Geology and Construction-Material Resources of Morris County, Kansas

GEOLOGICAL SURVEY BULLETIN 1060-A

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

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By MELVILLE R. MUDGE, CLAUDE W. MATTHEWS, and JOHN D. WELLS

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GEOLOGY AND CONSTRUCTION-MATERIAL RESOURCES OF MORRIS COUNTY, KANSAS

By Melville R. Mudge, Claude W. Matthews, and John D. Wells

ABSTRACT

The geologic units cropping out in Morris County are rocks of the Permian and Quaternary systems, of which the oldest exposed Permian formation is the Foraker limestone and the youngest is the Wellington formation. The limestones in the formations are gray, massive, and fossiliferous; some of the limestones contain nodules and lenses of chert. The shales are mainly variegated and nonfossiliferous; however, beds of gray shale in some of the units are fossiliferous. In the northeastern part of the county biostromes are found in the Funston limestone and in the Threemile limestone member of the Wreford limestone.

The Quaternary units consist of loess and fluival deposits. Loess mantles much of the broad flat uplands, whereas extensive deposits of chert gravel, possibly late Tertiary in age, are present along many of the streams and Recent alluvial deposits are common along all the streams.

Much of the limestone is used for concrete aggregate, road metal, riprap, and structural stone. The limestone units most quarried are the Threemile limestone member of the Wreford limestone, the Fort Riley limestone member of the Barneston limestone, the Cresswell limestone member of the Winfield limestone, and the Cottonwood limestone member of the Beattie limestone.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

The State Highway Commission of Kansas and the United States Geological Survey are cooperating in the compilation of a State-wide construction materials inventory. The Morris County investigation is a part of the general inventory, and a contribution to the geologic mapping and mineral-resources investigation being made in connection with studies of the Missouri River basin (Congressional documents, 1944). A field party composed of personnel from the two cooperating agencies undertook an investigation of sources of engineering construction materials in Morris County, Kans. in the summer of 1948; it was completed in the fall of 1949. Plate 1 was prepared to show the geologic occurrence of the construction materials.

The primary objective of the investigation was to accumulate all field and laboratory data pertaining to the geologic materials in

Morris County that would be of use in the construction of dams, highways, railways, airports, and other engineering structures. Additional geologic data are included in this report but only to the extent of providing information useful in the development of the prospects reported in the inventory or for the location of other materials required for future engineering needs.

GEOGRAPHY

AREA COVERED BY THE INVESTIGATION

Morris County is in the fourth east-west tier of Kansas counties south of the Nebraska border and in the fifth north-south tier west of Missouri. (See fig. 1.) The county is bounded on the north by Wabaunsee and Geary Counties, on the west by Dickinson and Marion Counties, on the south by Marion and Chase Counties, and on the east by Wabaunsee and Lyon Counties.

TOPOGRAPHY

The average altitude of Morris County is 1,300 feet. The lowest point, about 1,125 feet, is on the Neosho River at the southeastern boundary, and the highest points, about 1,525 feet, are in the central and southwestern parts of the county.

The three most conspicuous topographic features in the county are the valley of the Neosho River, the rolling upland plains in the north, central, and southwestern parts of the county, and the Flint Hill escarpment, which extends through the eastern part of the county. The Flint Hills have been carved by streams from alternating beds of shale and flint-bearing limestone. Conspicuous benches on the sides of most of the valleys have been formed by differential erosion of the limestone. The steep slopes between benches are composed of shale, which is eroded more rapidly than limestone.

Terrace and gravity-moved deposits (colluvium) are located along most of the streams, and extensive deposits of windblown silt (loess) occupy a large part of the upland area in the northern and western parts of the county.

DRAINAGE

The principal stream in Morris County is the Neosho River, which begins in the northwestern part of the county and flows southeast. (See pl. 1.) The northwesternmost part of the county lies in the drainage area of Clark Creek and the southwestern part is drained by Diamond Creek.

CLIMATE

Morris County is in an area of continental-type climate in which the summers are relatively long and hot and the winters are short and

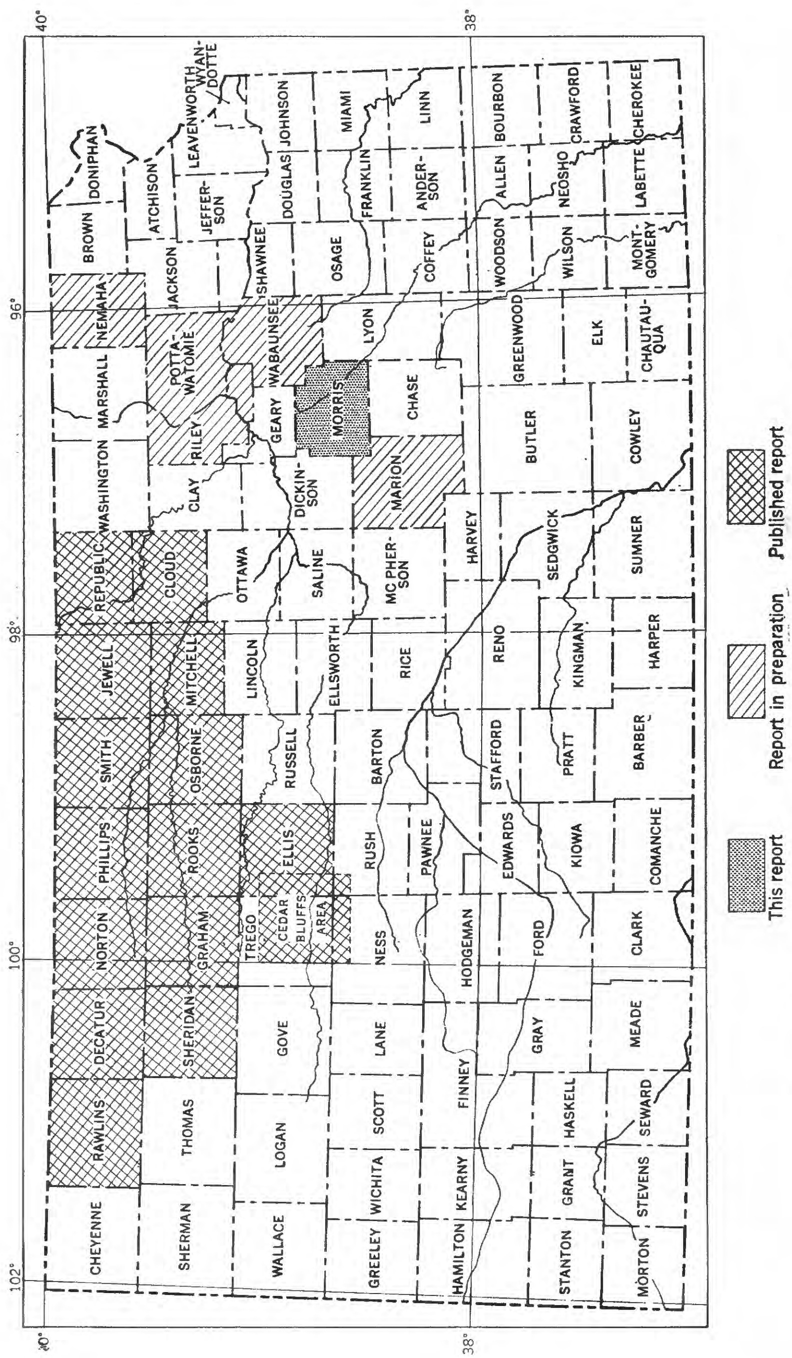

FIGURE 1.—Index map of Kansas showing area covered by this and other construction-materials reports.

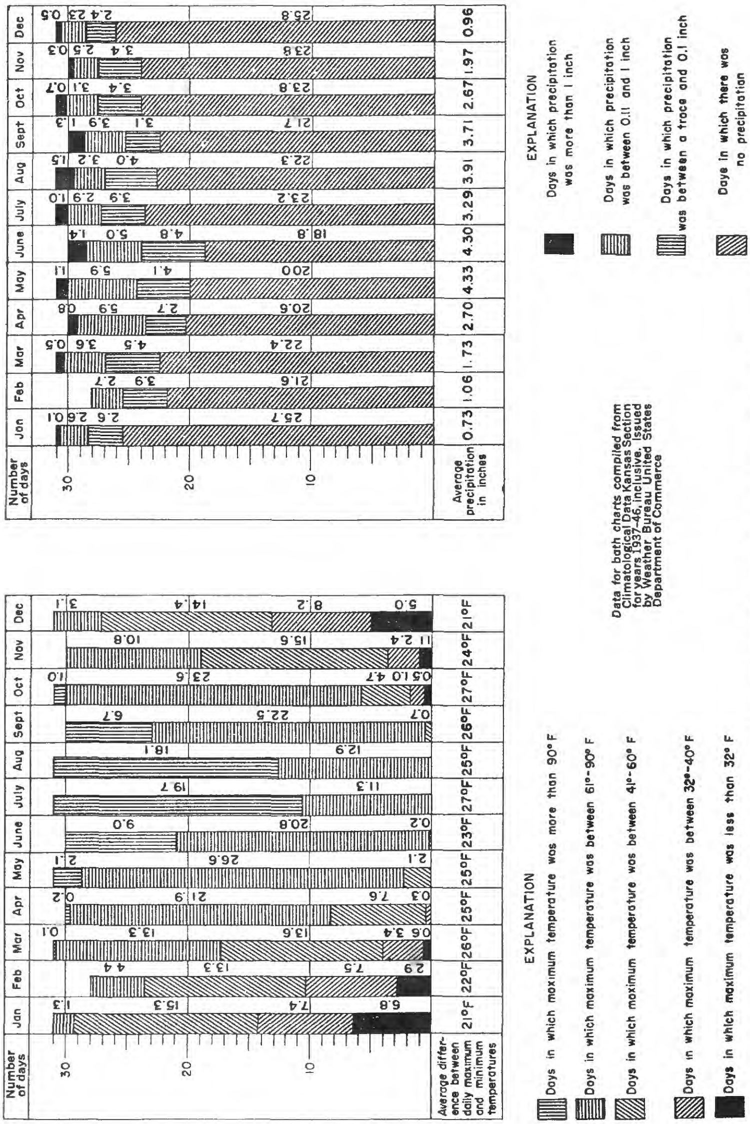

FIGURE 2.—Chart showing temperature and precipitation ranges at Council Grove, Kansas.

fairly cold. The mean annual temperature is 55° F, according to S. D. Flora (1948), and ranges from an average low of 29° F in January to a average high of 80° F in July. There are an average of 85 cloudy days, 95 partly cloudy days, and 185 clear days in a year. The average date of the first killing frost in the fall is October 18, the average date of the last killing frost in the spring is April 21, and the ground is covered with snow 25 days of the year.

Figure 2, a chart showing temperature and precipitation ranges of Council Grove, Kans. was compiled from Climatological Data furnished by the Kansas section of the Weather Bureau, U. S. Department of Commerce, for the years 1937 to 1946, inclusive, to provide basic data on temperature and precipitation in relation to engineering construction.

Days in which the maximum temperature does not exceed 32° F occur only during the period from November through March, with the maximum incidence, 7.4 days, in January. July is the warmest month of the year, and on an average there are 19.7 days having a maximum temperature which 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, 27° F, is in July and October, and the least difference, 21° F, is in January and December.

The ranges in precipitation were selected arbitrarily. Based on the 10-year average, there are, for example, 18.8 days in June, in which no measurable precipitation fell, 4.8 days in which the precipitation ranged from a trace to 0.1 inch, 5 days in which 0.11 to 1 inch of rain fell, and 1.4 days in which the precipitation was more than an inch. Continuing rains fall, for the most part, in the late spring and early fall, and other rainfall is generally in the form of showers of short duration. The normal annual precipitation is 31.36 inches.

TRANSPORTATION ROUTES

Morris County is served by three railroads, the Chicago, Rock Island, and Pacific; the Missouri Pacific; and the Missouri, Kansas, and Texas. (See pl. 1.) Transcontinental Highway U. S. 56 extends through the county, as do four State highways. (See pl. 1.)

Roads are on section lines in the relatively broad, flat areas. Where the topographic relief is great, however, the roads have been located along stream valleys and, in some places, along the interstream areas. In the central and south-central parts of the county, where dissection has been greatest, the number of roads is relatively small. U. S. Highway 56 and part of combined State Highways 13 and 57 are constructed of bituminous materials. The other State highways are surfaced with sand and gravel. All principal county roads are

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surfaced with local material or sand and gravel obtained from outside the county. Minor or farm-access roads are surfaced or are maintained as earth roads. All roads, other than Federal and State, are maintained by the county.

INVESTIGATION PROCEDURE

The base map used in the field was compiled from aerial photographs (scale: 1 inch equals 1 mile) provided by the State Highway Commission of Kansas. The photographs were also used in the placement of the contact lines between adjacent stratigraphic units. Some of the mapped units are single lithologic units, but most of them are composed of limestone and the shale overlying it. The mapped stratigraphic units are those recognized by Moore, Frye, Jewett and others (1951). The principal emphasis of this report is on construction materials. Those geologic problems which are not critically related to construction materials are considered, for purposes here, to be of secondary importance. Fossils were identified and used by the field party as an aid to the identification of stratigraphic units.

An effort was made to assemble all existing data pertaining to construction materials in the county; these are presented in table 1.

ACKNOWLEDGMENTS

Appreciation is expressed to the following for their aid in contributing information used in the compilation of the geologic map and the construction-materials data included in this report: State Highway Commission of Kansas at Topeka and Manhattan, Kans., R. D. Finney, engineer of materials, W. E. Gibson, engineer of tests, and S. E. Horner, chief geologist; and the State Geological Survey of Kansas at Lawrence, Kans., J. C. Frye, former executive director, and J. M. Jewett, geologist. We wish to thank the engineer of Morris County for his aid in the materials survey and the many residents of Morris County who readily cooperated with us.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

This discussion of the outcropping stratigraphic units of Morris County emphasizes the areal distribution, general characteristics, and thickness of each formation or group of formations, and presents the geologic information required for the location and effective development of the construction materials.

A summary of the geologic and construction-materials data for each stratigraphic unit is presented in plate 2. The areal distribution of the stratigraphic units is shown on a geologic map of Morris County (pl. 1), and each mapped unit is indicated by an identifying symbol.

Representative measured sections for most of the stratigraphic units are included in the part of this report entitled "Stratigraphic sections" and are referred to in the discussion of each unit. This is done as an aid to the identification of the geologic formations locally in the field.

The locations of pits and quarries are also shown on plate 1. The symbols indicate whether the pit or quarry has been operated, or is a prospect; the type of construction material available at each site; and the quantity of the material (in units of 10,000 cubic yards) that can be removed under 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 material according to the following plan: the numbering starts in the northeasternmost township and continues along the same tier to the western boundary of the county; it is continued in the next tier south starting again with the township in the easternmost range and proceeding to the western 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.

PERMIAN SYSTEM

All the consolidated rocks exposed in Morris County are of Permian age. (See pl. 2.) The Wellington is the only formation of the Sumner group in this county. The Council Grove and Chase groups are exposed in Morris County; however, the oldest group, the Admire, is not exposed. The areal distribution of the Council Grove, Chase and Sumner groups is shown on plate 1.

The discussion of the outcropping rocks of the Permian system is organized on the basis of formations. Key beds, ones which are more easily identified than other beds, are indicated in the following descriptions. Those units which are not key beds are best identified by their position above or below a key bed. The color described for each formation and member pertains only to the unweathered exposures of the rocks.

COUNCIL GROVE GROUP

The Council Grove is the lowest group of Permian rocks exposed in Morris County. (See pl. 2.) It includes the formations from the top of the Speiser shale down to the base of the Foraker limestone. All of these formations, except the Foraker limestone, are exposed in Morris County. Formations and the members of which they may be composed are described separately and their outcrop areas are shown on plate 1.

Outcrops of the Council Grove group are found in the east-central and southeastern parts of the county. (See pl. 1.) The conspicuous hillside benches are the result of differential weathering of the resistant limestone beds; the nearly vertical slopes are composed of shale which is more readily eroded. The average thickness of that part of the Council Grove group exposed in the county is 264 feet.

JOHNSON SHALE

Only the upper part of the Johnson shale (pl. 2) crops out in this county. It is a silty and calcareous tan-gray thin-bedded shale interbedded with many thin calcareous lenses and nodules. The exposed thickness of the Johnson shale is 4 feet. (See measured section 39.)

RED EAGLE LIMESTONE

The Red Eagle limestone is composed of three members which are, in ascending order, the Glenrock limestone, Bennett shale member, and Howe limestone member. It is about 13 feet thick. (See pl. 2.)

Glenrock limestone member.—The Glenrock is soft to medium-hard, light-gray porous limestone. It contains clay nodules, weathers blocky, and has an oolitic texture in its basal part. Small fusulinids are abundant in its middle part. It is 0.8 foot thick. (See measured section 39.) The Glenrock limestone member is characterized by its thickness, color, and abundance of fusulinids.

Bennett shale member.—The Bennett is composed of silty calcareous olive-drab thin-bedded shale, contains a variety of fossils which are most abundant in its upper part, and is about 9 feet thick. (See measured section 39.)

Howe limestone member.—The Howe is composed of massive layers of medium-hard porous gray-orange to tan-brown limestone. Crystals of pink or white celestite (strontium sulfate) are generally found on its weathered surface. Microfossils (ostracodes) are abundant in the uppermost beds. This member is about 3 feet thick. (See measured section 39.)

The Howe is easily identified by its color, thickness, and the abundance of microfossils in its upper part.

ROCA SHALE

The Roca shale (pl. 2) is largely a clayey and calcareous thin-bedded tan-gray shale, but tan-brown, gray-green, and purple beds are also present. Thin lenses of clayey gray limestone occur in its middle and lower parts. Calcareous nodules and concretions are common in some of the shale beds. Minute fossils are common in most of the layers of limestone, but were not found in the shales. The Roca shale averages 23 feet in thickness. (See measured section 38.)

GRENOLA LIMESTONE

The Grenola limestone (pl. 2) consists of five 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. The average thickness of the formation is about 40 feet.

Sallyards limestone member.—The Sallyards consists of a single bed of fossiliferous limestone, which is generally medium hard, gray, and locally clayey and shaly. It generally weathers blocky to platy. This member averages 0.5 feet in thickness. (See measured section 38.)

Legion shale member.—The Legion is a nonfossiliferous gray, tan-gray, and olive-drab thin-bedded shale with a dark-gray bed of shale in the lower part. It is about 7 feet thick.

Burr limestone member.—The Burr consists of two layers of limestone separated by a thin bed of shale. The upper limestone bed is medium hard, tan gray, massive, and weathers platy. The lower limestone bed is soft, gray brown, and massive. The intervening bed of shale is silty, gray to tan gray, and thin bedded. Fossils are present at most places in the limestones, but are absent from the shale. This member averages about 8 feet in thickness.

Salem Point shale member.—The Salem Point is a silty calcareous olive-drab to dark-gray shale in the upper part, and is clayey, calcareous, and tan gray in the lower part. This member is nonfossiliferrous, and averages 12 feet in thickness. (See measured section 37.)

Neva limestone member.—The Neva consists of numerous thick layers of limestone, and a thick layer of shale interbedded in its lower part. The uppermost layers of limestone are hard, porous, and massive, with bedding planes apparent on weathered surfaces. The middle bed of limestone is massive, soft, and porous to cavernous. The bed of shale in the lower part of the member is gray green to tan gray and thin bedded near the top, but it is dark gray and fissile near the base. The lowermost bed of limestone is hard, tan, and blocky. A prominent hillside bench formed by the Neva is about 25 feet beneath the Cottonwood limestone member of the Beattie limestone. Fossils are generally present in the shale bed and in most of the limestones. This member is about 13 feet thick. (See measured section 36.)

The Neva is a good marker bed and is easily recognized by its massive limestone members, the porous zone near the middle, its thickness, and by the shale zone in its lower part.

ESKRIDGE SHALE

The Eskridge shale (pl. 2) is mostly a clayey calcareous tan-gray to gray-green shale, but maroon, green, and purple zones are also present in many exposures. In many places there is a massive clayey tan-gray limestone bed in the upper part of the formation and one or more shaly limestone beds in the lower part. The upper limestone is slightly more than a foot thick and weathers to platy fragments. A massive lens of hard gray limestone in the lower part of the formation crops out in an exposure in the center of sec. 33, T. 17 S., R. 9 E., in which fossil clams (pelecypods) are very abundant; they are common in the other limestone lenses. A bed of impure coal, 0.2 of a foot thick, was observed in the upper part of the Eskridge shale in the SW¼NE¼ sec. 1, T. 17 S., R. 9 E., and fossil leaves are present in a thin bed of shale near the middle of the formation in the SW¼NW¼ sec. 15, T. 17 S., R. 9 E., and in the SW¼NE¼ sec. 1, T. 17 S., R. 9 E. The formation is about 25 feet thick. (See measured sections 33–35.)

The Eskridge shale is easily recognized by its varicolored zones, thin beds of fossiliferous limestone, and by its position between the Beattie and Grenola limestones.

BEATTIE LIMESTONE

The Beattie limestone (pl. 2) consists of three members which are, in ascending order, the Cottonwood limestone member, Florena shale member, and Morrill limestone member. Its average thickness is about 22 feet.

Cottonwood limestone member.—The Cottonwood is a hard massive light-gray limestone. Two or three bands of chert nodules from 0.2 to 0.3 foot thick, generally occur in the middle and upper parts and isolated nodules are scattered throughout in most exposures. Solution channels are conspicuous in many of the outcrops. A light-gray rounded ledge is characteristic of the prominent hillside bench formed by this member. Small fusulinids are abundant in its upper part but are not so numerous in the lower part. The average thickness of the member is 5.5 feet. (See measured sections 32 and 33.) The Cottonwood limestone member is a good marker bed and is easily identified by its massiveness, thickness, color, thin bands of chert, the abundance of small fusulinids, and its prominence as an erosional feature.

Florena shale member.—The Florena is silty in the upper part but its lower part consists of interbedded silty and clayey zones, both of which are carbonaceous. The upper part is blocky, tan, and gray green, whereas the lower part is fissile to thin bedded and black to tan gray. Fossils are very abundant in the lower part, especially *Chonetes*, but are absent from the upper part. The Florena is about 12 feet thick. (See measured section 32.)

The Florena shale member is easily identified by the abundance of fossils in its lower part and by its position just above the prominent outcrops of the Cottonwood limestone member.

Morrill limestone member.—The Morrill is composed of two thin beds of limestone separated by a thin bed of shale. The upper limestone bed is tan gray, medium hard, and platy to blocky. The lower limestone bed is gray to tan gray, soft, massive, cavernous, and contains numerous thin bands of red calcite. The bed of shale is clayey and tan brown. This member forms a recognizable hillside bench at only a few places. Its average thickness is about 5 feet. (See measured section 32.)

The Morrill is best identified by its platy and cavernous limestone and by its position above the easily identified Cottonwood limestone member of the same formation.

STEARNS SHALE

The Stearns shale (pl. 2) is mostly silty, calcareous, and gray green, but tan, tan-gray, blue-gray, brown, and black zones are also present. Many thin lenses of limestone are distributed throughout the shale, and most of them are soft, clayey, and weather blocky or to a shaly appearance. Fossils, including plants, are in some of the lenses of limestone and beds of shale. The formation is about 35 feet thick. (See measured section 32.)

BADER LIMESTONE

The Bader limestone consists of three members which are, in ascending order, the Eiss limestone member, Hooser shale member, and the Middleburg limestone member. (See pl. 2.) This formation averages about 20 feet in thickness.

Eiss limestone member.—The Eiss consists of two beds of limestone separated by a bed of shale. The upper limestone bed is hard, dense in some zones and porous in others, gray, very fossiliferous and massive, whereas the lower is medium hard, gray, less fossiliferous and weathers to form plates and small irregular-shaped chips. The intervening bed of shale is clayey, calcareous, gray, and blocky. A minor hillside bench formed in part by the upper limestone bed is about 30 feet beneath the prominent bench formed by the Crouse limestone. The surface of this bench contains small blocks of porous limestone. This member is about 7 feet thick. (See measured sections 31 and 32.) The Eiss limestone member is easily identified by the upper layer of porous blocky limestone and by the lower layer of very fossiliferous platy limestone.

Hooser shale member.—The Hooser is a silty and calcareous varicolored shale. Tan-gray and gray-green zones are most numerous, but maroon and purple zones are also present. The Hooser is nonfossiliferous and averages about 6 feet in thickness. (See measured section 31.) The Hooser is easily recognized by its varicolored shales and by its position immediately above the Eiss limestone member.

Middleburg limestone member.—The Middleburg consists of two beds of limestone separated by a layer of shale. The limestone is hard, dense, massive, and tan gray to gray brown. The upper limestone bed weathers to small, irregular-shaped blocks whereas the lower limestone bed weathers to small, irregular-shaped plates. The intervening bed of shale is silty, calcareous, black to dark gray, and thin bedded to very thin bedded (fissile). The erosional feature of this member is a smaller and less conspicuous hillside bench than is characteristic of the Eiss limestone member. Fossils are common in the two layers of limestone but none were observed in the intervening shale. The average thickness of the Middleburg is 7 feet. (See measured section 29.)

EASLY CREEK SHALE

Most of the Easly Creek shale (pl. 2) consists of beds of silty and calcareous olive-drab to gray-green shale, although thin zones of maroon, tan, and green shale are present in some exposures. Very calcareous shale, which contains many calcareous concretions, is present in the lower part of the formation. The average thickness of the Easly Creek shale is 17 feet. (See measured sections 28–30.)

CROUSE LIMESTONE

The Crouse limestone (pl. 2) consists of thick beds of limestone in the upper part, a thick bed of shale in the middle part, and a thin bed of hard limestone in the lower part. The upper beds of limestone are hard, light gray, massive, and commonly weather into numerous plates; they are separated by one or more partings of calcareous shale which are 0.05 to 5.5 feet in thickness. The thick shale in the middle part of the formation is clayey to silty, calcareous, olive drab, and about 8 feet thick. The lower bed of limestone is hard, somewhat dense, gray to gray orange, and massive; it ranges from 1.5 to about 3 feet in thickness.

This formation forms a very prominent hillside bench which is characteristically covered by small plates of weathered limestone. Fossils are present in the beds of limestone. The average thickness of the formation is about 16 feet. (See measured sections 27–29.) The Crouse limestone is easily recognized by the abundant plates of light-gray limestone which typically mantle its outcrops.

BLUE RAPIDS SHALE

The Blue Rapids shale (pl. 2), composed of silty and clayey beds of tan to gray-green shale, has one or more layers of limestone in its upper part. The limestone is tan or gray, medium hard, and in most places contains calcareous nodules and some clay balls. Calcareous lentils and pockets of celestite are common in the beds of shale. A 1.3-foot-thick bed of limestone in the upper part of this formation forms a small bench in the area south of Council Grove. Fossils occur only in the beds of limestone. The Blue Rapids shale is about 26 feet thick. (See measured section 27.)

FUNSTON LIMESTONE

The Funston limestone (pl. 2) is generally composed of two or more limestone beds separated by thin beds of shale. The upper bed of limestone is thick, massive, soft, and light gray, whereas the other limestone beds are thin, dense, and dark gray. Small calcareous discs of algal origin are fairly common in the limestone. The intervening beds of shale are usually silty, calcareous, and tan to tan gray. A small hillside bench about 15 feet beneath the very prominent bench containing the Threemile limestone member of the Wreford limestone is typical of the Funston limestone. Large blocks of porous crossbedded limestone are present in the Funston terrace in the NE¼ sec. 25, T. 15 S., R. 9 E. This formation averages 12 feet in thickness.

The biostrome in the Funston coincides in areal distribution in this county with that of the biostrome of the Threemile and can be traced into western Wabaunsee County and southeastern Riley County. This facies of the Funston consists of thick beds of massive light-gray limestone composed almost entirely of oolites. The weathered surface clearly shows crossbedding in the limestone. A silty and calcareous tan-gray bed of shale is in the lower part of the formation and is underlain by a thin bed of limestone. The total thickness of this biostrome in Morris County is not known, because only 6 feet of the upper part is exposed, but it is 28½ feet thick in Wabaunsee County. (For detailed descriptions of the Funston limestone, see measured sections 24–27.) This formation can be recognized by its many thin gray limestone beds and by its position beneath the easily identified Threemile limestone member of the Wreford limestone.

SPEISER SHALE

The Speiser shale (pl. 2) is composed of beds of varicolored shale and generally includes a thin bed of limestone in its upper part. The beds of shale are silty to clayey and are mostly calcareous; tan-gray and gray-green zones are characteristic of the upper part of the formation and gray-green and maroon zones predominate in the lower part. The thin bed of limestone is hard, clayey, gray, and weathers blocky to thin bedded. A second thin lens of the limestone, also in the upper part of the formation, is present in some exposures. The uppermost beds of shale and some exposed beds of the limestone are fossiliferous. Speiser shale averages 15 feet in thickness. (See measured sections 21, 23–26.)

The Speiser shale is readily recognized by its varicolored beds and the thin limestone and tan-gray fossiliferous shale in its upper part.

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It is overlain by the Threemile limestone member of the Wreford limestone, an excellent marker bed.

CHASE GROUP

The Chase is the uppermost group of formations in the Permian of Morris County. (See pl. 2). Formations of the Chase group crop out in all parts of the county except the extreme eastern and southeastern parts. (See pls. 1 and 2.) Conspicuous and easily identified hillside benches are characteristic of the Herington, Cresswell, Towanda, Fort Riley, Florence, and Threemile units. The average thickness of the Chase group is 304 feet.

WREFORD LIMESTONE

The Wreford limestone is the basal formation of the Chase group. (See pl. 2.) Prominent hillside benches formed by this formation can be seen in the vicinity of Council Grove and in the east-central part of the county. The Wreford limestone is divided into three members which are, in ascending order, the Threemile limestone member, Havensville shale member, and the Schroyer limestone member. Its average thickess is 37 feet.

Threemile limestone member.—Numerous exposures of the Threemile member can be seen in streambanks and road cuts in the east-central part of the county and are especially well exposed in the vicinity of Council Grove. This member makes a prominent rounded hillside bench. A massive bed of light-gray limestone in the upper part of the member often erodes as a conspicuous ledge which clearly indicates its outcrops on a hillside. The Threemile is generally composed of massive beds of hard light-gray limestone, most of which contain lenses and scattered chert nodules. A persistent, very calcareous and silty gray shale near the base of the unit is underlain by a bed of fossiliferous limestone 2 to 3 feet thick which contains 1, 2, or 3 lenses of chert. This bed of limestone marks the base of the member and contains brachiopods, bryozoans and microfossils. This member averages about 13 feet in thickness.

A biostrome is present in a belt extending from a point south of Parkerville, southeast to Council Grove, and north along Munker Creek from that city. Mudge and Burton (in press) have traced this biostrome of the Threemile into the southwestern part of Wabaunsee County. The upper part of the limestone consists of thick, massive light-gray beds which are medium hard, porous, and contain only scattered nodules of chert. The lower part consists of soft dolomitic cavernous beds containing nodules and lenses of chert and a thick bed of shale. The shale is silty and very calcareous, dolomitic in some zones, and contains many geodes and calcareous nodules and lenses. This facies of the Threemile limestone member is fossiliferous, and its average thickness is 30 feet. (For detailed descriptions of the Threemile, see measured sections 18–25.) It is a good marker bed and is easily identified by the continuous bed of shale in its basal part, the massive noncherty limestone in its upper part, the abundance of chert it contains in most zones, and the presence of the varicolored Speiser shale beneath it.

Havensville shale member.—The Havensville is mainly a silty and calcareous gray shale. There is a thick massive bed of gray limestone in its upper part and somewhat thinner lenses of limestone occur locally in the middle and lower parts. Calcareous nodules and fracture fillings and calcite-filled geodes characterize the upper part of this shale in many places. The beds of limestone and the lower beds of shale are generally fossiliferous. The average thickness of this member is 12 feet, but in areas where the underlying Threemile is a biostrome, this shale is only 6 feet thick. (See measured sections 17–21.)

The Havensville is best identified by its position between the two cherty limestones, the Schroyer and Threemile.

Schroyer limestone member.—Outcrops of the Schroyer limestone member are generally associated with those of the underlying Threemile limestone member. Where these two members are present, the Schroyer erodes to a less conspicuous bench, above and farther back on the hillside than the prominent, rounded bench formed by the Threemile. The Schroyer consists of thick beds of limestone which contain numerous nodules and lenses of chert. The limestone is massive, gray, and soft to medium hard. The chert is hard dense gray to light gray, and weathers with a typical conchoidal fracture, most of the lenses of chert weather into small rectangular blocks 2 or 3 inches in diameter.

Thin beds of silty calcareous tan shale occur locally at several levels within the member. In the center of the SW¼ sec. 23, T. 15 S., R. 8 E. the Schroyer lacks the usual shale breaks, but does include a thick, massive bed of soft porous noncherty limestone in its middle part. Fossils are common in most of the beds of limestone. This member ranges from 7 to 19 feet in thickness. It averages 12 feet thick. (See measured sections 17–19.)

The Schroyer member is best identified by its chertiness and by its position above the Threemile member of the same formation.

MATFIELD SHALE

The Matfield shale crops out on hillsides beneath the prominent bench of the Florence, but is mostly covered by mantle slump. The Matfield shale is divided into three members which are, in ascending order, the Wymore shale member, Kinney limestone member and the

Blue Springs shale member. (See pl. 2.) This formation averages 66 feet in thickness.

Wymore shale member.—The Wymore member is rarely exposed because of the absence of a good bench-forming limestone overlying it. It consists of beds of silty and calcareous shale, and is tan gray and thin bedded in the upper part and gray green, maroon, and blocky in the lower part. There is a thin bed of clayey limestone in its upper part. This member averages 30 feet in thickness. (See measured sections 16–18.)

Kinney limestone member.—The Kinney is a single bed of massive medium-hard gray to tan-brown limestone. Elsewhere in the State the Kinney consists of two limestone beds separated by a fossiliferous shale bed. In Morris County the upper limestone is absent, therefore, the contact between the Kinney limestone member and the overlying Blue Springs shale member is placed at the top of the fossiliferous bed of shale. (See measured section 16.) This member crops out on many hillsides about 35 feet beneath the Florence, but in most areas it does not erode to a discernible bench. However, one such hillside bench has developed in the SE¼ sec. 10, T. 17 S., R. 8 E. This bench is covered by large light-gray blocks of weathered limestone and has a line of small bushes near its base. Other benches characteristic of this limestone can be seen in the SW¼SW¼ sec. 15, T. 17 S., R. 9 E. and in the SE¼SW¼ sec. 9, T. 17 S., R. 8 E. Microfossils are abundant in its upper part and larger fossils are present in the remainder of the member. The Kinney ranges from less than a foot to about 4 feet in thickness. (See measured section 16.) The Kinney limestone member is easily recognized by its color, the presence of microfossils in its upper part, and by its position beneath the Florence limestone member of the Barneston limestone.

Blue Springs shale member.—The Blue Springs is a clayey shale in its upper part, but is mostly silty in the lower part. Maroon and gray green are the most conspicuous colors, but zones of tan, gray, and purple are also present. Almost all of the beds are blocky and calcareous and in many places there are one or more thin beds of clayey limestone near the middle. Fossils are very abundant in the lower part of this member. It averages 34 feet in thickness. (See measured section 16.)

BARNESTON LIMESTONE

The Barneston limestone crops out in the northern, northeastern, central, and south-central parts of the county. This formation is divided into three members which are, in ascending order, the Florence limestone member, Oketo shale member, and the Fort Riley limestone member. (See pl. 2.) The Barneston limestone averages 68 feet in thickness.

Florence limestone member.—Outcrops of the Florence are abundant in the northeastern, central, and south-central parts of the county. The prominent hillside bench characteristic of this member is covered with small blocks and fragments of chert.

The Florence consists of thick beds of limestone that contain many nodules and bands of chert. The chert is gray to light gray, is generally mottled with dark gray, has a conchoidal fracture, and commonly has limonite and iron stains on the fracture planes. The bands of chert commonly fracture to form small elongated blocks 2 to 4 inches in width. Concentric banding is well displayed in some of the fragments.

Thick beds of silty calcareous tan-gray shale generally occur in the upper and lower parts of this member, and thin beds of this material are also present in the middle part in some outcrops. Fossils and fossil fragments occur in most of the layers of limestone and are present in some of the bands of chert. The Florence is well displayed in road cuts in the NW¼NW¼ sec. 22, T. 15 S., R. 7 E. and the NE¼NW¼ sec. 36, T. 14 S., R. 8 E. This member averages 25 feet in thickness. (See measured sections 14 and 15.)

The Florence limestone member is easily recognized by the prominent, rounded hillside bench, the abundance of chert it contains, and by its thickness.

Oketo shale member.—The Oketo is generally a thin-bedded to blocky, silty and calcareous tan-gray shale mottled with some blue-gray areas. A thin lens of limestone is present in its upper part. Fossils are abundant in some exposures but are rare in others. This member averages 6 feet in thickness. (See measured sections 12–14.)

Fort Riley limestone member.—Outcrops of the Fort Riley member are conspicuous in the north-central, central, and south-central parts of the county. (See pl. 1.) It is composed of thick beds of limestone separated by thin partings of shale with a thick bed of shale usually present in the lower part. A thick layer of resistant limestone occurs at or near its base and is a very prominent rim on many hillsides; for this reason the bed is known as the rimrock. In some places, one of the beds of limestone near the middle of the member has similar outcrop characteristics. The basal rimrock layer is medium-hard light-gray somewhat porous limestone, is 3 to 6 feet thick; in many outcrops only 2 or 3 feet of this bed are exposed. The other limestone beds in the member are soft and weather in a manner similar to shale.

The Fort Riley is very well exposed in the NW¼NW¼ sec. 13, T. 17 S., R. 7 E. Two ledges of massive limestone are displayed in the south-central part of the county, one in the upper part of the member and the other in the lower part. Many sinks have developed in the upper part of the member, such as those in sec. 31, T. 16 S., R. 6 E., secs. 5, 8, 11, 12, 24, and 25, T. 17 S., R. 7 E., and sec. 5, T. 16 S., R. 7 E. There are fossils in some of the limestones, but they are rarely found in the shales. This member averages 67 feet in thickness. (See measured sections 12–14.)

The rimrock of the Fort Riley is an excellent marker bed. It is easily identified by its prominent outcrop, thickness, color, and pitted surface.

DOYLE SHALE

The Doyle shale (pl. 2) crops out in the western and central parts of the county. This formation is divided into three members which are, in ascending order, the Holmesville shale member, Towanda limestone member, and the Gage shale member. The Doyle shale averages 37 feet in thickness.

Holmesville shale member.—The Holmesville is mostly a clayey-shale in its upper part and silty-shale in its lower part. Gray and gray-green zones are most abundant but there is a thin bed of maroon shale in the middle part. The upper beds are highly calcareous and locally include calcareous plates and nodules. There may be one or more beds of gray somewhat dense limestone in the lower part which generally weather porous and cavernous. There are no fossils in this member, and it averages 16 feet in thickness. (See measured section 11.)

Towanda limestone member.—The Towanda consists of many beds of hard gray to tan-brown limestone. It weathers blocky to platy and the surface of some of the weathered blocks are markedly pitted. Iron stains are common on fracture and bedding planes. This member forms a prominent hillside bench 30 to 40 feet above the rimrock of the Fort Riley limestone member of the Barneston limestone. Fossils are rare or absent. It averages 11 feet in thickness. (See measured section 11.)

The Towanda member is easily recognized by its thickness and color and by the small hard weathered blocks and plates associated with its outcrops.

Gage shale member.—The Gage consists of tan and tan-gray clayey shale beds in the upper part, and gray-green and maroon silty shale beds in the lower part. A thin bed of tan crystalline limestone is locally present in its upper part. The only fossils in the member occur in this bed of limestone. The total thickness of the Gage is about 40 feet. (See measured section 10.)

WINFIELD LIMESTONE

Outcrops of the Winfield limestone are numerous in the western part of the county. The formation is divided into three members which are, in ascending order, the Stovall limestone member, Grant shale member, and the Cresswell limestone member. The Winfield limestone is about 23 feet thick.

Stovall limestone member.—The Stovall is a massive bed of hard gray limestone. It contains one or more lenses, and many scattered nodules, of chert. The lenses are 0.2 of a foot thick in some exposures in the northern outcrop area but are 0.7 foot in the NE¼NW¼ sec. 36, T. 17 S., R. 6 E. The limestone is 2.7 feet thick in the SE¼SE¼ sec. 14, T. 17 S., R. 5 E. and contains three lenses of chert each of which is 0.3 to 0.5 of a foot thick. This member consists only of a bed of chert 0.3 of a foot thick in the SW¼SE¼ sec. 20, T. 16 S., R. 6 E. Most outcrops of the Stovall are covered with blocks of weathered limestone and nodules of chert. Fossils are common to abundant in this member. A small bench comprising this limestone underlies the prominent one containing the Cresswell limestone. Small folds and faults are abundant, but extend only a short distance vertically and laterally into the adjacent zones of the overlying Grant shale member and the underlying Gage shale member of the Doyle shale. The Stovall ranges from 0.3 of a foot to 2.7 feet in thickness. (See measured sections 9 and 10.)

The Stovall member is easily recognized by its thickness, the presence of lenses and nodules of chert, and by its position beneath the readily identified Cresswell limestone member.

Grant shale member.—The Grant is a silty and calcareous tan-gray shale. The lower part of this member is highly calcareous. In its upper part, in the SE¼SE¼ sec. 14, T. 17 S., R. 5 E., calcite-filled geodes are present; in lesser number, other geodes filled with chalcedony and quartz are also present. Fossils are uncommon in some exposures but are abundant in others. The Grant is about 10 feet thick. (See measured sections 8 and 9.)

Cresswell limestone member.—The Cresswell consists of many beds of light-gray limestone. Its lower part is tan gray, hard, massive, and weathers into irregular blocks. Thin lenses of chert were observed in this part of the Cresswell in the SE¼SE¼ sec. 31, T. 14 S., R. 5 E. whereas, over the remainder of its outcrop area, the chert occurs only as nodules scattered throughout the limestone. The middle part of the Cresswell consists of massive beds of medium-hard limestone, and its upper part is platy and soft to medium hard. Geodes of calcium carbonate and, less commonly, of silica are abundant in the upper part. Fossils are abundant only in the lower part of this member, and long spines of echinoids are especially abundant and characteristic. The Cresswell averages 12 feet in thickness. A prominent hillside bench is characteristic of this limestone; the outcrop is generally ragged because of the slumping of the limestone ledge. (See measured sections 7 and 8.)

The Cresswell limestone member is a good marker bed and can easily be indentified by its thickness, color, the presence of geodes, and the abundant echinoid spines in its lower part.

ODELL SHALE

The Odell shale is mainly silty, calcareous, and varicolored. Gray-green and maroon zones are abundant in its upper part and tan-gray and gray zones are typical of the lower part. No fossils were found in this formation. It averages about 20 feet in thickness. (See measured sections 4 and 6.)

NOLANS LIMESTONE

The Nolans limestone (pl. 2) is divided into three members which are, in ascending order, the Krider limestone member, Paddock shale member, and the Herington limestone member. It averages 23 feet in thickness.

Krider limestone member.—The Krider consists of one or more beds of soft dolomitic limestone. The beds are generally gray or tan, weather blocky, and have a "sugary" or sandy texture. Pelecypods are usually common to abundant. This member is rarely part of a prominent hillside bench but small, poorly developed benches underlain by it can be observed in secs. 18, 19, and 30, T. 16 S., R. 5 E. The average thickness of the Krider member is 1.1 feet. (See measured sections 4, 5, and 6.)

The Krider is easily recognized by its thickness, color, softness, fossils, and its position beneath the Herington and Paddock members.

Paddock shale member.—The Paddock is blocky, clayey, and generally noncalcareous, but in some places in its upper part it includes beds of very calcareous shale. It is tan to tan gray in the upper part and gray green in the lower part. A thin bed of hard dolomitic gray to gray-brown limestone occurs in the lower part of this member, but it is very thin in the southern part of the county. Fossils are abundant in some of the beds of shale. They are generally present in the limestone bed in the northern part of the outcrop area, but are absent from it in the southern part. The Paddock averages 15 feet in thickness. (See measured sections 4 and 5.)

Herington limestone member.—Outcrops of the Herington are conspicuous in the western part of the county. (See pl. 1.) The member consists of thick beds of medium-hard slightly dolomitic limestone which are light gray, tan, and gray brown. The limestone is massive, weathers blocky, and contains some small calcite-lined cavities (geodes). The beds in the lower part of the member are soft and marked by many minute black specks.

A prominent, rounded hillside bench is characteristic of the Herington and, in most areas, the upper part of the Paddock shale member is exposed beneath it. The member is well exposed in a railway cut in the SE¼NE¼ sec. 7, T. 16 S., R. 5 E. Fossil clams (pelecypods) are common to abundant in almost all exposures of this limestone. It is about 7 feet thick. (See measured sections 4 and 5.)

The Herington is a useful marker bed because it is easily identified by its thickness, color, and fossils.

SUMNER GROUP—WELLINGTON FORMATION

The Summer group is the uppermost group of Permian age in Morris County. The only formation of the Summer group present in the county is the Wellington formation (pl. 2), which crops out only in the southwestern part of the county. The part of this formation exposed in Morris County is composed mainly of tan-gray to gray-green shale, which is generally silty and thin bedded. A bed of limestone, 4 to 7 feet thick, is included in this formation and caps many of the hills in the outcrop area. This limestone has been called locally the Hollenberg limestone bed and it is generally hard, gray to gray brown, and has a somewhat crystalline texture. It is massive, but weathers blocky and porous to cavernous. Plates, nodules, and concretions of iron oxide (limonite) are present in the uppermost zone of the Hollenberg limestone bed in the NE¼SE¼ sec. 6, T. 17 S., R. 5 E., and many clay nodules and iron stains are found in some exposures. Additional thin limestone beds are interbedded in the shale in the lower part of the formation. No fossils were observed in any of the beds. The formation averages 30 feet in thickness. (See measured section 3.)

The Wellington formation is best identified by its position above the easily recognized Nolans limestone. The color and weathering characteristics of the Hollenberg limestone bed aid in its identification.

QUATERNARY SYSTEM

The most recently deposited sediments in Morris County are those of the Quaternary system (pl. 2), nearly all of which are unconsolidated. These sediments of nonmarine origin were deposited by wind, streams, slopewash, or by soil-mantle creep. Material deposited by the wind occurs on the interstream areas, including the broad, relatively flat uplands and along the sides of some valleys. Stream-deposited sediments are present along all of the major streams and their tributaries and are mostly restricted to the valley flats, but may also occur at higher levels on the valley walls of some of the larger streams. The materials which were deposited by soil-mantle creep or slopewash are present along the sides of most of the valleys and on some of the rock benches.

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SANBORN FORMATION

AREAL DISTRIBUTION

The Sanborn formation of Pleistocene and Recent(?) age is the most widely distributed stratigraphic unit that crops out in Morris County. (See pls. 1 and 2.) Frye and Fent (1947) have subdivided the formation into members, but this subdivision is not justified in a construction-materials inventory because the physical characteristics of the materials in separate units are not markedly dissimilar. The Sanborn formation, therefore, is treated as a single unit in this report.

As here defined, the Sanborn formation consists of materials deposited by wind (loess), by slopewash, by streams, and through the action of soil or mantle creep (colluvium). This formation consists of loess on the crests of the lower interstream areas and on the high upland flats; of slopewash, colluvium, and older terrace materials along the margins of the terraces of the major streams and in the valleys of their tributaries; and of loess and colluvium on limestone benches at various levels above the streams. Deposits of loess are most extensive in the vicinity of Dwight and White City, and in the central and southwestern parts of the county.

GENERAL DESCRIPTION

The loess of the Sanborn formation is gray, gray brown, or red brown and is composed of silt- and clay-size particles. Clay-size particles are the principal constituent of these deposits. The part of the Sanborn formation moved by slopewash and mantle creep is a heterogeneous mixture of silt, clay, and granule- to boulder-size angular fragments of chert, limestone, and shale. The silt and clay are commonly red brown but may be gray or gray brown. The stream-deposited material included in the Sanborn formation is composed of gray to red-brown silt and clay, with numerous interbedded lenses of angular and subangular particles of chert and limestone in the basal part.

Extensive deposits of chert gravel occur in the Sanborn formation, such as those along the north side of Indian Creek, the north side of Four Mile Creek and the west side of its tributaries, the west side of Rock and East Fork Creeks, and along streams tributary to the upper part of the Neosho River. They are composed of angular and subangular particules of chert, that differ in size from granules to cobbles; pebble-size particles are the most abundant. The matrix of silt and clay in which the gravel is embedded is generally red brown. Some of the chert gravels are at a higher level than most of the others, such as those in secs. 18 and 19, T. 17 S., R. 8 E., and appear to be older inasmuch as many of the fragments of chert are considerably weathered to tripoli. These may correspond in age to the Tertiary chert gravels reported in south-central Kansas by Moore, Frye, and Jewett (1944). Siliceous nodules are present in some of the chert deposits in the southwestern part of the county.

The Sanborn formation averages about 15 feet thick; it ranges from a few inches in some places to a maximum of 50 feet in thickness in the northern part of the county. (For a detailed description of the Sanborn formation, see measured section 2.)

TERRACE DEPOSITS

AREAL DISTRIBUTION

Terrace deposits of Quaternary age are composed of materials laid down by present-day streams in earlier cycles of deposition. They are mapped in the valleys of most streams in Morris County. (See pls. 1 and 2.) Two terrace levels were observed in some places along the Neosho River and Rock Creek. The upper contact of this material is not well defined and it grades into the lower part of the Sanborn formation; this terrace level, therefore, was mapped with the Sanborn formation. The average width of the terrace deposits along the Neosho River is 1 mile. The width of the terraces of Rock and East Fork Creeks does not exceed a mile, and terraces of the other streams are not more than one-half mile wide.

GENERAL DESCRIPTION

The terrace deposits consist largely of gray to brown silt- and clay-size particles, but contain some lenses of chert and limestone gravel. Vertical banks are characteristic of terrace sediments, and they show crude columnar jointing. The lenses of gravel are composed of granules and pebbles of subgranular chert and, less abundantly, subangular to rounded fragments of limestone, occur in the lower part of a deposit. (For a detailed description, see measured section 1.) The terraces above stream level range from a few feet along small streams to 50 feet or more in thickness along the Neosho River. The exact thickness of the terrace deposits could not be determined without drill-hole data.

ALLUVIUM

AREAL DISTRIBUTION

The sediment deposited by a stream on its present flood plain is alluvium. (See pl. 2.) Alluvium is mapped along the Neosho River and averages about 0.3 mile in width. The alluvium extends from the southeast corner of the county to a point 2 miles south of Council Grove. The straightening of the Neosho River and the presence of dikes prevent deposition of alluvium in the vicinity of Council Grove.

TABLE 1.—*Summary of tests on construction*

Location: All township designations are south and all range designations are east throughout table.
Authority for test data: HC, State Highway Commission of Kansas. GS, sample collection and
Accessibility to all sites is good except for ls 15 which is fair.

Number on plate 1	Location	Estimated amount of material (cubic yards)	Thickness (feet)		Geologic unit	Authority for test data	Date of test
			Material (average)	Overburden (maximum)			
Chert gravel [1]							
cg 1	SE¼SE¼ sec. 31, T. 14 S., R. 9 E.	5,000	5	0	Terrace deposit	GS	Sept. 1948
cg 2	SE¼SE¼ sec. 13, T. 16 S., R. 7 E.	1,000	2	3	Sanborn	GS	Sept. 1948
cg 3	NE¼NE¼ sec. 3, T. 17 S., R. 9 E.	15,000	6	0	Sanborn	GS	Sept. 1948
Limestone							
ls 1	NE¼NW¼ sec. 33, T. 14 S., R. 8 E.	20,000	9	5	Fort Riley	GS	Sept. 1948
ls 2	NE¼SE¼ sec. 21, T. 14 S., R. 7 E.	10,000	5	10	Fort Riley	GS	Sept. 1948
ls 3	NW¼NW¼ sec. 13, T. 14 S., R. 5 E.	10,000	10	5	Towanda	GS	Sept. 1948
ls 4	NE¼NW¼ sec. 1, T. 15 S., R. 8 E.	20,000	8	5	Florence	GS	Sept. 1948
ls 5	SW¼SW¼ sec. 23, T. 15 S., R. 8 E.	10,000	2.5	6	Schroyer	HC	Aug. 1935
ls 6	NE¼SW¼ sec. 26, T. 15 S., R. 8 E.	1,000	2	4	Kinney	GS	Sept. 1948
ls 7	SW¼SW¼ sec. 30, T. 15 S., R. 8 E.	5,000	6	5	Threemile	GS	Sept. 1948
ls 8	SE¼SW¼ sec. 11, T. 15 S., R. 6 E.	20,000	10	3	Towanda	HC	Mar. 1935
ls 9	SE¼SW¼ sec. 26, T. 15 S., R. 5 E.	10,000	4	5	Cresswell	GS	Sept. 1948
ls 10	SW¼SE¼ sec. 28, T. 15 S., R. 5 E.	10,000	3	5	Herington	GS	Sept. 1948
ls 11	NW¼NW¼ sec. 17, T. 16 S., R. 9 E.	1,700	5	8	Threemile	HC	Aug. 1935
ls 12	NW¼NW¼ sec. 18, T. 16 S., R. 9 E.	27,000	5	6	Threemile (Ledge No. 1)	HC	Dec. 1945
					Threemile (Ledge No. 2)	HC	Dec. 1945
ls 13	NW¼NE¼ sec. 26, T. 16 S., R. 9 E.	10,000	6	5	Cottonwood	GS	Sept. 1948
ls 14	NE¼NE¼ sec. 33, T. 16 S., R. 9 E.	5,000	1.5	5	Middleburg	GS	Sept. 1948
ls 15	NE¼NW¼ sec. 11, T. 16 S., R. 8 E.	50,000	20	2	Threemile	GS	Sept. 1948
ls 16	SE¼NW¼ sec. 18, T. 16 S., R. 8 E.	25,000	5	5	Fort Riley	HC	Jan. 1935
ls 17	SE¼NE¼ sec. 23, T. 16 S., R. 8 E.	3,000	5	4	Threemile	HC	Mar. 1938
ls 18	NW¼SE¼ sec. 23, T. 16 S., R. 8 E.	5,000	6	10	Funston	HC	Jan. 1946
ls 19	SE¼NE¼ sec. 27, T. 16 S., R. 8 E.	5,000	3	5	Schroyer	GS	Sept. 1948

[1] Gradation factor for cg 1, 5.89; cg 2, 4.12; cg 3, 5.38.

materials of Morris County, Kansas

description of material by U. S. Geological Survey; laboratory tests by State Highway Commission.

Description of materials	Laboratory test data					
	Water absorbed (percent)	Specific gravity (dry)	Los Angeles (percent loss)	Soundness (25 cycles)	Toughness	Laboratory No.
Chert gravel [1]						
Sieve analysis: Percent on ¾ in. 24; ⅜ in. 49; no. 4, 69; no. 16, 86; no. 100, 92; percent passed no. 200 (wash), 7.48.	-------	2.32	-------	0.89	----	60552
Sieve analysis: Percent on ¾ in. 25; ⅜ in. 36; no. 4, 46; no. 16, 59; no. 100, 63; percent passed no. 200 (wash), 36.24.	-------	2.12	-------	0.99	----	6C561
Sieve analysis: Percent on ¾ in. 39; ⅜ in. 55; no. 4, 65; no. 16, 73; no. 100, 76; percent passed no. 200 (wash), 23.53. Mostly flint pebbles, but some limestone pebbles, in a matrix of clayey silt.	-------	2.34	-------	0.93	----	60543
Limestone						
Hard platy tan limestone	-------	2.46	36.5	0.90	----	60548
Massive yellow-gray fossilifeous limestone	9.61	1.96	43.2	0.97	----	60542
Platy yellow-gray limestone; includes porous zones	2.07	2.46	34.0	0.97	----	60559
Massive gray limestone; includes several thin bands of chert.	9.81	2.07	39.6	0.85	----	60544
Massive light-gray limestone. Rejected because of excessive wear, 7.3 percent (Deval).	2.22	2.47	-------	Sound	5	2646
Hard massive crystalline gray limestone	4.04	2.46	30.4	0.97	----	60549
Blocky light-gray limestone; includes nodules of flint in some zones but not in this. Nonflinty ledge near top of member.	11.25	2.01	62.9	0.96	----	60560
Gray light-brown and red granular porous limestone. Rejected for use as surfacing material because of excessive wear, 8.0 percent (Deval).	2.9	2.02	-------	Sound	4	25355
Blocky light-gray fossiliferous limestone	2.96	2.40	31.2	0.95	----	60557
Soft powdery yellowish limestone; somewhat porous and contains numerous geodes.	13.38	1.88	8.86	0.92	----	60558
Light-yellow limestone which contains 10–15 percent flint. Rejected for use as surfacing material because of excessive wear, 5.6 percent (Deval).	5.79	2.23	-------	Not sound	7	26465
Light-yellow porous limestone. Rejected under secs. 107–112, and 114, standard specifications, 1945 ed.	10.54	1.88	72.1	0.97	----	49152
White somewhat crystalline limestone. Accepted under secs. 107, 108, and 114, standard specifications, 1945 ed.	9.87	2.02	46.3	0.93	----	49153
Hard massive light-yellow-gray limestone; somewhat porous.	-------	2.26	36.6	0.92	----	60545
Blocky crystalline light-yellow and gray limestone	5.51	2.25	39.8	0.95	----	60556
Massive tan-gray limestone; contains a few nodules of blue-gray flint.	15.7	1.94	61.8	0.94	----	60551
Massive light-yellow-gray limestone; contains numerous solution channels. Wear = 11.4 percent; rejected under sec. 60, standard specifications, 1934 ed.	7.7	1.94	-------	Sound	4	24720
Soft light-yellow and brown limestone. Accepted for use as surfacing material; percentage of wear = 14.75.	9.0	2.02	-------	-------------	5	34042
Massive crystalline light-gray limestone. Accepted under secs. 107–112, and 114, standard specifications, 1945 ed.	-------	2.38	34.7	0.96	----	491
Massive porous light-gray limestone. Samples taken from nonflinty zone near top of member.	4.68	2.32	32.6	0.96	----	605

TABLE 1.—*Summary of tests on construction*

Number on plate 1	Location	Estimated amount of material (cubic yards)	Thickness (feet)		Geologic unit	Authority for test data	Date of test
			Material (average)	Overburden (maximum)			
Limestone—Continued							
ls 20	NE¼NE¼ sec. 36, T. 16 S., R. 7 E.	20,000	10	5	Fort Riley (Ledge No. 1)	HC	Dec. 1945
					Fort Riley (Ledge No. 2)	HC	Dec. 1945
ls 21	SW¼NW¼ sec. 11, T. 16 S., R. 5 E.	10,000	3	2	Herington	HC	Jan. 1935
ls 22	NE¼NE¼ sec. 12, T. 16 S., R. 5 E.	50,000	12	6	Cresswell	HC	May 1950
ls 23	SW¼SE¼ sec. 19, T. 16 S., R. 5 E.	150,000	10	6	Herington	HC	Nov. 1934
ls 24	SE¼SW¼ sec. 12, T. 17 S., R. 9 E.	15,000	7	4	Neva	GS	Sept. 1948
ls 25	NW¼NW¼ sec. 22, T. 17 S., R. 9 E.	5,000	4	5	Crouse	GS	Sept. 1948
ls 26	NW¼NW¼ sec. 25, T. 17 S., R. 9 E.	5,000	5	2	Burr	GS	Sept. 1948
ls 27	SE¼NE¼ sec. 28, T. 17 S., R. 9 E.	5,000	4	5	Morrill	GS	Sept. 1948
ls 28	C ¼SE¼ sec. 17, T. 17 S., R. 6 E.	50,000	10	5	Florence	HC	Apr. 1950
ls 29	NE¼NE¼ sec. 26, T. 17 S., R. 6 E.	2,000	5	2	Threemile	HC	Feb. 1946
ls 30	NE¼NW¼ sec. 5, T. 17 S., R. 5 E.	5,000	3	5	Wellington	GS	Sept. 1948

Small areas of alluvium are present north of Council Grove but are not of sufficient extent to be mapped. The alluvium of Rock Creek is present only on the inner curves of meanders and has a maximum width of about 0.3 mile. It extends from the Neosho River north to U. S. Highway 56. Deposits of alluvium too small to be mapped are also present along the other major streams in the county.

GENERAL DESCRIPTION

The alluvium along the Neosho River consists predominantly of silt and clay with interbedded thin lentils of gravel. The silt and clay are gray brown to gray. The gravel lentils contain mostly subrounded and round pebbles of local limestone and small percentages of clay and silt.

The alluvium along Rock Creek and other streams consists of gray-brown silt and clay and many gravel lenses. These lenses contain subangular to angular particles of local limestone and chert, and small quantities of shale, silt, and clay.

materials of Morris County, Kansas—Continued

Description of materials	Laboratory test data					
	Water absorbed (percent)	Specific gravity (dry)	Los Angeles (percent loss)	Soundness (25 cycles)	Toughness	Laboratory No.
Limestone—Continued						
Light-yellow and white limestone; some zones porous. Accepted under secs. 107, 108, and 114, standard specifications, 1945 ed.	10.33	2.02	50.0	0.97	----	49150
Fine-grained gray and light-gray limestone. Accepted under secs. 107-112, and 114, standard specifications, 1945 ed.	2.86	2.47	34.6	0.96	----	49151
Soft yellow-gray limestone streaked with harder layers of gray limestone. Percentage of wear = 9.3; rejected for use as cover stone under sec. 60, standard specifications, 1934 ed.	3.2	2.45	-------	-------------	3	24721
Light yellow-gray fine-grained limestone. Accepted under supplemental specification 45-407 and secs. 108 and 114, standard specifications, 1945 ed.	5.27	2.36	49.0	0.97	----	67597
Dense light-yellow limestone. Percentage of wear = 10.4; rejected for use in experimental matt surfacing.	6.4	2.23	-------	Sound	3	24485
Hard platy yellow-gray limestone	5.09	2.19	42.6	0.89	----	60546
Dense blocky light-gray limestone	9.22	2.14	41.1	0.97	----	60553
Dense hard massive gray and yellow limestone	-------	2.40	34.0	0.91	----	60547
Blocky somewhat porous yellow limestone	-------	2.30	38.0	0.97	----	60555
Flinty light-yellow limestone. Unsound, rejected under supplemental specification 45-407 and secs. 108, 109, 111, and 114, excessive wear under secs. 109-112, standard specifications, 1945 ed.	8.02	2.17	46.2	0.84	----	67280
Porous light-yellow-gray limestone. Accepted for use in grading and construction of rock embankment.	-------	-------	-------	Sound	10	50077
Platy crystalline yellow limestone	1.28	2.58	40.0	0.94	----	60554

Bars of gravel are abundant in the beds of almost all the streams, and consist mostly of particles of chert but contain some fragments of limestone and shale. The particles range in size from granules to boulders, with those of pebble size the most abundant. The maximum estimated thickness of alluvium along the Neosho River is 30 feet. In the valleys of the other streams in the county, it is about 20 feet thick.

INVENTORY OF CONSTRUCTION MATERIALS

This inventory of construction materials in Morris County defines the construction materials as they are classified in this report, and relates the materials to the map units in which they occur. Where available, laboratory test data have been included to aid the reader in an evaluation of the materials. The information given in table 1 is based on standard testing procedures of the State Highway Commission of Kansas (1945), and the American Association of State Highway Officials (1947). It is expected that prospects shown on plate 1 will be proved by subsequent augering, drilling, or test pitting and that the materials themselves will be subjected to laboratory testing prior to production for specific uses.

Although many prospect pits and quarries were located, no attempt was made to complete a survey of all possible sources of materials. In relating the construction materials that are available in Morris County to the geologic formations mapped on plate 1, the use of the map should aid in the search for the materials needed in a construction project.

AGGREGATE FOR CONCRETE

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Aggregate for concrete is classified as fine aggregate, mixed aggregate, and coarse aggregate. In this report the distinction is an arbitrary one based on the percentage of material retained on a standard No. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. Material is classified as coarse aggregate if the coarse fraction is 15 percent or more by weight of the whole sample, as mixed aggregate if the coarse fraction is between 5 and 14 percent, and as fine aggregate if the coarse fraction is less than 5 percent.

The materials reported in this and other classifications are exposed at the surface or are under soft or unconsolidated overburden sufficiently thin that they may be developed. Deposits that are overlain by thick or consolidated beds, or that are relatively inaccessible, usually are not included in this inventory because of the additional expense involved in their removal or transportation.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

No deposits of sand and gravelly sand were found in Morris County. Almost all of the aggregate used in concrete construction in the county is obtained from the alluvium of the Kansas River in the vicinity of Junction City. Loess is considered by Plummer and Hladik (1948, p. 27–111) to be of prime importance as raw material for the manufacture of ceramic slag and for railroad ballast and concrete aggregate. They report that tests of ceramic slag by the road-materials laboratory of the State Highway Commission of Kansas indicate that it is a superior aggregate with a low density.

Four of the limestones included in table 1 were accepted by the State Highway Commission as rock to be crushed for the coarse fraction in aggregate for concrete. Numbers after the unit names in the following discussion have been assigned to the tested materials, which are designated by these numbers in table 1 and plate 1. These are the middle part of the Threemile limestone member of the Wreford limestone (ls 17), the Funston limestone (ls 18), the rimrock and the next overlying bed of the Fort Riley limestone member of the Barneston limestone (ls 2 and ls 20), and the Cresswell limestone member of the Winfield limestone (ls 9 and ls 22).

Other possible sources of limestone which might be used as the coarse fraction in aggregate for concrete are the Towanda limestone member of the Doyle shale (ls 3), the Kinney limestone member of the Matfield shale (ls 6), the Middleburg limestone member of the Bader limestone (ls 14), the upper part of the Schroyer limestone member of the Wreford limestone (ls 19), the Crouse limestone (ls 25), the Morrill limestone (ls 27) and the Cottonwood limestone (ls 13) members of the Beattie limestone, and the Hollenberg limestone bed (of local usage) of the Wellington formation (ls 30).

MINERAL FILLER

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Material composed predominantly of silt-size mineral particles (in which 50 percent or more of the material passes the No. 200 sieve) is classified in this report as mineral filler. It has no more than a trace of organic debris, but may contain minor amounts of fine sand or clay. 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.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

No samples of material to be tested as mineral filler were collected inasmuch as all of the possible sources investigated contain such a high percentage of clay that the coefficient of cementation would be too high for acceptance.

An intensive search of the terrace deposits should reveal small quantities of acceptable mineral filler. It is doubtful that the Sanborn formation contains material that is acceptable for this use.

RIPRAP

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Riprap is any rock material suitable for protecting earthen fills from erosion. To be acceptable for this use the material must be relatively sound and free from cracks and other structural defects or impurities that would cause it to disintegrate through erosion, slaking, or freezing and thawing. It is desirable that the material be producible in blocks having approximately rectangular faces 7 inches or more in width and that the specific gravity be 2 or higher.

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STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

The limestone beds of the Permian system are the only sources of riprap known to be present in Morris County. Acceptable rock can be obtained from the stratigraphic units evaluated in the following discussion.

The noncherty layer of the Threemile limestone member of the Wreford limestone (ls 20) has been accepted for use as riprap by the State Highway Commission. Other possible sources are the Kinney limestone member of the Matfield shale (ls 6), the Cresswell limestone member of the Winfield limestone (ls 9 and ls 22), the Cottonwood limestone member of Beattie limestone (ls 13), the Middleburg limestone member of the Bader limestone (ls 14), the Funston limestone (ls 18), the upper part of the Schroyer limestone member of the Wreford limestone (ls 19), and the rimrock bed of the Fort Riley limestone member of the Barneston limestone (ls 20).

Test data for the Towanda limestone member of the Doyle shale (ls 3) indicate that it would fulfill the requirements for riprap, but field observation reveals that it fractures into small blocks too readily.

Rock from the Funston limestone and the massive beds of the Crouse limestone was installed as riprap on the upstream face of the dam at Lake Kahola. The bed of noncherty limestone in the Threemile member was the source of riprap placed along the Neosho River in Council Grove. The rimrock bed of the Fort Riley and the noncherty beds of the Florence limestone members of the Barneston limestone were used as riprap on the dam at Lake Council Grove. A small pond in the center of the NE¼ sec. 8, T. 15 S., R. 8 E. was riprapped with limestone from the Fort Riley member. A pond in the center of the NE¼ sec. 13, T. 16 S., R. 9 E., was riprapped with limestone from the Threemile member. The Funston and Crouse limestones and the Middleburg and Cottonwood members of the Beattie limestone were the sources of rock used on a railway fill in the SE¼ sec. 35, T. 16 S., R. 9 E.

STRUCTURAL STONE

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Structural stone is any hard, dense rock 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.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

Many limestone beds of the Permian system cropping out in the county have been used as structural stone, their use having been governed principally by the accessiblility of quarries. Use of the following limestones as structural stone was observed.

Cresswell limestone member of the Winfield limestone.—This rock was used in the construction of a house and barn in the NE¼NE¼ sec. 34, T. 15 S., R. 5 E.

Fort Riley limestone member of the Barneston limestone.—Rimrock was used as structural stone in the courthouse in Council Grove. The stone has weathered only slightly, although some of the blocks have changed in color to dark gray or yellow brown. Stone from this member was also used in the construction of the stadium and a fence in the park at Council Grove, and of a single-arch bridge in the NE¼ SE¼ sec. 26, T. 14 S., R. 7 E.

Threemile limestone member of the Wreford limestone.—This rock has been used in foundations and buildings in Council Grove. It. was also used in a retaining wall in the NE¼ sec. 10, T. 16 S., R. 8 E and in a house in the SE¼SE¼ sec. 7, T. 16 S., R. 9 E. The stone in these structures shows very little deterioration through weathering.

Cottonwood limestone member of the Beattie limestone.—This stone has been used extensively in the construction of buildings in Dunlap. The limestone shows slight weathering changes, including a darkening of the original gray.

ROAD METAL

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Road metal, known also as surfacing material, base-course material, crushed stone, and aggregate, is material that may be applied to a road to improve the performance characteristics of that road and to insure an all-weather surface. Many geologic materials fulfill this requirement, and the list of such materials varies from one area to another.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

Mixed aggregate from the Kansas River is used as metal on all State highways except the part of Kansas Highway 13 that has been constructed as a bituminous mat. It also has been placed on farm-to-market roads west of Burdick, south of Parkerville, south of Dwight, and on streets in White City, Dwight, Dunlap, Wesley, and Burdick.

Chert gravel is used extensively in eastern Kansas as metal on light-traffic roads. As defined in this report, it 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, incorporated in a matrix of clay- and silt-size particles. This material may also contain subrounded to rounded gravel-size fragments of local limestones.

Chert gravel from the Sanborn formation and terrace deposits, and creek gravel, have been used in large quantities as metal for light-traffic roads. The performance of these gravels is generally good. The material from the Sanborn formation is best for road metal inasmuch as it contains a clay binder and the particles do not exceed pebble size. Creek gravel is least desirable because of the wide range in the size of the gravel particles, the absence of a clay binder, and the difficulty in gaining access to deposits of it.

Alluvium.—Test data for a sample of chert gravel (cg 1) are given in table 1. This material came from a creek bed and is known locally as "creek gravel." (Because of the scale of plate 1, it was necessary to map this source as a terrace deposit.) About 80 percent of the particles are chert and 10 percent are limestone and shale. In comparison with other gravels, this material is unusually coarse, although it contains a small percentage of wash. There are similar small deposits along most of the tributaries of the Neosho River and Rock, Clarks, and Diamond Creeks.

Sanborn formation.—Two samples of chert gravel (cg 2 and cg 3) were obtained from the Sanborn formation. (See table 1 and pl. 1.) Both of these gravels are composed of sound and relatively coarse particles, but they contain a large percentage of wash. The gravels are predominantly fragments of chert and do not exceed pebble size. The wash is red-brown clay and silt.

Similar deposits can be found north of Indian Creek, along Four Mile Creek and its tributaries, along Haun and Crooked Creeks, in the interstream areas southeast of Wilsey, and along the eastern tributaries of Diamond Creek. Most of the gravel deposits occur in the basal part of the Sanborn formation in these areas.

Several of the limestones and one of the shales cropping out in Morris County have been crushed and used as road metal.

Wellington formation.—Rock from this formation was used in the construction of roads along the west and south boundaries of sec. 32, T. 16 S., R. 5 E. A thickness of 5 to 6 inches of shale is placed on the road and graded and rolled to form a self-bonding type of macadam. This material, according to local residents, makes a good road as it is not excessively dusty and is not slick when wet. The Wellington is composed predominantly of silty and calcareous shales. Other similar shales in the Permian system might also prove acceptable for a similar use.

Cresswell limestone member of the Winfield limestone.—This rock has been quarried extensively in the NE¼NE¼ sec. 12, T. 16 S., R. 5 E. and used as road metal and for the coarse fraction in aggregate for concrete at the Herington Airbase. Crushed rock from this quarry is now being used on nearby farm-to-market and land-access roads.

Fort Riley limestone member of the Barneston limestone.—Large quantities of limestone from the Fort Riley have been quarried in the SE¼NE¼NE¼ sec. 36, T. 16 S., R. 7 E. The crushed rock from this quarry has been used as ballast along the Missouri Pacific Railroad and in the construction of a stabilized base for many of the roadways in the Herington Airbase. It was also used as road metal on some of the nearby farm-access roads. Rock obtained from a large quarry in the NW¼SW¼ sec. 14, T. 14 S., R. 7 E. was used as ballast on the Chicago Rock Island and Pacific, and Union Pacific Railroads.

Florence limestone member of the Barneston limestone.—In 1949 the noncherty beds of limestone of the Florence were crushed at a quarry in the center of the SE¼ sec. 17, T. 17 S., R. 6 E. This material was used as road metal on farm-to-market and land-access roads in that vicinity.

Threemile limestone member of the Wreford limestone.—In 1949 a large quarry in the biostrome of the Threemile limestone member was operated in the NW¼NE¼ sec. 10, T. 16 S., R. 8 E. Material from this and other quarries in the Threemile in the vicinity of Council Grove has been used as riprap, structural stone, as the coarse fraction in aggregate for concrete, and as crushed rock for base-course constructional on part of U. S. Highway 56. It is also used as metal on many of the farm-to-market and land-access roads in the area.

SUBGRADE AND EMBANKMENT MATERIAL

ENGINEERING AND GEOLOGIC CHARACTERISTICS

The following definition of subgrade and embankment material is adapted from the specifications compiled by the American Association of State Highway Officials (1937, p. 37–38). Suitable geologic materials for this kind of construction are: (1) fine granular unconsolidated sediments, including soil, of which 50 percent or more of weight passes through a No. 200 sieve; (2) 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; (3) broken or crushed rock.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

All of the preceding materials listed are available in Morris County for the construction of subgrades and embankments and can be obtained as the product of excavation along a project or from immediately adjacent areas. The geologic formations from which these materials can be produced are: (1) Fine granular sediments. The Sanborn formation and terrace deposits contain almost unlimited quantities of clayey silt. (2) Coarse granular sediments. The alluvium in the valleys of most of the streams in the county contains small quantities of limestone and chert gravel. (3) Broken or crushed rock. Most limestones of the Permian system are durable and resist crumbling and solution; they are thus acceptable for use in the construction of subgrades and embankments.

The shales of the Permian system vary greatly in their physical characteristics. The Matfield, Speiser, and Easly Creek shales have been used in the construction of embankments. These shales are predominantly silty and calcareous; other silty shales which might prove acceptable for this use are:

Wellington formation.
Odell shale.
Grant shale member of the Winfield limestone.
Oketo shale member of the Barneston limestone.
Wymore shale member of the Matfield shale.
Havensville shale member of the Wreford limestone.
Hooser shale member of the Bader limestone.
Stearns shale.
Salem Point shale member of the Grenola limestone.
Bennett shale member of the Red Eagle limestone.
Johnson shale.

The shales which are predominantly clay and are possibly usable for that reason are:

Paddock shale member of the Nolans limestone.
Gage shale member of the Doyle shale (Clayey in upper part, silty in lower part).
Holmesville shale member of the Doyle shale (Clayey in upper part, silty in lower part).
Paddock shale member of the Nolans limestone.
Gage shale member of the Doyle shale (Clayey in upper part, silty in lower part).
Holmesville shale member of the Doyle shale (Clayey in upper part, silty in lower part).
Blue Springs shale member of the Matfield shale (Clayey in upper part, silty in lower part but has been used in some construction).
Speiser shale. (Interbedded silty and clayey zones; however, this material has been used in some construction).
Blue Rapids shale (Interbedded silty and clayey zones).
Florena shale member of the Beattie limestone (Silty in upper part, clayey in lower part).
Eskridge shale.
Roca shale.

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STRATIGRAPHIC SECTIONS

The following stratigraphic sections include at least one of each geologic formation or member (except the Burr limestone and Legion shale members of the Grenola limestone) that crops out in Morris County. All sections were measured by the authors.

1. *Terrace deposit in SE¼NW¼ sec. 11, T. 16 S., R. 8 E.*

Soil; silt with some clay, dark gray (2± feet).	
Quaternary terrace deposit:	*Feet*
3. Silt, dark-gray; stands in vertical bank and shows crude columar structure	6. 0
2. Silt, blocky, tan-brown; shows columar structure and some stratification	15. 9
1. Silt, brown; numerous interbedded lenses of gravel composed of fragments of chert and limestone	2. 0
Thickness exposed	23. 9
Based covered.	

2. *Road cut in the NW¼NW¼ sec. 21, T. 14 S., R. 6 E.*

Soil, black, granular (1.0 foot).	
Sanborn formation:	*Feet*
3. Silt, clayey, blocky, dark-brown; some calcareous concretions	4. 6
2. Silt, blocky, reddish-brown; some gravel-size fragments of limestone and chert	3. 0
1. Silt, reddish-brown; numerous gravel-size fragments of limestone and chert	3. 0
Thickness exposed	10. 6
Base covered.	

3. *Road cut in the NE¼NW¼ sec. 5, T. 17 S., R. 5 E.*

	Feet
Soil, silty, black; contains fragments of limestone (1.0 foot).	
Wellington formation:	
12. Limestone, somewhat sandy, soft, thin-bedded, gray; part of the Hollenberg bed (of local usage)	1.0
11. Limestone, crystalline, blocky, gray, some limonite stains, base of the Hollenberg bed (of local usage)	.5
10. Shale, silty, calcareous, granular; tan with some white streaks	2.2
9. Limestone, clayey, tan; weathers thin bedded	.2
8. Shale, clayey, calcareous, blocky, light-gray; weathers gray	1.4
7. Shale, silty, calcareous, blocky, tan	.3
6. Shale, silty, calcareous, blocky, gray-green	2.6
5. Covered interval	4.0
4. Limestone, hard, crystalline, blocky, light-gray; weathers gray	.5
3. Shale, silty, calcareous, blocky, gray-green	.3
2. Covered interval	1.9
1. Limestone, soft, chalky, blocky, gray; weathers light gray	.6
Thickness exposed	15.5

Base covered.

4. *Road cut in the NW¼NE¼ sec. 31, T. 16 S., R. 5 E.*

	Feet
Soil, clay, silty, dark-gray; weathered limestone in lower part; about 3 feet thick.	
Nolans limestone:	
Herington limestone member:	
6. Limestone, medium-hard, massive, gray-brown; dense in part; weathers tan gray and blocky to nodular; some iron stains; fossil fragments abundant	4.3
5. Limestone, hard, massive, light-gray; weathers tan gray and blocky; some limonite stains and calcite-lined cavities; fossils common	1.9
Thickness exposed	6.2
Paddock shale member:	
4. Shale, clayey, noncalcareous, blocky, tan-gray; some iron stains	15.3
3. Limestone, hard, dolomitic, massive, gray-brown; weathers tan gray and blocky; some limonite stains	.3
Covered interval	2.0
Thickness exposed	17.6
Krider limestone member:	
2. Limestone, hard, somewhat crystalline, massive, tan-gray; weathers blocky; some iron stains; some pelecypods	1.4
Total thickness of Nolans limestone exposed	25.2
Odell shale:	
1. Shale, silty, calcareous, thin-bedded to blocky, gray-green; calcareous zones in middle part; some limonite stains	4.0

Base covered.

5. *Railway cut in the NW¼NW¼ sec. 31, T. 15 S., R. 5 E.*

Soil; silty, reddish-brown, granular (3.0 feet).

	Feet
Nolans limestone:	
Herington limestone member:	
14. Limestone, soft, massive, tan; weathers tan gray and blocky; many vertical joints; weathered surface pitted; calcite-filled cavities	2.0
13. Limestone, medium-hard, massive, tan; weathers platy and tan gray	2.0
12. Limestone, medium-hard, massive, tan-gray; weathers tan and blocky; iron stains on surface	1.6
Thickness exposed	5.6
Paddock shale member:	
11. Shale, silty, noncalcareous, blocky, gray-green; weathers tan gray	1.0
10. Shale, silty, very calcareous, thin-bedded, tan-gray mottled with blue-gray; many calcareous lenses; very fossiliferous	1.8
9. Shale, clayey, calcareous, blocky, tan-gray; weathers gray	4.3
8. Shale, silty, very calcareous, thin-bedded, gray, lenticular; very fossiliferous	.2
7. Shale, silty, calcareous, thin-bedded, tan-gray to gray-green, fossiliferous	2.9
6. Shale, silty, calcareous, thin-bedded, dark-gray to gray-green; some limonite stains	2.3
5. Shale, silty, calcareous, thin-bedded, dark-gray	.3
4. Limestone, hard, dark-gray; weathers blocky; fossils common	.6
3. Shale, silty, calcareous, thin-bedded, olive-drab mottled with gray; very fossiliferous in upper part	1.6
2. Shale, silty, calcareous, thin-bedded, gray-green to gray	.9
Thickness exposed	15.9
Krider limestone member:	
1. Limestone, hard, gray; weathers tan and blocky; fossils abundant, especially pelecypods	.8
Total thickness of Nolans limestone exposed	22 3

Base covered.

6. *Streambank in the NW¼NW¼ sec, 29, T. 16 S., R. 5 E.*

Soil: silty, dark-gray; fragments of weathered limestone (1.0± foot).

	Feet
Nolans limestone:	
Krider limestone member:	
5. Limestone, soft, blocky, tan; weathers gray	1.0
Odell shale:	
4. Shale, silty, calcareous, granular, gray-green	0.7
3. Shale, silty, very calcareous, blocky, gray-green	.1
2. Shale, silty, calcareous, blocky, gray-green	3.8
1. Shale, silty, calcareous, blocky, maroon	3.9
Thickness exposed	8.5

Base covered.

7. *Quarry in the NE¼NE¼ sec. 12, T. 16 S., R. 5 E.*

Soil, silty, gray-brown; some limonite fragments (2± feet).
Winfield limestone member:

	Feet
Cresswell limestone member:	
2. Limestone, medium-hard, massive, light-gray; weathers blocky in the lower part and platy in the upper part; geodes abundant and contain chalcedony and crystals of calcite	6.2
1. Limestone, hard, massive, blue-gray; weathers tan and to large blocks; contains siliceous nodules 1 to 3 inches in diameter	4.6
Thickness exposed	10.8

Base covered.

8. *Road cut in the SE¼SE¼ sec. 31, T. 14 S., R. 5 E.*

Soil; silty, dark-gray; fragments of weathered limestone (0.5 foot).
Winfield limestone:

	Feet
Cresswell limestone member:	
2. Limestone, medium-hard, massive, tan-gray; weathers to irregularly shaped blocks, some lenses of chert; echinoid spines abundant, other fossils common	4.6
Grant shale member:	
1. Shale, clayey, calcareous, thin-bedded, gray, fossiliferous. Exposed	11.1
Total thickness of Winfield limestone exposed	15.7

Base covered.

9. *Streambank in the SE¼SE¼ sec. 14, T. 17 S., R. 5 E.*

Winfield limestone:

	Feet
Grant shale member:	
2. Shale, silty, calcareous, thin-bedded to blocky, tan-gray; weathers tan; contains numerous calcite-filled geodes and some filled with chalcedony and quartz; fossils rare	6±
Stovall limestone member:	
1. Limestone, hard, massive, tan-gray; weathers tan and blocky, 3 chert lenses, each 0.3 to 0.5 foot thick; chert nodules in upper part	2.7
Total thickness of Winfield limestone exposed	8.7±

Gage shale member of the Doyle shale.

10. *Road cut in the SW¼SW¼ sec. 25, T. 14 S., R. 5 E.*

Soil, weathered fragments of chert and limestone from Stovall limestone member of the Winfield limestone (1± foot).
Doyle shale:

	Feet
Gage shale member:	
13. Shale, clayey, calcareous, thin-bedded, light tan-gray	4.0
12. Covered interval	5.3
11. Limestone, hard, crystalline, tan, limonite-stained; weathers gray and blocky; some microfossils	.3
10. Shale, silty, very calcareous, blocky, light-gray; weathers gray; some iron stains	1.8

	Feet
9. Shale, clayey, calcareous, blocky, gray, gray-green, and tan; weathers gray	0.7
8. Shale, silty, calcareous, thin-bedded, tan-gray; weathers tan; some limonite stains	.8
7. Shale, silty, calcareous, thin-bedded, gray-green mottled with brown and yellow; some iron stains	3.6
6. Shale, silty, calcareous, thin-bedded, olive-drab, limonite-stained; weathers gray	.8
5. Shale, silty, calcareous, blocky, maroon; weathers light maroon	.5
4. Shale, silty, calcareous, blocky, gray-green; weathers gray	.5
3. Shale, silty, calcareous, blocky, dark-gray-green	.5
2. Shale, silty, calcareous, thin-bedded; maroon with gray-green lenses	.2
1. Shale, silty, calcareous, blocky; gray green with purple tint near the base	.3
Thickness exposed	19.3

Base covered.

11. *Road cut in the SW¼NW¼ sec. 6, T. 14 S., R. 6 E.*

Soil, silt with some clay, dark-gray; numerous limestone fragments (1± foot).

Doyle shale:

Towanda limestone member:

	Feet
16. Limestone, hard, platy, gray; weathers light gray; badly weathered and fractured	2.3
15. Limestone, hard, crystalline, blocky, gray	.6
14. Limestone, soft, tan; weathers gray and shaly; weathered surface pitted	1.1
13. Limestone, hard, massive, tan; weathers gray and platy	2.5
Thickness exposed	6.5

Holmesville shale member:

12. Shale, clayey, very calcareous, thin-bedded, tan; numerous calcareous plates and nodules	1.8
11. Shale, very calcareous, blocky, tan-gray; clayey in upper part, silty in lower part; weathers gray; calcite-filled fractures; numerous calcareous plates	2.0
10. Shale, silty, calcareous, blocky green; weathers gray green; iron stains on fracture planes	3.2
9. Shale, silty, very calcareous, blocky, light-gray-green; weathers gray	.8
8. Shale, silty, calcareous, blocky, gray-green; iron stains on fracture planes	.9
7. Shale, silty, calcareous, blocky, maroon	.6
6. Shale, silty, calcareous, blocky, gray-green; some limonite stains	.4
5. Shale, clayey, very calcareous, platy, tan- to light-gray	.3
4. Limestone, crystalline, massive, gray; dense in part; weathers blocky and light gray	.7
3. Shale, silty, very calcareous, granular, gray-green; numerous calcareous concretions; iron stains on fracture planes	1.1

		Feet
2.	Shale, silty, calcareous, thin-bedded to blocky, gray-green; iron stains on fracture planes	2. 4
1.	Shale, silty, calcareous, granular to blocky, dark-gray	1. 9
	Thickness exposed	16. 1
	Total thickness of Doyle shale exposed	22. 6

Base covered.

12. *Road cut in the NE¼NE¼ sec. 5, T. 14 S., R. 6 E.*

Weathered limestone and silty, dark-gray soil (2± feet).

Barneston limestone:

		Feet
Fort Riley limestone member:		
7.	Limestone, soft, tan, porous; weathers tan gray and blocky; some limonite strains	0. 6
6.	Limestone, soft, massive, tan- to tan-gray; weathers thin bedded in upper part and blocky in lower part; weathers light gray	11. 6
5.	Shale, silty, very clacareous, thin-bedded, tan; some limonite stains	. 6
4.	Limestone, medium-hard, massive, light-tan, porous; weathers tan gray and blocky; numerous fractures; some limonite stains; fossiliferous; forms "rimrock" outcrop	5. 4
3.	Shale, silty, very calcareous, thin-bedded to platy, tan-gray; weathers tan	1. 3
2.	Limestone, hard, tan-gray; weathers blocky in lower part and platy in upper part; some limonite stains; fossiliferous	1. 0
	Thickness exposed	20. 5
Oketo shale member:		
1.	Shale, silty, very calcareous, thin-bedded, tan-gray; weathers tan; fossiliferous	5. 3

Top of Florence limestone member.

13. *Road cut in the NE¼NE¼ sec. 8, T. 14 S., R. 6 E.*

Soil, silty and clayey, brown- to dark-gray; numerous weathered limestone fragments (1± foot).

Barneston limestone:

		Feet
Fort Riley limestone member:		
5.	Limestone, medium-hard, gray, massive, porous; weathers blocky; forms "rimrock" hillside bench	3. 0
4.	Limestone, medium-hard, tan-gray, fossiliferous; weathers platy	2. 0
	Thickness exposed	5. 0
Oketo shale member:		
3.	Shale, silty, calcareous thin-bedded, olive-tan	. 5
2.	Limestone, soft, clayey, blocky, brown; some fossils	. 3
1.	Shale, silty, calcareous, blocky, olive-tan, fossilifereous; weathers gray	4. 0
	Thickness exposed	4. 8
	Total thickness of Barneston limestone exposed	9. 8

Base covered.

14. *Quarry in the center of NE¼ sec. 36, T. 16 S., R. 7 E.*

Soil, silty, gray-brown; some limestone fragments (3 ± feet).

Barneston limestone:

Fort Riley limestone member:

	Feet
20. Limestone, soft, massive, porous, gray; weathers tan; thin stringers of calcite	2.5
19. Limestone, soft, tabular, light-gray, porous	2.4
18. Limestone, soft, massive, light-gray; each bed is about 0.6 foot thick, interbedded with a silty, calcareous, thin-bedded, tan shale which is 0.1 foot thick	2.1
17. Limestone, soft, tan; weathers blocky; some iron stains	.8
16. Shale, silty, calcareous, thin-bedded, brown	.2
15. Limestone soft, tan; weathers gray; some iron stains	1.7
14. Shale, silty, calcareous, thin-bedded, gray	.3
13. Limestone, soft, dolomitic, gray; weathers shaly	.2
12. Shale, silty, calcareous, thin-bedded, gray	.2
11. Limestone, medium-hard, tan, massive; weathers blocky and gray	4.0
10. Limestone, soft, brecciated, tan-gray; shaly in upper part	2.8
9. Limestone, medium-hard, dense, massive to nodular, light-gray; weathers tan brown; small solution channels	1.3
8. Limestone, soft, clayey, blocky, dark-gray, fossiliferous	2.7
7. Limestone, medium-hard, massive, light-gray, fossiliferous; weathers tan and blocky; forms "rimrock" hillside bench	4.4
6. Limestone, clayey, soft, blocky, light-gray; weathers tan; very fossiliferous	.9
5. Limestone, medium-hard, massive, tan; weathers blocky to shaly and tan gray; some iron stains and fossil fragments	3.2
Thickness exposed	29.7

Oketo shale member:

4. Shale, silty, calcareous, thin-bedded, olive-drab; weathers tan; calcareous lenses abundant; a calcareous lentil 0.9 foot thick grades laterally into shale; some iron stains; fossiliferous exposed	7.7

Florence limestone member:

3. Limestone, hard, massive, tan to blue-gray, weathers blocky; some chert nodules and fossils	1.2
2. Shale, silty, calcareous, thin-bedded, tan- to blue-gray; some calcareous lenses and fossil fragments	1.1
1. Limestone, hard, massive, tan to blue-gray, fossiliferous; weathers blocky; alternating thick beds of limestone and thin lenses of chert; chert nodules abundant	8.5
Thickness exposed	10.8
Total thickness of Barneston limestone exposed	48.2

Base covered.

15. *Spillway of Council Grove Lake in the NE¼NE¼ sec. 8, T. 16 S., R. 8 E.*

Soil, silty, brown; many chert fragments (1± foot).
Barneston limestone:
Florence limestone member:

	Feet
14. Limestone, medium-hard, massive, gray; weathers blocky; numerous interbedded bands of blue-gray chert, each about 0.2 foot thick	6.7
13. Limestone, medium-hard, thin-bedded, light-gray	.6
12. Limestone, medium-hard, massive, gray; weathers blocky; numerous interbedded bands of blue-gray chert, each about 0.2 foot thick	2.9
11. Limestone, hard, crystalline, massive, light-gray, fossiliferous; weathers blocky; numerous stringers of chert	1.7
10. Shale, silty, calcareous, thin-bedded, tan	.1
9. Limestone, medium-hard, blocky to platy, light-gray; weathers gray; numerous stringers of chert; some fossil fragments	.5
8. Shale, silty, calcareous, thin-bedded, tan; weathers gray	1.0
7. Limestone, medium-hard, platy, gray, fossiliferous	.4
6. Shale, very calcareous, platy, tan; weathers gray; some fossils	.7
5. Limestone, medium-hard, tan, fossiliferous; weathers bocky	.8
4. Shale, silty, calcareous, thin-bedded, tan; weathers gray	.1
3. Limestone, medium-hard, blocky, tan, cherty; weathers gray	.7
2. Shale, very calcareous, thin-bedded, tan-gray; weathers tan	.3
1. Limestone, medium-hard, platy, tan-gray; weathers gray; some veinlets of calcite present	.5
Thickness exposed	17.0

Base covered.

16. *Road cut and streambank in the SE¼SE¼ sec. 31, T. 14 S., R. 9 E.*

Soil, silty, dark-gray; fragments of chert (4± feet).
Matfield shale:
Blue Springs shale member:

	Feet
32. Shale, clayey, calcareous, thin-bedded, gray-green; weathers gray; some bands of secondary calcite	4.1
31. Shale, silty, calcareous, blocky, maroon	2.0
30. Shale, clayey, calcareous, blocky, gray-green	.7
29. Shale, silty, calcareous, blocky, maroon	.8
28. Shale, clayey, very calcareous, blocky; dark gray green in upper part, dark gray to purple in lower part	.7
27. Shale, clayey, very calcareous, thin-bedded, maroon	1.1
26. Shale, clayey, calcareous, blocky, dark gray-brown mottled with green and maroon; calcite veinlets	3.2
25. Shale, clayey, very calcareous, blocky, green	.8
24. Limestone, soft, clayey, gray-green; contains solution cavities	.3
23. Shale, clayey, calcareous, blocky, green and tan; some calcareous lenses	.5
22. Shale, silty and somewhat sandy, calcareous, nodular, tan	.3
21. Limestone, clayey, gray-green, lenticular and wavy	.5
20. Shale, clayey, noncalcareous, massive, tan; some limonite stains	.2
19. Shale, clayey, calcareous, blocky, gray-green	1.8
18. Shale, silty, calcareous, blocky, maroon	1.1
17. Shale, silty, calcareous, blocky, gray-green	.3

	Feet
16. Shale, silty, calcareous, blocky, maroon	0. 6
15. Shale, silty, calcareous, blocky, gray-green	14. 1
Thickness exposed	33. 1
Kinney limestone member:	
14. Shale, very calcareous, thin-bedded, tan-gray very fossiliferous	. 4
13. Limestone, crystalline, blocky, dark-gray, fossiliferous; poor outcrop expression	3. 8
Thickness exposed	4. 2
Wymore shale member:	
12. Shale, silty, calcareous, thin-bedded, tan-gray	2. 3
11. Limestone, clayey, platy, tan-gray	. 5
10. Shale, silty, calcareous, thin-bedded, tan-gray	6. 0
9. Shale, silty, very calcareous, massive, tan-gray; weathers blocky	5. 1
8. Shale, clayey, calcareous, thin-bedded, tan-brown	0. 4
7. Shale, silty, calcareous, blocky, gray-green	3. 2
6. Shale, clayey, calcareous, blocky, maroon	1. 2
5. Shale, silty, calcareous, blocky, gray-green	. 7
4. Shale, silty, calcareous, blocky, maroon	1. 2
3. Shale, silty, calcareous, blocky, dark-gray; weathers gray	. 9
2. Shale, silty, very calcareous, maroon; weathers gray	1. 9
1. Shale, silty, calcareous, blocky, green	1. 0
Thickness exposed	24. 4
Total thickness of Matfield shale exposed	61. 7

Base covered.

17. *Road cut in the center of SW¼ sec. 23, T. 15, S., R. 8 E.*

Soil, silty and clayey, brown; some chert fragments (0 to 4 feet).

Matfield shale:

	Feet
Wymore shale member:	
11. Shale, clayey, calcareous, blocky, gray-green; some iron stains. exposed	0. 5
Wreford limestone:	
Schroyer limestone member:	
10. Limestone, medium-hard, massive, gray; weathers tan gray and blocky, but is platy in uppermost part; contains microfossils	2. 7
9. Limestone, medium-hard, gray; weathers tan gray and thin bedded; two thin partings of shale; contains microfossils and pelecypods	. 6
8. Limestone, medium-hard, gray, fossiliferous; weathers tan gray and blocky; some iron stains	. 5
7. Limestone, soft, porous, massive, light-gray, fossiliferous; weathers tan gray, blocky, and in thin irregular beds in the upper part; stylolites common; some iron stains	4. 3
6. Limestone, soft, light-gray mottled with gray, fossiliferous; weathers blocky to shaly	. 8
5. Limestone, medium-hard, gray; weathers tan and blocky; contains a 0.4-foot lens of chert in middle; some microfossils	1. 0

	Feet
4. Limestone, medium-hard, massive, gray; weathers tan and blocky; contains a chert lens 0.7-foot thick in upper half and a 0.3-foot lens at the base; some microfossils	1. 7
3. Shale, silty, very calcareous, thin-bedded, gray; weathers tan; some calcite-lined geodes	. 4
2. Limestone, medium-hard, massive, light-gray; weathers tan and blocky to platy; contains calcite-filled pores and some fossil fragments	2. 6
Thickness exposed	14. 6
Havensville shale member:	
1. Shale, silty, calcareous, thin-bedded; tan gray to blue gray at base; very calcareous in lower part. Exposed	3. 4
Total thickness of Wreford limestone exposed	18. 0

Base covered.

18. *Road cut in the SW¼SW¼ sec. 15, T. 15 S., R. 7 E.*

Soil, silty and clayey, red-brown; some chert gravel (3± feet).

Matfield shale:

	Feet
Wymore shale member:	
11. Limestone, hard, gray, very fossiliferous; weathers tan and blocky	0. 6
10. Shale, silty, calcareous, thin-bedded, tan, very fossiliferous	5. 3
Thickness exposed	5. 9

Wreford limestone:

	Feet
Schroyer limestone member:	
9. Limestone, hard, dense in part, massive, light-gray; weathers tan gray and blocky to platy; some small pores and fossils	2. 9
8. Shale, silty, calcareous, thin-bedded, tan; weathers light tan; thin calcareous lenses and nodules common	1. 3
7. Limestone, medium-hard, massive, light-gray; weathers tan gray and blocky; numerous chert nodules and lentils; two chert lenses near the base; contains some fossils	3. 2
6. Shale, silty, calcareous, thin-bedded, tan, fossiliferous; weathers tan to light gray; contains numerous nodules of limestone and some of chert	1. 4
5. Limestone, medium-hard, dense in part; massive, gray; weathers blocky; contains chert nodules, lenses, and some fossil fragments	1. 8
Thickness exposed	10. 6
Havensville shale member:	
4. Shale, silty, calcareous, blocky to thin-bedded, gray-brown; weathers tan; numerous calcareous nodules and stains	1. 9
3. Limestone, medium-hard, massive, gray, lenticular; weathers tan gray and blocky to shaly; some iron stains	. 1
2. Shale, silty, very calcareous, thin-bedded, tan, very fossiliferous	3. 9
Thickness exposed	5. 9

Threemile limestone member:	*Feet*
1. Limestone, soft to medium-hard, dense in part, massive, tan- to light-gray, porous; weathers blocky; weathered surface pitted; some chert nodules and microfossils present	20. 9
Total thickness of Wreford limestone exposed	37. 4

Base covered.

19. *Streambank and road cut in the SE¼NW¼ sec. 35, T. 15 S., R. 8 E.*

Soil, clayey, brown; some limestone fragments (2± feet).

Wreford limestone:	
Schroyer limestone member:	*Feet*
17. Limestone, medium-hard, massive, porous, gray, fossiliferous; weathers blocky to platy in upper part; weathers tan gray	2. 6
16. Limestone, hard, dense in part, massive, gray; weathers tan gray and blocky; contains some fossils	1. 4
15. Chert, hard, dense, gray to light-gray, lenticular; weathers blocky; some iron stains	. 3
14. Limestone, medium-hard, light-gray; weathers tan gray and blocky; some chert nodules and fossils	. 5
13. Chert, hard, dense, gray to light-gray, lenticular, iron-stained; weathers blocky	. 7
12. Limestone, hard, somewhat crystalline, gray, fossiliferous; weathers tan and blocky; some chert nodules	. 2
11. Chert, hard, dense, tan to gray, lenticular, iron-stained; weathers blocky	. 2
10. Limestone, soft, tan-gray; weathers tan and blocky; some microfossils	. 6
9. Limestone, medium-hard, massive, light-gray; weathers tan gray and platy; some chert nodules, lentils, and fossil fragments	1. 2
Thickness exposed	7. 7
Havensville shale member:	
8. Shale, silty, calcareous, thin-bedded, tan-gray; weathers tan; calcareous lens near top; some iron stains	2. 6
7. Limestone, hard, dense, gray, lenticular; weathers tan and blocky; has glass-like fracture; contains limonite nodules	. 2
6. Shale, clayey, calcareous, thin-bedded, gray-green; weathers tan; calcareous stains present	. 3
5. Limestone, medium-hard, dark-gray; weathers tan and platy; some chert nodules and fossils	. 4
4. Shale, silty, very calcareous, thin-bedded, tan-gray; weathers tan; some calcite-lined cavities	1. 1
3. Limestone, hard, massive, gray; weathers tan gray and blocky to platy; limonite nodules and fossile fragments abundant; some clay balls	1. 3
2. Shale, clayey, calcareous, thin-bedded, tan-gray, weathers tan; some calcareous nodules	4. 4
Thickness exposed	10. 3

		Feet
Threemile limestone member:		
1.	Limestone, medium-hard to soft, massive, light-gray, porous; weathers gray and blocky; some stylolites, chert nodules and lentils; upper part fossiliferous	17. 1
	Total thickness of Wreford limestone exposed	35. 1

Base covered.

20. *Road cut in the SW¼NE¼ sec. 23, T. 16 S., R. 8 E.*

Wreford limestone:

		Feet
Havensville shale member:		
17.	Limestone, hard, massive, very fossiliferous; weathers tan gray	2. 3
16.	Shale, silty, calcareous, thin-bedded, olive-drab; weathers tan	3. 3
15.	Shale, silty, very calcareous, thin-bedded to platy, dark-gray, fossiliferous; weathers light to dark gray	. 9
	Thickness exposed	6. 5
Threemile limestone member:		
14.	Limestone, hard, massive, light-gray; weathers tan gray and to irregular plates or blocks; numerous chert nodules; chert lens near middle	1. 9
13.	Chert, light- to dark-gray, fossiliferous; weathers blocky	. 5
12.	Limestone, hard, light-gray, fossiliferous; weathers tan gray and blocky	1. 0
11.	Chert, light to dark-gray, very lenticular; weathers blocky; some iron stains	0 to . 4
10.	Limestone, hard, massive, light-gray, porous; weathers tan gray, blocky, and to thin irregular beds; limonite stains	2. 9
9.	Chert; light- to dark-gray, iron-stained; weathers blocky	. 3
8.	Limestone, medium-hard, massive, light-gray, iron-stained; weathers tan gray and blocky; soft in middle	2. 2
7.	Chert; light- to dark-gray, lenticular, iron-stained; weathers blocky and nodular	. 2
6.	Limestone, medium-hard, light-gray, porous; weathers tan gray and blocky; some iron stains	. 7
5.	Chert, light-gray to dark-gray, lenticular, iron-stained; weathers blocky and nodular; some fossil fragments	. 2
4.	Limestone, hard, light-gray; weathers tan gray and blocky; contains numerous fossil fragments	. 7
3.	Limestone and chert, hard, light-gray; weathers tan and blocky; chert lenses and nodules abundant	1. 1
2.	Shale, silty, calcareous, thin-bedded, fossiliferous; weathers tan; some calcareous plates	1. 1
1.	Limestone, hard, massive, light-gray, iron-stained; weathers tan gray and blocky; three lenses of chert present; some fossils	2. 4
	Thickness exposed	15. 6
	Total thickness of Wreford limestone exposed	22. 1

Speiser shale.

21. *Quarry and streambank in the SE¼SW¼ sec. 2, T. 16 S., R. 8 E.*

	Feet
Wreford limestone:	
Havensville shale member:	
11. Limestone, medium-hard, massive, tan-gray, fossiliferous; weathers platy	1. 1
10. Shale, clayey, calcareous, thin-bedded, gray-green; weathers tan gray; contains some fossils	1. 0
Thickness exposed	2. 1
Threemile limestone member:	
9. Limestone, hard, dense in part, blocky, dark-gray; weathers tan gray; irregular bedding	. 5
8. Limestone, medium-hard, massive, light-gray, vertically jointed; weathers tan gray and blocky; some chert lentils; some stylolites	16. 1
7. Limestone, soft, massive, tan, cavernous; weathers dark gray to tan brown and blocky to platy; bands of chert nodules, some calcite-filled cavities and fossils present	7. 1
6. Chert, hard, dense, blue-gray to light-gray; weathers blocky to nodular	. 4
5. Shale, clayey, calcareous, red-brown, cavernous; clay lentils in upper part; calcite-filled cavities and dense calcareous nodules; grades laterally into limestone	. 5
4. Chert, dense, hard, blocky, blue-gray to light-gray, lenticular; some clay-filled cavities	. 9
3. Shale, silty, massive- to thin-bedded, light-gray-green, very calcareous; dolomitic in part; contains numerous calcareous nodules and lenses; geodes abundant	2. 2
2. Chert, dense, hard, blue-gray to light-gray, lenticular; weathers blocky, contains clay-filled cavities	. 9
1. Limestone, medium-hard, blocky, tan; some chert nodules	. 7
Thickness exposed	29. 3
Total thickness of Wreford limestone exposed	31. 4
Speiser shale.	

22. *Streambank and road ditch in the SW¼NW¼ sec. 15, T. 15 S., R. 7 E.*

Soil, silty and clayey, red-brown; some chert gravel (0–4 feet).

	Feet
Wreford limestone:	
Threemile limestone member:	
7. Limestone, soft, massive, gray; weathers tan gray; fossil fragments abundant	2. 2
6. Limestone, soft- to medium-hard, dense in part, massive, tan- to light-gray, porous; weathers to irregular blocks; some iron stains, chert nodules and lentils; some fossils in upper part	18. 3
5. Limestone, soft, massive, tan, porous; weathers tan gray; chert nodules; 2 thin lenses of chert in upper part	2. 5
4. Chert, hard, dense, gray, lenticular; weathers blocky	. 5
3. Limestone, soft, dolomitic, massive, tan-gray, porous, weathers gray	1. 9

	Feet
2. Chert, hard, dense, gray- to light-gray, lenticular	0.5
1. Limestone, medium-hard, massive, tan; weathers tan gray and blocky; some fossil fragments	1.9
Thickness exposed	27.8

Base covered.

23. *Stream cut in the SE¼SW¼ sec. 30, T. 15 S., R. 8 E.*

Wreford limestone:

Threemile limestone member:

	Feet
11. Limestone, medium-hard, light-gray, porous; thin lens of chert in middle part; stylolites near base, some chert nodules and fossil fragments	11.9
10. Chert, hard, dense, blocky, dark-gray, lenticular	.3
9. Limestone, medium-hard, massive, light-gray; weathers gray and blocky	.8
8. Chert, hard, dense, blocky, dark-gray, lenticular, iron-stained; weathers gray to dark gray	.3
7. Limestone, medium-hard, massive, gray- to light-gray, fossiliferous; weathers to irregular plates	.6
6. Shale, silty, very calcareous, thin-bedded, gray; grades upward into limestone; weathers tan gray; fossils rare	.7
5. Limestone, hard, massive, light-gray, fossiliferous; weathers tan gray and blocky; thick lens of chert in middle part; some chert nodules	1.8
Thickness exposed	16.4

Speiser shale:

4. Shale, silty, very calcareous, thin-bedded, tan-gray, fossiliferous; more resistant zone in middle part; some iron stains	2.9
3. Limestone, medium-hard, gray; weathers tan gray and to thin chips; some fossil fragments	.6
2. Shale, clayey, calcareous, thin-bedded, green; light green in upper part; some iron stains on bedding planes	4.9
1. Shale, calcareous, blocky; clayey with some silt; maroon becoming purple in the upper part	3.7
Thickness exposed	12.1

Base covered.

24. *Road cut in the NW¼SE¼ sec. 23, T. 16 S., R. 8 E.*

Soil, silty, gray, numerous chert fragments (1 ± foot).

Wreford limestone:

Threemile limestone member:

	Feet
11. Limestone and chert, hard, massive, light-gray to dark-gray; weathers blocky	1.8
10. Shale, silty, calcareous, thin-bedded, olive-drab, fossiliferous; weathers tan; numerous calcareous plates	1.1
9. Limestone, hard, massive, light-gray, iron-stained; weathers tan gray and blocky; three lenses of chert; contains fossil fragments	2.4
Thickness exposed	5.3

	Feet
Speiser shale:	
8. Shale, silty, calcareous, thin-bedded, olive-drab to tan-gray; weathers tan gray; numerous calcareous nodules	3. 9
7. Shale, silty, slightly calcareous, thin-bedded to blocky, gray- to gray-green; weathers light gray; some iron stains. Hard, clayey, gray limestone 0.3 foot thick is present in south end of road cut but thins toward north end	2. 4
6. Limestone, clayey, hard, massive, gray; weathers tan gray and blocky; some iron stains	1. 5
5. Shale, silty, very calcareous, gray-green; weathers light gray green	3. 7
4. Shale, calcareous, thin-bedded to blocky, maroon mottled with gray and gray-green; silty with some clay; weathers maroon	4. 7
3. Shale, calcareous, thin-bedded, gray-green; silty with some clay; some thin calcareous plates; maroon stains on surface	. 7
Thickness exposed	16. 9
Funston limestone:	
2. Limestone, hard, somewhat crystalline, massive, gray; weathers tan gray and blocky but becomes shaly near base; weathered surface shows crossbedding; maroon stains on surface	5. 7
1. Shale, silty, calcareous, thin-bedded, tan-gray; weathers tan; numerous thin calcareous lenses	5. 5
Thickness exposed	11. 2

Base covered.

25. *Quarry in the SW¼NE¼ sec. 13, T. 16 S., R. 8 E.*

	Feet
Wreford limestone:	
Threemile limestone member:	
11. Limestone, medium-hard, dense in part, massive, light-gray, porous to cavernous; weathers gray and blocky; vertical fractures; contains some chert lentils, nodules and fossils	7. 7
10. Chert, dense, hard, gray- to light-gray, lenticular; weathers blocky	. 7
9. Limestone, soft, massive, gray to gray-green, porous, fossiliferous; weathers tan and shaly; some calcite-filled cavities	1. 9
8. Limestone, hard, massive, light-gray; weathers tan gray and blocky; two lenses of chert; some chert nodules	2. 1
Thickness exposed	12. 4
Speiser shale:	
7. Shale, silty, calcareous, thin-bedded, gray grading upward into gray-green, fossiliferous; some iron stains; some calcareous nodules and lenses; lower part more resistant to weathering	4. 1
6. Shale, clayey, calcareous, thin-bedded to blocky, gray to gray-green; weathers gray green; iron stains on bedding planes	2. 4
5. Shale, silty, very calcareous, massive, light-green; resistant to weathering	1. 1
4. Shale, silty, calcareous, massive to blocky, light-green; becomes dark gray green in lower part	1. 9

	Feet
3. Shale, silty, calcareous, blocky, dark-green; weathers gray; some iron stains on fracture planes	0. 2
2. Shale, silty to clayey, calcareous, thin-bedded, maroon, limonite-stained; becomes blocky in the lower part; calcium carbonate nodules in lower part	5. 0
Thickness exposed	14. 7

Funston limestone:

1. Limestone, medium-hard, massive, tan-gray, porous, very oolitic, fossiliferous; weathers blocky; weathered surface shows some crossbedding	6. 1

Base covered.

26. *Road cut in the NW¼SE¼ sec. 23, T. 16 S., R. 8 E.*

Speiser shale:	Feet
8. Shale, clayey, calcareous, thin-bedded, gray-green	0. 5

Funston limestone:

7. Limestone, medium-hard, massive, gray-green to light-gray; weathers gray and blocky	4. 8
6. Shale, silty, calcareous, thin-bedded, tan	. 1
5. Limestone, hard, dense, tan-gray; weathers blocky	. 6
4. Shale, silty, calcareous, thin-bedded, tan	. 1
3. Limestone, hard, dense, gray, tabular; weathers blocky	. 1
2. Shale, silty, calcareous, thin-bedded, tan; weathers tan gray	2. 3
1. Limestone, soft, dark-gray; weathers blocky to shaly	. 5
Thickness exposed	8. 5

Base covered.

27. *Road cut in the NW¼NE¼ sec. 23, T. 16 S., R. 8 E.*

Soil, silty, dark-gray; contains numerous limestone fragments and blocks (1.5 ± feet).

Funston limestone:	Feet
15. Shale, clayey, slightly calcareous, very thin bedded, tan mottled with gray; weathers tan; calcareous plates on surface	3. 2
14. Limestone, medium-hard, blocky, gray; weathers tan; some calcareous nodules and fossils	. 6
13. Shale, silty, calcareous, thin-bedded, tan-gray; weathers tan; numerous calcareous lenses	1. 6
12. Limestone, medium-hard, massive, tan-gray; weathers tan and blocky but is shaly in upper part; some limonite stains; fossil fragments abundant	1. 3
11. Shale, clayey, calcareous, thin-bedded to blocky; dark gray in lower part, gray and tan gray in upper part; some iron stains	6. 4
10. Limestone, medium-hard, clayey, thin-bedded, gray; weathers tan gray; some carbon stains; heavily limonite stained in upper part; limonite nodules and clay balls abundant in upper part	. 6
Thickness exposed	13. 7

	Feet
Blue Rapids shale:	
9. Shale, clayey and partly silty, calcareous, tan; massive to blocky in lower part, becoming thin-bedded in upper part; some limonite stains	1.4
8. Shale, clayey, calcareous, blocky, gray-green; weathers light gray green; limonite and iron stains on fracture planes	1.9
7. Shale, silty, calcareous, thin-bedded, tan-gray; weathers tan; thin calcareous lenses in middle part which join in part of the exposure to form a very soft, porous, clayey limestone	3.7
6. Shale, silty, with some clay, calcareous, blocky, gray-green; weathers light gray green	2.0
5. Shale, silty, calcareous, tan-gray; thin-bedded, but thick bedded in middle part; weathers tan; some limonite stains	3.2
Thickness exposed	12.2
Crouse limestone:	
4. Limestone, medium-hard, thin-bedded, light-gray; weathers tan	1.1
3. Limestone, hard, massive, light-gray; weathers tan and blocky; bedding apparent in part of the exposure	1.4
2. Shale, silty to clayey, calcareous, thin-bedded, tan	.1
1. Limestone, medium-hard, massive; weathers tan, thin-bedded in lower part, blocky in upper part; tan gray with numerous gray areas; numerous thin partings of shale; some limonite stains	5.7
Thickness exposed	8.3

Base covered.

28. *Road cut in the NW¼NE¼ sec. 14, T. 16 S., R. 9 E.*

Soil, silty, dark green; limestone fragments (2 ± feet).

	Feet
Crouse limestone:	
7. Limestone, medium-hard, platy, tan-gray; weathers tan; some iron stains; numerous thin partings of shale	2.4
6. Limestone, hard, tan-brown; weathers tan gray and blocky; numerous limonite nodules; abundantly fossiliferous	1.3
5. Limestone, medium-hard, platy, tan-brown; weathers tan; some iron stains	.6
4. Limestone, hard, somewhat crystalline, massive, tan-brown, fossiliferous, iron-stained; upper part dense; weathers tan and blocky	1.1
3. Shale, calcareous, blocky to thin-bedded, olive-drab; clayey with some silt; weathers tan to gray; some iron stains	6.9
2. Limestone, hard, massive, gray, slightly clayey, fossiliferous; dense in part; weathers tan gray and to thin chips	3.2
Thickness exposed	15.5
Easly Creek shale:	
1. Shale, silty, calcareous, blocky, gray-green; fractures are iron stained. Exposed	3±

Base covered.

29. *Road cut in the NE¼NE¼ sec. 13, T. 16 S., R. 9 E.*

	Feet
Crouse limestone:	
11. Limestone, medium-hard, thin-bedded, tan; weathered and covered by slump; contains some fossils	3.0
10. Limestone, medium-hard, blocky, tan-gray; weathers tan; pitted along joints	1.5
9. Shale, silty, calcareous, thin-bedded, tan-gray; mostly covered	5.5
8. Limestone, clayey, medium-hard, platy, light-gray, fossiliferous; weathers blue gray	1.4
7. Limestone, medium-hard, blocky, tan-gray; weathers tan	1.3
6. Shale, silty, calcareous, thin-bedded, olive-drab, very fossiliferous; weathers tan; some calcareous lenses in lower part	8.8
5. Limestone, hard, dense in part, gray-orange, limonite-stained; weathers tan brown; weathers to shaly appearance near the top, blocky in lower part; contains some fossils	1.3
Thickness exposed	22.8
Easly Creek shale:	
4. Shale, silty, calcareous, blocky to thin-bedded, gray-green; weathers light gray green; iron stains on fracture planes.	9.7
Bader limestone:	
Middleburg limestone member:	
3. Limestone, hard, dense in part, massive, tan-gray fossiliferous; weathers gray brown and blocky; weathered surface shows bedding planes; some limonite nodules	1.9
2. Shale, silty, calcareous, very thin bedded, black- to dark-gray	3.2
1. Limestone, hard, massive, gray-brown; weathers tan gray and to irregular plates and blocks; some iron stains	2.3
Thickness exposed	7.4

Base covered.

30. *Road ditch in the NW¼NW¼ sec. 22, T. 17 S., R. 9 E.*

Crouse limestone: badly weathered and eroded (1 ± foot).

	Feet
Easly Creek shale:	
14. Shale, clayey, calcareous, thin-bedded, brown	0.2
13. Shale, clayey, calcareous, blocky, gray-green; weathers gray	2.0
12. Shale, clayey, highly calcareous, blocky, gray-green	1.0
11. Shale, clayey, calcareous, granular, gray-green	.4
10. Shale, silty, calcareous, granular, maroon	.6
9. Shale, clayey, calcareous, thin-bedded, gray-green	.4
8. Shale, silty, calcareous, blocky, maroon	1.1
7. Shale, silty, calcareous, blocky, gray-green	1.0
6. Shale, clayey, calcareous, mottled gray-green and maroon; thin-bedded but with thin blocky layers interbedded	1.5
5. Shale, silty, calcareous, blocky, dark-gray-green	.5
4. Shale, silty, calcareous, thin-bedded, gray-green	.8
3. Shale, very calcareous, concretionary, gray	.6
2. Shale, calcareous, thin-bedded, gray-green	1.4
1. Shale, very calcareous, concretionary, tan	3.4
Thickness exposed	14.9

Middleburg limestone member of the Bader limestone.

31. *Road cut in the SE¼NE¼NE¼ sec. 13, T. 16 S., R. 9 E.*

Base of Middleburg limestone member of the Bader limestone.
Bader limestone:

	Feet
Hooser shale member:	
5. Shale, silty, calcareous, thin-bedded, tan-gray, limonite-stained; weathers tan; calcareous nodules	2.5
4. Shale, silty, calcareous, blocky, maroon	.4
3. Shale, silty, calcareous, blocky; gray green mottled with purple in middle part; calcareous nodules in middle part	2.6
Thickness exposed	5.5
Eiss limestone member:	
2. Limestone, hard, dense in part, gray- to tan-gray, fossiliferous; weathers blocky to nodular	1.4
1. Shale, clayey, calcareous, blocky, gray, heavily limonite stained; weathers tan gray	3.5
Thickness exposed	4.9
Total thickness of Bader limestone exposed	10.4

Base covered.

32. *SE¼NW¼ sec. 36, T. 16 S., R. 9 E.*

Soil, silty, gray, some weathered limestone fragments (2± feet).
Bader limestone:

	Feet
Eiss limestone member:	
39. Limestone, medium-hard, platy, gray; weathers tan. Fossil fragments abundant	2.2
Stearns shale:	
38. Shale, silty, calcareous, granular, gray-green	2.2
37. Shale, silty, calcareous, granular, tan-gray, fossiliferous	3.3
36. Shale, silty, calcareous, blocky, tan-gray	1.0
35. Shale, silty, calcareous, thin-bedded, gray-green	1.5
34. Shale, silty, calcareous, thin-bedded, gray-green; contains fragments of pink crystalline limestone	1.2
33. Shale, silty, calcareous, blocky, dark-blue-gray	1.0
32. Shale, silty, calcareous, thin-bedded; dark-blue-gray	5.2
31. Limestone, hard, crystalline, blocky, dark-blue-gray, fossiliferous	.6
30. Shale, clayey, slightly calcareous, blocky, dark-blue-gray	1.4
29. Shale, very calcareous, brown, very fossiliferous; weathers tan gray; contains numerous calcareous concretions and thin lenses of limestone	3.9
28. Shale, clayey, calcareous, granular, gray-green mottled with tan	1.1
27. Shale, carbonaceous, very thin bedded, black; some fossil plants	.1
26. Shale, clayey, calcareous, blocky, gray-green mottled with black	.5
25. Shale, carbonaceous, very thin bedded, black; some fossil plants	.9
24. Shale, silty, calcareous, platy, gray-green	2.2
23. Limestone, soft, gray-green; weathers shaly to blocky	.4
22. Shale, silty, very calcareous, thin-bedded to blocky, tan	.1
21. Limestone, soft, gray-green; weathers shaly to blocky	.4
20. Limestone, soft, thin-bedded, red-brown	.1

	Feet
19. Shale, silty, calcareous, blocky, light-gray-green	1. 2
18. Limestone, soft, concretionary, tan-brown	. 1
17. Shale, silty, calcareous, blocky, gray-green	1. 1
16. Shale, clayey, calcareous, blocky, light-tan-gray	. 7
15. Shale, silty, very calcareous, blocky, gray-green	1. 9
14. Shale, silty, calcareous, blocky, tan	. 5
13. Shale, silty, calcareous, blocky, gray-green	. 3
12. Shale, silty, calcareous, blocky, tan-gray	. 6
Thickness exposed	33. 5

Beattie limestone:

Morrill limestone member:

11. Limestone, medium-hard, tan-gray; weathers blocky	0. 5
10. Limestone, medium-hard, dark-tan-gray; weathers light gray and platy	. 8
9. Limestone, medium-hard, blocky to platy, dark-tan-gray; weathers tan	1. 0
8. Shale, clayey, calcareous, thin-bedded, tan-brown	. 4
7. Limestone, medium-hard; blocky, dark-tan-gray; weathers light gray and platy	. 4
6. Limestone, soft, cavernous, dark-gray; interbedded thin bands of red calcite	1. 5
Thickness exposed	4. 6

Florena shale member:

5. Shale, clayey, noncalcareous, thin-bedded to blocky, tan	0. 6
4. Shale, silty, calcareous, blocky, gray-green; contains some fossils	3. 6
3. Shale, silty, calcareous, thin-bedded, tan-gray; thin zones of calcareous concretions	3. 9
2. Shale, carbonaceous, very thin bedded, black, very fossiliferous	1. 3
Thickness exposed	9. 4

Cottonwood limestone member:

1. Limestone, hard, massive, tan-gray; weathers blocky and light gray to tan; interbedded thin bands of chert; forms a prominent hillside bench; fusulinids abundant	5. 3
Total thickness of Beattie limestone exposed	19. 3

Eskridge shale.

33. *Spillway of Lake Kahola in the NW¼ SE¼ sec. 33, T. 17 S., R. 9 E.*

Beattie limestone:

Cottonwood limestone member:

	Feet
10. Limestone, hard, massive, light-gray, porous, limonite-stained; weathers tan gray and blocky; occasional chert nodules; some solution channels; fractures to large blocks; forms a very prominent hillside bench. Fusulinids abundant in upper part, fossil fragments abundant in lower part	4. 9

Eskridge shale:	Feet
9. Shale, blocky to thin-bedded, tan-gray; clayey with some silt; weathers gray; iron stains on fracture planes; calcareous lenses in upper part	10.4
8. Limestone, clayey, tan-gray; weathers platy; iron stains on fracture planes in lower part	1.8
7. Shale, clayey, calcareous, blocky to thin-bedded, gray-green; calcareous nodules and iron stains in lower part	2.0
6. Shale, clayey, calcareous, blocky, maroon; some iron stains	1.4
5. Shale, clayey, calcareous, blocky to thin-bedded, gray-green; maroon tint in middle part; iron stains on fracture planes	3.5
4. Limestone, hard, dense, blocky, gray; weathers light gray	.9
3. Shale, clayey, calcareous, blocky to thin-bedded, gray-green; iron stains on fracture planes	4.6
2. Limestone, hard, massive, gray, porous; weathers tan gray and blocky; pelecypods abundant	1.9
1. Shale, clayey, calcareous, blocky, tan- to tan-gray; thin limestone lens in upper part; cavernous in middle part	3.7
Thickness exposed	30.2

Neva limestone member of the Grenola limestone.

34. *Streambank in the SW¼NW¼ sec. 15, T. 17 S., R. 9 E.*

Cottonwood limestone member of the Beattie limestone:

Eskridge shale:	Feet
26. Covered	10.0
25. Shale, clayey, calcareous, blocky, gray-green; weathers light gray	.8
24. Shale, clayey, calcareous, gray-green; weathers light green	.3
23. Shale, clayey, calcareous, extremely carbonaceous, platy to massive, black; weathers gray	.3
22. Shale, clayey, calcareous, platy, red-brown to gray-brown; weathers tan	.1
21. Shale, clayey, calcareous, extremely carbonaceous, platy, black; weathers gray	.4
20. Shale, clayey, carbonaceous, calcareous, platy, dark-gray; weathers gray	.3
19. Shale, clayey, carbonaceous, calcareous, platy; dark-gray with orange streaks; weathers gray	.6
18. Shale, clayey, calcareous, platy, black; weathers gray; abundant fossil plants	.7
17. Shale, clayey, calcareous, platy, dark-gray to tan; weathers gray; fossil leaves abundant	.2
16. Limestone, massive, black- to tan-gray; weathers gray	.1
15. Shale, clayey, calcareous, blocky, light-green; weathers light gray	.5
14. Shale, clayey, calcareous, gray-green; weathers light gray	.4
13. Shale, clayey, very calcareous, blocky, light-green to tan; weathers tan	1.1
12. Shale, clayey, calcareous, platy, light-gray	.6
11. Shale, clayey, calcareous, blocky, light-gray	.4
10. Shale, clayey, very calcareous, blocky, gray-green; weathers light gray	.7

	Feet
9. Shale, clayey, very calcareous, blocky, orange- to gray-green; weathers tan	1.1
8. Shale, clayey, calcareous, blocky, red-brown; weathers tan	.9
7. Shale, clayey, calcareous, gray-orange; weathers tan	.7
6. Shale, clayey, very calcareous, light-tan-gray; weathers white, and to a fretwork	1.7
5. Shale, clayey, calcareous, blocky, gray-green; weathers light green	.8
4. Shale, clayey, very calcareous, light-tan-gray	1.5
3. Shale, clayey, very calcareous, platy, turquoise; weathers gray	.2
2. Limestone, massive, light-gray	.6
1. Shale, clayey, very calcareous, blocky to platy, dark-gray-green; weathers light gray green; some limy zones	1.3
Thickness exposed	26.3

Base covered.

35. *Road cut in the SE¼NW¼ sec. 1, T. 17 S., R. 9 E.*

Cottonwood limestone member of the Beattie limestone:

Eskridge shale:

	Feet
19. Shale, clayey, calcareous, platy, tan; weathers light tan; numerous limestone zones	0.9
18. Shale, clayey, calcareous, blocky, tan; weathers light tan	2.2
17. Shale, clayey, calcareous, blocky, gray-brown; weathers tan	3.8
16. Limestone, shaly, platy, tan-gray, weathers gray	1.1
15. Limestone, platy, tan-gray to light-gray; weathers gray	.6
14. Shale, clayey, calcareous, light-green; weathers light gray	.1
13. Shale, clayey, calcareous, blocky, gray-green, weathers light gray green	3.9
12. Shale, clayey, calcareous, blocky, gray-brown; weathers gray	.2
11. Shale, clayey, calcareous, blocky, gray-green; weathers light green	.3
10. Shale, clayey, calcareous, orange; weathers tan	.1
9. Shale, clayey, calcareous, dark-gray; weathers light gray	.2
8. Shale, clayey, calcareous, extremely carbonaceous	.2
7. Shale, clayey, calcareous, very thin bedded; gray to black with orange streaks; weathers gray; contains organic material	.5
6. Shale, silty, calcareous, very thin bedded, black; weathers gray; fossil leaves abundant	.4
5. Shale, clayey, calcareous, orange; weathers tan	.2
4. Shale, clayey, calcareous, platy, red-brown; weathers tan	.3
3. Shale, clayey, very calcareous, platy, gray-orange; weathers tan	.4
2. Shale, clayey, very calcareous, platy, tan; weathers light tan	.2
1. Shale, clayey, very calcareous, platy, tan-gray; weathers gray	1.1
Thickness exposed	16.7

Base covered.

36. *Streambank in the NW¼NE¼ sec. 35, T. 16 S., R. 9 E.*

Soil, silty, gray-brown, granular (2± feet).
Grenola limestone:

	Feet
Neva limestone member:	
11. Limestone, medium-hard, platy, tan, badly weathered	1.0
10. Limestone, soft, massive; brown in lower part, tan brown in upper part; surface pitted	2.7
9. Limestone, medium-hard, fragmental, irregularly bedded, tan	1.3
8. Limestone, medium-hard, massive, tan-gray	1.0
7. Covered interval	2.0
6. Limestone, medium-hard, blocky, tan-brown	1.0
5. Limestone, soft, shaly, gray-green; contains fusulinids	.4
4. Shale, silty, calcareous, thin-bedded, gray-green, iron-stained	.4
3. Shale, silty, calcareous, platy, tan-gray, iron-stained	.7
2. Shale, carbonaceous, very thin bedded, black	.2
1. Limestone, hard, tan, fossiliferous; weathers light gray	1.0
Thickness exposed	11.7

Salem Point shale member.

37. *Road cut in the SW¼SW¼ sec. 24, T. 17 S., R. 9 E.*

Grenola limestone:
Base of Neva limestone member:

	Feet
Salem Point shale member:	
3. Shale, silty, calcareous, thin-bedded, olive-drab; weathers tan; some iron stains	5.5
2. Shale, silty, calcareous, thin-bedded, dark-gray to black; weathers gray	1.9
1. Shale, calcareous, blocky to thin-bedded, tan-gray to gray; clayey with some silt; weathers tan	3.9
Thickness exposed	11.3

Base covered.

38. *Road cut in the SE¼SE¼ sec. 23, T. 17 S., R. 9 E.*

Soil, silty, dark-gray, granular (0.5± foot).
Grenola limestone:

	Feet
Sallyards limestone member:	
24. Limestone, medium-hard, light-gray, fractured; iron stains on fracture planes; weathers platy	0.5
Roca shale:	
23. Shale, silty, calcareous, granular, tan-gray; weathers gray	1.7
22. Shale, clayey, calcareous, blocky, tan-gray; weathers gray	.7
21. Shale, clayey, calcareous, platy, gray-green	.3
20. Shale, clayey, calcareous, tan-brown; contains thin zones of calcareous concretions	1.3
19. Shale, clayey, calcareous, thin-bedded, gray-green; weathers tan	.8
18. Shale, clayey, calcareous, platy, tan-brown; scattered calcareous concretions	1.4
17. Shale, clayey, calcareous, platy, tan-gray; weathers tan; some iron stains and calcareous lenses	4.1

	Feet
16. Limestone, clayey, platy to blocky, light-gray, fossiliferous	0.2
15. Shale, silty, calcareous, thin-bedded, light-gray	.1
14. Limestone, clayey, very soft, light-gray; weathers platy; iron stains present	.2
13. Shale, silty, very calcareous, thin-bedded, gray	.6
12. Limestone, clayey, gray; weathers tan gray and blocky to platy; some limonite stains	.9
11. Limestone, hard, gray with purple tint, iron-stained; weathers to irregular blocks	.6
10. Shale, clayey, calcareous, blocky to thin-bedded, gray-green grading down to tan-green; some iron stains	1.3
9. Shale, silty, calcareous, blocky, tan-gray; some calcareous lenses	3.2
8. Shale, clayey, calcareous, thin-bedded, gray-green; iron stains on fracture planes	.9
7. Shale, very calcareous, thin-bedded to platy, gray to gray-green; iron stains on fracture planes	.2
6. Shale, silty, granular to thin-bedded, gray-green; calcareous in upper part, noncalcareous in lower part	1.8
5. Shale, silty, noncalcareous, blocky, dark-gray; weathers purple; some iron stains	.6
4. Shale, very calcareous, tan-gray to purple, cavernous to porous; some green lentils	.3 to .9
3. Shale, clayey, noncalcareous, blocky, tan-gray to dark-gray; weathers tan	1.0
2. Shale, silty, slightly calcareous, thin-bedded to blocky, maroon grading down to gray-green	1.8
1. Limestone, clayey, dense, hard, tan-brown; weathers tan gray and platy	.7
Thickness exposed	25.3

Base covered.

39. *Road cut in the NE¼NW¼SW¼ sec. 36, T. 17 S., R. 9 E.*

Soil, silty, gray-brown (2± feet).

Red Eagle limestone:

Howe limestone member:	Feet
5. Limestone, hard, gray-orange, limonite-stained; weathers gray and blocky; microfossils very abundant and give limestone sandy appearance	0.9
4. Limestone, medium-hard, tan-brown, porous; weathers blocky; celestite nodules on surface	.8
Thickness exposed	1.7

Bennett shale member:	
3. Shale, silty, calcareous, thin-bedded, olive-drab, limonite-stained, very fossiliferous; weathers tan	9.4

	Feet
Glenrock limestone member:	
2. Limestone, medium-hard to soft, light-gray mottled with gray-brown, porous; weathers blocky; clay nodules abundant; oolitic texture near base; fusulinids in middle part	0. 8
Total thickness of Red Eagle limestone exposed	11. 9
Johnson shale:	
1. Shale, silty, calcareous, thin-bedded, tan-gray; weathers tan; calcareous lenses and nodules present	4. 0
Base covered.	

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