some limonite stains. Thickness	6.8
Grayhorse limestone member:	
Limestone, hard, gray-brown, weathers tan brown and blocky; many small limonite and clay nodules; fossil fragments. Thickness	.8

	Feet
Wood Siding formation—Continued	
Plumb shale member:	
Shale, clayey, calcareous, gray-green, thin-bedded; many limonite-stained areas and many calcareous plates; some carbon-stained areas	4.3
Shale, silty, very calcareous, tan, thin-bedded; composed almost entirely of minute fossils and clay balls	.4
Shale, clayey, slightly calcareous, gray-green, blocky; carbon stains on bedding planes	.3
Shale (top of channel), silty, calcareous, conglomeratic, blocky; tan gray with green tint; contains many iron and calcium carbonate-cemented nodules	2.5
Conglomerate, medium-hard, tan to gray, blocky; weathers tan to brown; abundant iron and clay balls as much as 2 inches in diameter	1.4
(Disconformity.)	
Shale, sandy, micaceous, slightly calcareous, gray to tan-gray, thin-bedded; weathers tan; iron stains on bedding planes; becomes less sandy in upper part	17.1
Sandstone, hard, micaceous, calcareous, gray to brown, crossbedded; weathers brown; some iron nodules	1.1
Shale, sandy, micaceous, tan to tan-gray, thin-bedded; weathers tan; some crossbedding and iron nodules; some fossil leaves	21.6
Thickness exposed	48.7
Thickness of exposed Wood Siding formation	58.9

Base covered.

58. *Section from the basal conglomerate of a channel of the Towle shale member of the Onaga shale down to the base of the Dover limestone member of the Stotler limestone in a streambank in SW¼SE¼ sec. 4, T. 13 S., R. 13 E.*

	Feet
Onaga shale:	
Towle shale member (channel):	
Conglomerate, hard, partly dense, weathers platy and in irregular chips; fragments of brown sandstone up to 6 inches in diameter; average size is 1 inch; red siliceous clay balls common; limonite nodules and concretions, and limestone fragments common, all are angular; brachiopods, crinoid columnals, and bryozoans—a fauna characteristic of the Brownville limestone and the upper part of the Pony Creek shale. Thickness exposed	2.4
Unconformity.	
Wood Siding formation:	
Plumb shale member:	
Sandstone and sandy shale, micaceous, tan-gray to gray; thin-bedded; massive in part; many limonite nodules and plates; some carbon stains. Total thickness	11.2

Unconformity.

	Feet
Stotler limestone:	
Dry shale member:	
Shale, sandy, micaceous, clayey, gray, thin-bedded	1.5
Shale, clayey, calcareous, gray, thin-bedded; calcareous nodules very abundant; some iron stains	5.6
Thickness	7.1
Dover limestone member:	
Limestone, medium-hard, light-gray; weathers platy to nodular; contains crinoid columnals, fusulinids, and brachiopods	1.2
Shale, clayey, calcareous, gray, thin-bedded; fusulinids and crinoid columnals abundant	.9
Thickness exposed	2.1
Thickness of exposed Stotler limestone	9.2

Base covered.

59. *Section from the Towle shale member of the Onaga shale down into the French Creek shale member of the Root shale in a streambank in the NE¼SW¼SW¼ sec. 33, T. 10 S., R. 10 E.*

	Feet
Onaga shale:	
Towle shale member:	
Shale, silty, calcareous; tan gray in lower part; gray green in upper part; calcareous lentils in upper part	4.2
Shale, clayey, calcareous, blocky; purple mottled with maroon	.9
Thickness exposed	5.1
Wood Siding formation:	
Brownville limestone member:	
Limestone, soft, tan-gray, massive; weathers blocky in upper part; shaly in lower part; contains brachiopods. Thickness	1.1
Pony Creek shale member:	
Shale (covered by colluvium). Thickness	6.2
Grayhorse limestone member:	
Limestone, impure, light-gray; gray green tint; weathers blocky to nodular; some pelecypod fragments. Thickness	.5
Plumb shale member:	
Shale, silty, calcareous, light-gray, thin-bedded. Thickness	9.2
Nebraska City limestone member:	
Limestone, gray; very calcareous shale in lower part grading up into a hard limestone; weathers shaly in lower part; brachiopod fragments. Thickness	2.1
Total thickness of Wood Siding formation	19.1
Root shale:	
French Creek shale member:	
Shale, silty, calcareous, gray, thin-bedded; some iron stains	2.8
Coal, impure, black, thin-bedded	.8
Shale, clayey, gray, thin-bedded; many iron stains	.3
Thickness exposed	3.9

Base covered.

60. *Section from the Brownville limestone member down into the channel of the Pony Creek shale member of the Wood Siding formation in a streambank in the SE¼NW¼ sec. 7, T. 11 S., R. 10 E.*

	Feet
Soil silty gray to gray-brown; about 1.5 feet thick.	
Wood Siding formation:	
Brownville limestone member:	
Limestone, hard, dense, dark-brown; weathers brown to tan brown and into irregular blocks; brachiopods and crinoid columnals	1.9
Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; brachiopods and crinoid columnals in upper part	1.1
Limestone, hard, tan-brown, massive; weathers tan gray and blocky; brachiopods and crinoid columnals	1.5
Thickness	4.5
Pony Creek shale member:	
Shale, silty, calcareous, red-brown, thin-bedded, limonite-stained; weathers tan; some calcareous nodules; and brachiopods	1.2
Shale, silty, calcareous, gray-brown, thin-bedded; weathers tan; small septarian concretions; some pipettes of calcium carbonate	1.8
Limestone, hard, sandy, brown, lenticular; many calcium carbonate crystals; brachiopods and bryozoans	.1
Shale, sandy, olive-drab; some mica; weathers tan; blocky to thin-bedded; septarian concretions in upper part; limonite stained	7.8
Shale, sandy, micaceous, dark-gray, blue-gray, and gray-brown; weathers tan to blue gray; thin-bedded; thin lenticular siltstones; septarian concretions numerous and range up to large boulders in size; carbon and limonite stains on some bedding planes	13.9
Shale, sandy, calcareous, gray-brown; weathers tan; thin-bedded; many sandstone lenses which show conspicuously on weathered surfaces; large septarian concretions near base; iron stains on some bedding planes	8.8
Shale, sandy, calcareous, gray-brown to blue-gray; some mica; thin-bedded to fissile; many septarian concretions and limonite nodules; carbon stains on some bedding planes	22.6
Thickness exposed	56.2
Thickness of exposed Wood Siding formation	60.7
Base covered.	

61. *Section of the Brownville limestone member down into the channel of Plumb shale member of the Wood Siding formation in a road cut in the SE¼SE¼ sec. 27, T. 11 S., R. 12 E.*

	Feet
Soil, silty, dark-gray; limestone fragments; about 1 foot thick.	
Wood Siding formation:	
Brownville limestone member:	
Limestone, massive, medium-hard, gray to gray-green; weathers gray, blocky to shaly near the base; limonite stains; maroon stains on surface; brachiopods abundant, bryozoans. Thickness	2.1

	Feet
Wood Siding formation—Continued	
Pony Creek shale member:	
Shale, silty, calcareous, gray-green, blocky; limonite nodules near base; brachiopods and crinoid columnals in upper part	0.6
Shale, sandy, micaceous, noncalcareous, maroon, thin-bedded; some iron stains; many thin calcareous sandstone lenses; basal contact wavy	4.8
Shale, clayey, noncalcareous, gray, thin-bedded; some mica, weathers light gray green; some calcareous nodules near top	2.6
Thickness	8.0
Grayhorse limestone member:	
Limestone, hard, gray to gray-green, porous; weathers tan and blocky; some maroon stains on surface; contains many small limonite and clay balls, especially in top part; some fossil fragments; limestone pinches out in western part of the road cut. Thickness	.8
Plumb shale member:	
Shale (channel), silty, calcareous, gray-green; some mica; some maroon stains on surface and fracture planes; many thin calcareous lenses; some carbon stains and iron stains	1.2
Shale, silty, calcareous, olive-drab, thin-bedded; some mica	.2
Shale, silty, calcareous, very dark gray, blocky; weathers gray; some carbon stains	.6
Shale, silty, calcareous, olive-drab, blocky; weathers tan gray; many small limonite nodules and clay balls	.5
Shale, silty, calcareous, dark-gray, blocky; weathers gray; contains some clay balls	.4
Shale, silty, calcareous, gray-green; weathers light gray green; many limonite nodules; some calcareous lentils in the top part	.5
Shale, micaceous, slightly sandy, calcareous, thin-bedded, maroon; mottled with gray green at the base; the maroon shale pinches in and out to the west and east of the road cut; calcareous lenses differ in position throughout the shale	3.9
Shale, silty, micaceous, noncalcareous, gray-green, thin-bedded; thin lentils of siltstone	1.8
Siltstone, soft, micaceous, light-gray-green, massive; surface covered with maroon stains; lenticular, pinches out both east and west	.7
Shale, silty to sandy, micaceous, noncalcareous, gray to light gray-green, thin-bedded; iron stains on bedding and fracture planes	4.6
Thickness exposed	14.4
Thickness of exposed Wood Siding formation	25.3

Base covered.

62. *Section from the Brownville limestone member down into the channel in the Plumb shale member of the Wood Siding formation in a road cut in the SW¼SW¼ sec. 4, T. 13 S., R. 13 E.*

Wood Siding formation:	
Brownville limestone member:	*Feet*
Limestone, medium-hard, gray-brown to tan-brown; weathers blocky to nodular; brachiopods, crinoid columnals, and bryozoans present. Thickness	1.8
Pony Creek shale member:	
Shale, clayey, calcareous, gray, thin-bedded; iron-stained plates abundant; brachiopods in upper part. Thickness	9.4
Grayhorse limestone member:	
Limestone, medium-hard, conglomeratic, gray-brown; weathers blocky; rounded to subangular limonite and calcium carbonate nodules as much as one-eighth inch in diameter; pelecypods; fossil fragments. Thickness	2.8
Plumb shale member:	
Shale, (channel) sandy to silty, micaceous, noncalcareous, gray, thin-bedded to blocky; weathers tan to gray; many iron stains; some limonite concretions; sandy shale and lentils of sandstone more abundant in lower part	50.8
Sandstone and sandy shale, very micaceous, gray, massive; weathers in irregular plates; iron and carbon stains; sandstone firmly cemented	3.2
Thickness exposed	54.0
Thickness of exposed Wood Siding formation	68.0
Base covered.	

63. *Section from the Brownville limestone member of the Wood Siding formation down to the base of the Jim Creek limestone member of the Root shale in a streambank in the NE¼SW¼ sec. 29; T. 11 S., R. 13 E.*

Soil, silty, gray-brown; about 2 feet thick.	
Wood Siding formation:	
Brownville limestone member:	*Feet*
Limestone, medium-hard, tan to brown; weathers blocky to nodular; many limonite specks; brachiopods and crinoids. Thickness	2.4
Pony Creek shale member:	
Shale, silty, calcareous, gray green to tan; sandy and micaceous and mottled with maroon in lower part; thin-bedded; calcareous nodules in middle part; brachiopods in upper part	2.7
Shale, clayey, calcareous, thin-bedded; sandy, micaceous, and maroon mottled with gray green in upper part; some limonite nodules	5.2
Shale, clayey, slightly calcareous, light-gray-green, thin-bedded	2.7
Thickness	10.6

	Feet
Wood Siding formation—Continued	
Grayhorse limestone member:	
Limestone, hard, gray-orange, lenticular; limonite-stained, fossiliferous; weathers to large blocks; contains small clay-like particles	0.8
Plumb shale member:	
Shale, sandy, micaceous, light-gray, thin-bedded, limonite-stained	1.2
Shale, sandy, noncalcareous, maroon, thin-bedded; thin lenticular limestone in middle part	1.6
Shale, micaceous, noncalcareous, thin-bedded; gray green with maroon stains in upper part; weathers light gray	4.5
Shale, micaceous, gray-yellow, thin-bedded; weathers tan orange; deeply limonite stained	.6
Thickness	7.9
Nebraska City limestone member:	
Shale, silty, very calcareous gray, thin-bedded; weathers light gray; very fossiliferous. Thickness	2.5
Total thickness of Wood Siding formation	24.2
Root shale:	
French Creek shale member:	
Coal, impure, black, thin-bedded	.9
Shale, clayey, slightly micaceous, thin-bedded, gray-brown; some silt; weathers tan	2.7
Shale, silty, calcareous, gray, thin-bedded; weathers light gray; limonite stains in upper part	1.6
Coal, impure, black, thin-bedded to blocky	0.2
Shale, micaceous, noncalcareous, gray to blue-gray, thin-bedded; weathers tan to blue gray; contains, abundance of limonite-stained plates and areas; thin crystalline limestone lens in upper part; many iron sulfide nodules	15.9
Thickness	21.3
Jim Creek limestone member:	
Limestone, hard, dark-gray to brown, massive; purple tint; weathers tan and to irregular chips; contains limonite and calcareous nodules; very fossiliferous. Thickness	.9
Thickness of exposed Root shale	22.2

64. *Section from the Grayhorse limestone member of the Wood Siding formation down into the middle part of the French Creek shale member of the Root shale in a road cut in the SW¼SE¼SE¼ sec. 30, T. 14 S., R. 13 E.*

	Feet
Wood Siding formation:	
Grayhorse limestone member:	
Limestone, conglomeratic, hard, gray-brown; angular to rounded limonite nodules and clay balls; fossil fragments. Thickness	1.6

	Feet
Wood Siding formation—Continued	
Plumb shale member (type section):	
Shale, clayey, noncalcareous, gray-green, thin-bedded	2.9
Shale, cavernous, calcareous, gray; thin-bedded in part	2.4
Shale, clayey, noncalcareous, gray, blocky to thin-bedded	5.1
Sandstone and sandy shale, micaceous, gray-brown, thin-bedded; some carbon and iron stains	1.5
Shale, clayey, noncalcareous, gray-brown, thin-bedded, iron-stained; some silt	7.5
Coal, impure, black, thin-bedded	.3
Shale, silty, calcareous, gray-brown, thin-bedded; crinoid columnals, pelecypods, and brachiopods (this shale probably represents a facies of the Nebraska City limestone member	.6
Thickness	20.3
Nebraska City limestone member:	
Limestone, gray; shaly in middle part; weathers shaly; crinoid columnals, brachiopods, and pelecypods. Thickness	1.3
Thickness of exposed Wood Siding formation	23.2
Root shale:	
French Creek shale member:	
Shale, silty, calcareous, sandy, micaceous, gray-brown, thin-bedded; carbon specks abundant	1.0
Coal, impure, black, thin-bedded	.5
Shale, silty, calcareous, gray, thin-bedded; carbon and many limonite stained plates	11.3
Thickness exposed	12.8

Base covered.

65. *Section from the Grayhorse limestone member of the Wood Siding formation down to the top of the Friedrich shale member of the Root shale in a road cut in the SE¼SW¼SW¼ sec. 29, T. 14 S., R. 13 E.*

	Feet
Wood Siding formation:	
Base of Pony Creek shale member.	
Grayhorse limestone member:	
Limestone, hard, gray to gray-brown, conglomeratic; limestone fragments and limonite and clay balls up to 3 inches in diameter, rounded to angular; most are flat and elongated; fossil fragments and pelecypods. Thickness	1.3
Plumb shale member:	
Shale, clayey, thin-bedded; sandy in the middle part; gray green in upper part, gray in lower part; calcareous nodules in middle part	17.8
Coal, impure, black, thin-bedded	.3
Shale, clayey, noncalcareous, gray, thin-bedded	.3
Shale and nodular limestone	1.1
Thickness	19.5

	Feet
Wood Siding formation—Continued	
Nebraska City limestone member:	
Shale facies, very calcareous, gray; many limestone lentils; crinoid columnals, brachiopods, and pelecypods	1.3
Thickness of exposed Wood Siding formation	22.1
Root shale:	
French Creek shale member:	
Coal, impure, black, thin-bedded	.4
Shale, clayey, noncalcareous, gray, thin-bedded; some sand; limonite-stained plates abundant	22.6
Thickness	23.0
Jim Creek limestone member:	
Limestone, medium-hard, gray-brown; weathers tan and blocky; fossil fragments and pelecypods. Thickness	0.5
Thickness of exposed Root shale	23.5
Top of Friedrich shale member.	

66. *Section from a channel in the Plumb shale member of the Wood Siding formation that extends down into the Pillsbury shale in a road cut in the SW¼NW¼ sec. 6, T. 12 S., R. 13 E.*

	Feet
Wood Siding formation:	
Plumb shale member (channel):	
Sandstone, sandy shale and shale, micaceous, tan to tan-gray, thin-bedded; many thin sandstone and conglomerate beds; thin irregular coal beds in lower part as much as 0.8 of a foot thick and are black and thin-bedded; coal overlies a 0.9 foot underclay; conglomerate consists of wood fragments, clay balls, siliceous fragments not more than three-fourths of an inch in diameter; all are angular; crossbedding is apparent; beds dip steeply to the south and cut through the Grandhaven limestone, Dry shale and Dover limestone members of the Stotler limestone in south part of this road cut; marine gastropods in lower conglomerate. Thickness exposed	20–30±
Unconformity.	
Stotler limestone:	
Grandhaven limestone member:	
Limestone, hard, brown; weathers blocky; brachiopod fragments and echinoid spines. Thickness	0.8–2.6
Dry shale member:	
Shale, silty, slightly calcareous, gray-brown, thin-bedded, weathers tan. Thickness	13.6
Dover limestone member:	
Limestone, medium-hard, gray; weathers light gray and in small irregular plates; crinoid columnals and fossil fragments abundant	1.9

Stotler limestone—Continued	
Dover limestone member—Continued	*Feet*
Shale, silty, calcareous, gray, thin-bedded; crinoid columnals, echinoid spines and bryozoans	0.6
Limestone, hard, gray to tan-gray, massive; weathers blocky; fusulinids especially abundant in lower part; algae abundant	1.9
Thickness	4.4
Total thickness of Stotler limestone	19.0–20.6
Pillsbury shale:	
Shale, silty, very calcareous, gray, thin-bedded; large fusulinids abundant	1.7
Shale, sandy, micaceous, tan to gray, thin- to thick-bedded; some crossbedding; many sandstone beds; iron nodules common	15.9
Thickness exposed	17.6

Base covered.

67. *Section from the French Creek shale member of the Root shale to the top of the Grandhaven limestone member of the Stotler limestone in a streambank in the SE¼NE¼ sec. 17, T. 15 S., R. 13 E.*

Soil, silty, gray; about 3 feet thick.

Root shale:	
French Creek shale member:	*Feet*
Shale, clayey, noncalcareous, gray brown; weathers tan; fissile; limonite flakes on surface. Thickness exposed	8.0
Jim Creek limestone member:	
Limestone, medium-hard, brown; weathers tan and blocky; limonite nodules; crinoid columnals, brachiopods, bryozoans, and pelecypods. Thickness	.9
Friedrich shale member	
Shale, clayey, slightly calcareous, olive-drab to gray, thin-bedded to blocky; weathers tan and blue gray; calcareous lens near the base; brachiopods and crinoid columnals common in uppermost 1 foot. Thickness	13.2
Thickness of exposed Root shale	17.0

Stotler limestone: Top of Grandhaven limestone member.

68. *Section from the Jim Creek limestone member of the Root shale down into the Dover limestone member of the Stotler limestone in a road cut in the SW¼SW¼ sec. 8, T. 12 S., R. 13 E.*

Root shale:	
Jim Creek limestone member:	*Feet*
Limestone, hard, gray to gray-brown; weathers tan and blocky; crinoid columnals, brachiopods, gastropods, corals, bryozoans, and small fusulinids. Thickness	0.6

	Feet
Root shale—Continued	
Friedrich shale member:	
Shale, silty, calcareous, gray, thin-bedded; brachiopods and crinoid columnals	1.0
Shale, clayey, noncalcareous, thin-bedded; gray green mottled with purple and maroon in lower part	4.7
Shale, clayey, calcareous, maroon, blocky	1.9
Limestone, impure, soft, tan-brown; weathers blocky and nodular; iron stains abundant; some brown specks	1.2
Shale, clayey, noncalcareous, massive, tan-gray; mottled with maroon; iron stains and nodules very abundant	1.4
Shale, silty, noncalcareous, thin-bedded, maroon; mottled with some gray green in upper part; some clay	6.3
Covered interval	9.2
Thickness	25.7
Thickness of exposed Root shale	26.3
Stotler limestone:	
Grandhaven limestone member:	
Limestone, medium-hard, gray; weathers blocky and into irregular chips; crinoid columnals, bryozoans, and brachiopods. Thickness	1.6
Dry shale member:	
Shale, silty, calcareous, tan-gray, blocky; calcium carbonate nodules abundant	3.4
Shale (covered with colluvium)	2.1
Thickness	5.5
Dover limestone member:	
Limestone, hard, gray, massive; weathers blocky; large fusulinids especially abundant in lower part; crinoid columnals, some algae and corals	2.4
Shale, silty, very calcareous, gray, thin-bedded; large fusulinids abundant	2.5
Thickness exposed	4.9
Thickness of exposed Stotler limestone	12.0

Base covered.

69. *Section from the Friedrich shale member of the Root shale down to the Dover limestone member of the Stotler limestone in a road cut in the SE¼SW¼ sec. 30, T. 11 S., R. 13 E.*

	Feet
Root shale:	
Friedrich shale member:	
Shale, clayey, noncalcareous, tan-gray, some silt; weathers tan; fissile; limonite pellets on weathered surface. Thickness	5±

Stotler limestone:	
Grandhaven limestone member:	*Feet*
Limestone, hard; massive, brown; weathers tan to brown, blocky in upper part and platy in lower part; a rough limonite veneer over surface; some limonite nodules; brachiopods, small fusulinids, pelecypods, and crinoid columnals. Thickness	1.6
Dry shale member:	
Shale, silty, calcareous, olive-drab; weathers gray brown; blocky; many calcareous zones and nodules	1.0
Shale, very sandy, micaceous, blue-gray to tan, thin-bedded; weathers tan; limonite nodules and concretions abundant (possibly a transitional phase of Grandhaven limestone)	3.5
Shale, sandy, micaceous, noncalcareous, light-gray to tan, thin-bedded; weathers tan; some limonite stains	3.5
Sandstone, rust-brown, blocky to platy, lenticular; weathers brown; limonite stains and nodules common	.5
Shale, sandy, slightly micaceous and calcareous, tan, thin-bedded, limonite-stained	3.3
Shale, slightly sandy, blue-gray to tan; thin-bedded; weathers tan; many limonite nodules and stains; limonite-filled fractures	11.3
Thickness	23.1
Thickness of exposed Stotler limestone	24.7
Top of Dover limestone member.	

70. *Section from the Friedrich shale member of the Root shale down into the Dover limestone member of the Stotler limestone in a road ditch in the NW¼SW¼SW¼ sec. 9, T. 15 S., R. 13 E.*

Root shale:	
Friedrich shale member:	*Feet*
Shale, silty, calcareous, gray, thin-bedded; many limonite-stained zones. Thickness exposed	5.3
Stotler limestone:	
Grandhaven limestone member:	
Limestone, hard, dense, brown; weathers blocky; brachiopods bryozoans, and crinoid columnals. Thickness	1.5
Dry shale member:	
Shale, clayey, calcareous, gray to gray-green; iron-stained; weathers tan gray; some silt. Thickness	11.3
Dover limestone member:	
Limestone, conglomeratic, medium-hard, brown, thin-bedded; weathers gray; round limonite nodules and clay balls as much as one-eighth inch in diameter; brachiopods, bryozoans, and fusulinids	0.4
Shale, clayey, calcareous, gray, thin-bedded; crinoid columnals and brachiopods	1.1

	Feet
Stotler limestone—Continued	
Dover limestone member—Continued	
Limestone, medium-hard, gray to gray brown; weathers tan to brown and nodular; algae abundant; crinoid columnals, corals, brachiopods, and fusulinids	2.1
Thickness exposed	3.6
Thickness of exposed Stotler limestone	16.4

Base covered.

71. *Section from the lower part of the Friedrich shale member of the Root shale down into the upper part of the Pillsbury shale in a road cut in the NW¼SW¼ sec. 34, T. 12 S., R. 13 E.*

	Feet
Root shale:	
Friedrich shale member:	
Shale, silty, very calcareous, gray, thin-bedded; crinoid columnals and brachiopod fragments. Thickness exposed	1.3
Stotler limestone:	
Grandhaven limestone member:	
Limestone, hard, dark-gray; weathers gray brown, blocky and in small irregular chips; fossil fragments, brachiopods, crinoid columnals, and fusulinids. Thickness	.9
Dry shale member:	
Shale, clayey, micaceous, gray-green, thin-bedded; some sand; iron stains on bedding planes	4.7
Shale, silty, calcareous, tan to yellow, thin-bedded to blocky; iron stains abundant	4.0
Thickness	8.7
Dover limestone member:	
Limestone, hard, tan-gray; weathers light gray, blocky and in small irregular chips; algae and fusulinids abundant; crinoid columnals and brachiopods common	1.9
Total thickness of Stotler limestone	11.5
Pillsbury shale:	
Shale, silty, calcareous, gray, blocky to thin-bedded; some iron stains. Thickness exposed	3.6

Base covered.

72. *Section of the Dover limestone member of the Stotler limestone down into the Pillsbury shale in a streambank in the SW¼NW¼ sec. 3, T. 15 S., R. 13 E.*

Soil, silty, gray-brown; some limestone fragments; about 2 feet thick.

	Feet
Stotler limestone:	
Dover limestone member:	
Limestone, medium-hard, gray-brown, massive, iron-stained; weathers to irregular blocks; solution channels at base; algae very abundant; brachiopods and crinoid columnals common	1.9

	Feet
Stotler limestone—Continued	
Dover limestone member—Continued	
Limestone, soft, massive, gray; weathers light gray; weathers platy and to a shaly appearance; iron stained; fusulinids very abundant; brachiopods and crinoid columnals common	2.5
Thickness exposed	4.4
Pillsbury shale:	
Shale, sandy, tan-gray, thin-bedded, limonite-stained; weathers tan; some mica. Thickness exposed	4.0
Base covered.	

78. *Section from the Dover limestone member of the Stotler limestone to the Willard shale, inclusive, exposed in a road cut in the NE¼NE¼ sec. 19, T. 11 S., R. 13 E.*

	Feet
Stotler limestone:	
Dover limestone member:	
Limestone, medium-hard to soft, massive, light-gray; weathers gray and blocky to nodular; algae and fusulinids abundant. Thickness exposed	3.2
Pillsbury shale:	
Shale (mostly covered), sandy, tan-gray to gray, thin-bedded; contains mica; many limonite plates on surface; sandstone lens near the top; fusulinids very abundant in uppermost part. Thickness	45.6
Zeandale limestone:	
Maple Hill limestone member:	
Limestone, hard, massive, dark-gray; weathers tan gray and blocky; I-beam appearance; fusulinids, crinoid, columnals, and brachiopod fragments. Thickness	1.8
Wamego shale member:	
Shale, clayey, noncalcareous, gray; weathers tan gray; thin-bedded; limonite plates abundant. Thickness	9.8
Tarkio limestone member:	
Limestone, hard, massive, dark-brown; weathers tan brown and blocky; brachiopod fragments	4.1
Shale, silty, calcareous, tan-gray; weathers tan; thin-bedded; some fossils	.2
Limestone, hard, dense, massive, dark-brown; weathers tan to brown and blocky; large fusulinids abundant; brachiopods and corals common	3.4
Thickness	7.7
Total thickness of Zeandale limestone	19.3
Willard shale (about 4 feet exposed).	

74. *Composite section from the Dover limestone member of the Stotler limestone down into the Willard shale is in a road cut in the SE¼NW¼ sec. 15, T. 15 S., R. 13 E., and extends eastward along a creek bank to the Osage County line in the NE¼NE¼ sec. 15, T. 15 S., R. 13 E.*

Soil: silty, gray brown; about 1.5 feet thick.

	Feet
Stotler limestone:	
Dover limestone member:	
Limestone, hard, massive to blocky, gray; weathers light gray and to small irregular blocks; algae, large fusulinids, and crinoid columnals	1.7
Limestone, hard, tan-brown, massive, iron-stained; weathers to irregular blocks; fusulinids abundant; brachiopods and algae common	1.5
Thickness exposed	3.2
Pillsbury shale:	
Shale (partly covered), sandy, calcareous, blue-gray to tan, thin-bedded to blocky; weathers tan; iron stains on bedding planes; thin lenticular sandstone in upper half; limonite and sandstone plates on surface	26.3
Covered interval (slump and soil)	9.5
Total thickness	35.8
Zeandale limestone:	
Maple Hill limestone member:	
Limestone, hard, gray; weathers blocky and tan gray with purple stains near top; small fusulinids abundant; brachiopods, crinoid columnals, and algae common. Thickness	0.9
Wamego shale member:	
Shale, silty, noncalcareous, gray-brown, thin-bedded; weathers tan; iron stains on bedding planes; many limonite plates and nodules on weathered surface	8.2
Shale, clayey, noncalcareous, very dark-gray, thin-bedded; weathers gray; some silt; thin very fossiliferous limestone at the base; some limonite stains; brachiopods and crinoid columnals	2.9
Shale, silty, calcareous, gray-brown, thin-bedded; weathers tan	5.6
Shale, silty, calcareous, dark-gray, thin-bedded to blocky; weathers gray; very calcareous in upper part; pelecypods, brachiopods, crinoid columnals, bryozoans, and gastropods in upper part	3.5
Covered interval	4.0
Limestone, dense, hard, partly sandy, gray-orange to gray; some mica; weathers gray brown and massive; blocky and platy in part; some solution channels; pelecypods and gastropods	2.3
Shale, silty, calcareous, gray-brown, thin-bedded; weathers tan; many thin lenticular siltstone beds; some brachiopods	4.0
Shale, sandy, gray-green, blocky to massive; weathers light gray; some mica; many limonite and sandstone concretions	2.7
Covered interval	16.6
Thickness	49.8

Zeandale limestone—Continued

	Feet
Tarkio limestone member:	
Limestone, hard, dark-gray; a weathered 1-inch zone of brown; massive; weathers blocky except uppermost part which weathers platy and irregular; fusulinids abundant; crinoid columnals, brachiopods, bryozoans and coral. Thickness	1.9
Total thickness of Zeandale limestone	52.6
Willard shale:	
Shale, clayey, noncalcareous, gray-brown to dark-gray, blocky to thin-bedded; weathers tan to light blue gray; iron stains abundant on bedding and fracture planes; pelecypods rare. Thickness exposed	6.3

Base covered.

75. *Section from the Tarkio limestone member of the Zeandale limestone down into the Reading limestone member of the Emporia limestone in a road cut in the SE¼NE¼NE¼ sec. 35, T. 10 S., R. 9 E.*

	Feet
Zeandale limestone:	
Tarkio limestone member:	
Limestone (badly weathered), hard, dark-brown; weathers tan brown; massive; large fusulinids abundant; brachiopods and echinoid spines common. Thickness exposed	3.1
Willard shale:	
Shale, silty, calcareous, light-green, thin-bedded to blocky; weathers tan; contains many calcareous nodules; heavily limonite stained at base	2.3
Shale, silty, calcareous, gray-brown, thin-bedded to blocky; weathers tan; some clay; badly fractured; carbon and iron stains on bedding planes	18.4
Covered interval	12.0
Total thickness	32.7
Emporia limestone:	
Elmont limestone member:	
Limestone, hard, dense, massive, dark-gray; weathers tan and blocky; fractures to elongated blocks; porous and conglomeratic at the base; rust-brown platy zone near top; fusulinids, brachiopods, crinoid columnals, echinoid spines, and corals. Thickness	1.8
Harveyville shale member:	
Shale, clayey, slightly calcareous, tan-gray, thin-bedded; weathers gray; some mica and iron stains. Thickness	21.8
Reading limestone member:	
Limestone, hard, dense, massive, dark-gray; weathers tan gray; iron stains in upper and lower parts; small crinoid columnals. Thickness exposed	.8
Thickness of exposed Emporia limestone	24.4

Base covered.

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INDEX

Page

Aggregate, for concrete 113–115
Alluvium 111–113, 114, 115–116
Alma anticline 9, 10
Alma gas pool 124
Americus limestone member 51, 53–56, 166–167, 169, 172, 173, 175–176, 177, 179
Anticlines 11
Aquifers 75
Area of report, location of 3–5
Aspinwall limestone member 43–46, 183, 184, 185, 186, 188
Auburn shale 17

Bader limestone 77–81, 142–143, 149, 150, 152, 153
Barneston limestone 95–98, 128–130
Beattie limestone 71–76, 151, 153, 154–155, 156, 157, 158
Becraft, Wendal, cited 6
Bennett shale member 59–61, 166, 167, 169–170
Binder, calcareous 120–121
Biostrome 60, 85, 87, 89, 120, 121
Blue Rapids shale 84, 136, 138, 139, 140, 141, 144, 145, 146
Blue Springs shale member 94–95, 129, 130
Boulder, areal distribution 5; pl. 2
Brownville limestone member 39–40, 184, 185, 187, 188, 190, 191, 193
Burr limestone member 65–66, 161

Central Lowlands 6
Cherokee group, of Pennsylvania system 122
Chocolate limestone of swallow 21
Chonetes granulifera 40
Chonetes sp 25, 39, 75
Climate 7–9
Coal 33, 35, 48–49, 52, 70, 77, 122–123
Cottonwood limestone member 71–75, 151, 154, 155, 156, 157, 158
Crete member 107, 126, 127
Crouse limestone 82–83, 140, 141, 144, 146, 150
Crurithyris sp 68
Cryptozoon 28

Davis Ranch East oil pool 124
Davis Ranch pool, subsurface rocks 10, 124
Derbyia sp 34, 79
Dover limestone member 27–28, 190, 196–197, 198, 199, 200–201, 202
Doyle shale 98–99
Dragoon Creek 112
Drainage 6
Dry Creek 29
Dry shale member 28–29, 190, 196, 198, 199, 200

Easily Creek shale 81–82, 141–142, 146, 148, 149, 150
"Echo Cliff" 43
Eiss limestone member 78–79, 143, 149, 150, 152, 153

Page

Elmdale shale 53, 62
Elmont limestone member 19–20, 203
Emporia limestone 17–20, 203
Erratics, glacial 102, 118
Erosion 6
Eskridge shale 69–71, 151, 155, 156, 157–160, 161

Falls City limestone 47, 182
Features, physical, of Wabaunsee County 6
Five Point limestone member 49–51, 178, 179, 180–183
Flint Hills 6
Flint Hills escarpment 6
Florena shale member 75, 151, 154–155
Florence limestone member 95–96, 128, 129
Foraker limestone 53–58, 166–167, 168–169, 171–172, 173, 174–177
Fort Riley limestone member 97–98, 128
Fossils 50, 55, 106
French Creek shale member 32–33, 190, 194, 195, 196, 197
Friedrich shale member 31, 198, 199, 200
Funston limestone 84–86, 136, 138, 139, 140, 144, 145, 146, 147
Fusulinids 22

Glacial stages 10, 100
Glenrock limestone member 59, 166, 167, 169, 170
Grandhaven limestone member 29–30, 196, 198, 199, 200
Grand Island formation 104–105, 116, 127
Gravel, chert 115–116, 119–120
creek 113
limestone 115–116
Gravels, older 100–101
Grayhorse limestone member 37–38, 184, 186, 187, 188, 190, 192, 193, 194, 195
Great Plains province 6
Grenola limestone 63–69, 156, 158, 160–164, 167

Hamlin shale member 51–52, 172, 174, 176, 177, 178, 179
Harveyville shale member 18–19, 203
Havensville shale member 91–92, 132, 133, 134
Hawxby shale member 46, 183
Highway Commission, State 2, 5
Highways, in report area 7
History, geologic, of report area 9–10
Holmesville shale member 99
Hooser shale member 79–80, 142, 149, 150
Howe limestone member 61–62, 164, 165, 166, 167, 169, 170
Hughes Creek shale member 56–57, 166, 168, 171–172, 173, 174, 175, 176, 177

Page
Indian Cave sandstone member 42
Ice-contact deposits, glacial 103-104
Introduction 2-5

Janesville shale 47-52, 172, 174, 176, 177, 178, 179-181, 182
Jim Creek 32
Jim Creek limestone member 32, 194, 196, 197
Johnson shale 58, 166, 168, 169, 171, 174

Kansas River 6, 10
Kinney limestone member 93-94, 131

Laboratory, materials-testing, of State Highway Commission 3
Langdon shale 25
Legion shale member 64-65, 161, 162-165
Lime, agriculture 6, 61, 74, 124-125
Literature cited 204-207
Little Grayhorse anticline 37
Loess 10, 16, 106, 108
Long Creek limestone member 57-58, 166, 168, 171, 173, 174, 175
Lorton coal 33, 123
Loveland loess 108, 126, 127

McKissick Grove shale member 31
Map, base 3
index, of Kansas 4
Maple Hill 35
Maple Hill limestone member 24-25, 201, 202
Marais des Cygnes River 6, 100
Marginifera sp 25, 39
Marginifera Wabashensis 40
Matfield shale 93-95, 129-131
Middleburg limestone member 80-81, 142, 149, 150
Mill Creek 6, 10, 110, 112
Mill Creek oil pool 124
Mineral filler 116-117
Mission Creek 6
Mollusks 106
Morrill limestone member 76, 151, 153, 154, 155

Nebraska City limestone member 34, 190, 194, 195, 196
Nemaha anticline 9, 10
Nemaha Mountains 10
Nemaha Range 9
Neva limestone member 66-69, 156, 158, 160-163, 162-164
Newbury oil pool 124

Oketo shale member 96-97, 129
Older gravels 100-101, 115, 119
Onaga shale 41-46, 183, 184, 185, 186-187, 188, 189, 190
Orthomyalina 38
Osage plains 6
Ostrocodes 62, 66, 94, 106
Outcropping stratigraphic units 12-15

Peoria loess 108, 126, 127
Petroleum 123-124
Photographs, aerial 3, 41, 54
Physical features 6
Pierson Point shale 23
Pillsbury Crossing 26

Page
Pillsbury shale 25-26, 197, 200, 201, 202
Pits 5, 104; pl. 2
Plant fossils 55
Plumb shale member 34-37, 184-185, 186, 188, 189, 190, 192, 193, 194, 195, 196
Pony Creek shale member 38-39, 184, 186, 187, 188, 190, 191, 192, 193
Precipitation 7-9
Preston limestone 19

Quarries 5, 74, 98; pl. 2

Railroads, serving area 6
Reading limestone member 17-18, 203
Red Eagle limestone 58-62, 164, 165, 166, 167, 169-170
Riprap 117-118
Road metal 119-120
Roca shale 62-63, 120, 161, 163, 164, 165, 167, 169
Root shale 30-31, 190, 194, 195, 196, 197, 198, 199, 200

Salem Point shale member 66, 160, 162, 163, 164
Sallyards limestone member 63-64, 161, 162, 163, 164, 165, 167
Sanborn formation 106-110, 114, 115, 126, 127
Sappa formation 105-106, 126, 127
Schroyer limestone member 92-93, 131, 133
Seas, Pennsylvanian and Permian 9
Seeps 16
Soldier Creek 6
Somphospongia(?) sp 86
Speiser shale 87, 132-133, 136, 137, 139, 140, 143, 144
Spontiostroma 6, 55, 85, 89
Springs 16
Stearns shale 76-77, 143, 150-151, 152, 153
Stotler limestone 26, 190, 196-197, 198, 199-201, 202
Stratigraphic sections 125-203
Stratigraphic units, areal distribution 5; pl. 2
Structural stone 118-119
Structure 10-11
Subgrade and embankment material 121, 122

Talus deposits 16
Tarkio limestone member 21-23, 201, 203
Temperature ranges, Wabaunsee County 7, 8
Terrace deposits 110-111, 116, 125, 126
Threemile limestone member 88-91, 118, 132, 134, 135, 136, 137, 138, 140
Till 16, 101-103
Towle shale member 42-43, 183, 184, 185, 187, 188, 189, 190
Transportation routes 6-7
Travertine 99, 111
Triticites ventricosus 22

Wakarusa limestone 17
Wamego shale member 23-24, 201, 202
West Branch shale member 48-49, 178, 179-181, 182
Willard shale 20, 201, 203
Woodbury oil pool 124
Wood Siding formation 33-34, 184-186, 187-190, 191-196
Wreford limestone 88-93, 131, 136, 137, 138
Wymore shale member 93, 131

Zeandale limestone 21-25, 201, 202-203