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PRELIMINARY REPORT AND MAPS ON THE GEOLOGIC CONSTRUCTION MATERIAL RESOURCES IN WABAUNSEE COUNTY, KANSAS

by

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PREPARED IN COOPERATION WITH
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PRELIMINARY REPORT ON THE

GEOLOGIC CONSTRUCTION MATERIAL RESOURCES

IN WABAUNSEE COUNTY, KANSAS

by

Melville R. Mudge and Robert H. Burton

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 Wabaunsee County investigation is a part of the general inventory, and a contribution to the geologic mapping and mineral resource investigation being made in connection with studies of the Missouri River Basin.1/ A field party composed of personnel from the two

1/ Missouri River Basin, conservation, control, and use of water resources: 78th Cong., 2d sess., S. doc. 191, 1944.

cooperating agencies undertook an investigation of sources of engineering construction materials in Wabaunsee County, Kans. in the summer of 1948. A map was prepared to show the geologic occurrence of the construction materials and is appended to this report. (See pl. 1.)

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

<u>Area covered by the investigation</u>.--Wabaunsee County is in the third tier of Kansas counties south of the Nebraska border and in the fourth tier west of Missouri. (See fig. 1.) The county is bounded on the north by Pottawatomie and Shawnee Counties, on the west by Riley, Geary and Morris Counties, on the south by Morris and Lyon Counties, and on the

east by Osage and Shawnee Counties.

Topography.--Wabaunsee County is near the western boundary of the Central Lowlands physiographic province.2/ The county is included in that

2/ Frye, J. C., and Swineford, Ada, the Plains Border physiographic section: Kansas Acad. Sci. Trans., vol. 52, no. 1, pp. 71-81, 1949.

subdivision of the Central Lowlands province known as the Osage Prairie, and the Flint Hills escarpment extends through the western part. The Flint Hills have been carved by streams from alternating beds of shale and flint-bearing limestones. Many of the limestones form conspicuous benches on the hillsides above the streams that dissected them. The shales are more rapidly eroded than the limestones and, therefore, form the steep slopes between benches.

Glacial sediments, both till (deposited directly by glacial ice) and outwash (deposited by meltwater from a glacier) occur in the northern part of the county. Terrace deposits are found along most of the streams, and small deposits of wind-blown silt (loess) occupy the crests of many inter-stream areas, especially in the southern part of the county.

Drainage.--The principal stream in Wabaunsee County is the Kansas River which flows eastward along the northern boundary. (See pl. 1) The northern and western parts of the county lie in the drainage basin of Mill Creek and its numerous tributaries, whereas the southern part is drained by Rock Creek, Marais Des Cygnes River, Dragoon Creek, and Mission Creek.

Climate.--Wabaunsee County is in an area of continental-type climate in which the summers are relatively long and hot and the winters short and fairly cold. The mean annual temperature is 55° F. and ranges from a mean of 29° F. in January to a mean of 79° F. in July. There are 85 cloudy days, 100 partly cloudy days, and 180 clear days in a year. The average date of the first killing frost in the fall is October 18, the average date of the last killing frost in the spring is April 14, and the ground is covered with snow 25 days of the year.3/

3/ Flora, S. D., The climate of Kansas: Kansas State Board of Agriculture, vol. 67, no. 285, 1948.

Figure 2, a chart showing temperature ranges at Eskridge, Kans. was compiled from Climatological Data 4/ for the years 1937 to 1946, inclusive,

4/ Weather Bureau, U. S. Department of Commerce, Climatological Data, Kansas section.

to provide basic data on temperatures in relation to engineering construction. The chart indicates, for the 10-year period, the number of days each month in which the maximum daily temperature fell within ranges based on temperatures important in various phases of engineering construction.

Days in which the maximum temperature does not exceed 32° F. occur only from November to March, inclusive, with the maximum incidence, 7.5 days, in January. July is the warmest month of the year, and on an average there are 19.1 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, 26°F., is in July; and the least difference, 19° F., is in December and January.

Inasmuch as precipitation also influences the number of working days in engineering construction, figure 3, a chart showing precipitation ranges at Eskridge, Kans. is presented to show the effect of this climatic factor.

During the ten-year period of 1937 to 1946 (Climatological Data, Kansas section, 1937-1946) there averaged 17.9 days in June, for example, without measurable precipitation, 5 days in which the precipitation ranged from a trace to 0.1 inch, 5.3 days in which 0.11 to 1 inch of rain fell, and 1.9 days in which the precipitation was more than 1 inch. Continuing rains, for the most part, fall in the late spring and early autumn. Other rainfall is generally in the form of showers. The normal annual precipitation is 33.94 inches.

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

There are no transcontinental (U.S.) highways in Wabaunsee County but there are 6 State highways. (See pl. 1 and highway map at end of report.)

Roads follow section lines in the relatively broad, flat areas. Where the topographic relief is great, however, the roads have been located in stream valleys and, in some cases, in the interstream areas. In the central and western parts of the county, where dissection has been greatest, roads are relatively few. Twenty-five miles of the State highways are constructed of bituminous materials; otherwise they are metalled with sand-gravel. All county roads are metalled with local material. Township roads are metalled or are maintained as earth roads.

Investigation procedure

The base map used in the field was compiled from aerial photographs (scaled 8 inches equal 1 mile) provided by the Production and Marketing Administration of the United States Department of Agriculture. The photographs were also used in the placement of the contact lines between adjacent stratigraphic units. Some of the mapped units are single geologic formations; most of them are composed of two geologic formations; a limestone and the shale overlying it. The mapped stratigraphic units are those recognized by the United States Geological Survey 5/ and the Kansas

5/ Wilmarth, M. G., Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pts. 1 and 2, 2396 pp., 1938.

Geological Survey.6/ The principal emphasis of this report is on

6/Moore, R. C., Frye, J. C., and Jewett, J. M., Tabular description of outcropping rocks in Kansas: Kansas Geol. Survey Bull. 52, pt. 4, 212 pp., 1944.

construction materials. Those geologic problems which are not critically related to construction materials are considered to be of secondary importance. Fossils were identified and used by the field party as an aid to the identification of stratigraphic units. The names of the fossils and the units in which they occur are on file in the office of the U. S. Geological Survey, Kansas State College, Manhattan, Kans.

An effort was made to accumulate all existing data pertaining to construction materials in the county; these are presented in table 1, a summary of material tests.

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; the State Geological Survey of Kansas at Lawrence, Kans., J. C. Frye, executive director, and J. M. Jewett, geologist. We wish to thank H. Diepenbrock, engineer of Wabaunsee County for his aid in the materials survey and the many residents of Wabaunsee County who so readily cooperated with us.

This report, in manuscript form, was reviewed by various members of the State Highway Commission of Kansas.

CHARACTERISTICS OF THE OUTCROPPING

STRATIGRAPHIC UNITS

Introduction

This discussion of the outcropping stratigraphic units of Wabaunsee County emphasizes the areal distribution, general characteristics, thickness, and the construction materials in each formation or group of formations. This part of the report presents the geological 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 figures 4A to 4F. The areal distribution of the local stratigraphic units is shown on plate 1, a geologic map of Wabaunsee County, and each mapped unit is indicated by an identifying symbol. Concentrations of glacial boulders are shown as black dots, the number of dots indicates in a general way the abundance of boulders in an area. Groups of formations of the Quaternary, Pennsylvanian, and Permian systems are shown by distinctive patterns overprinted in color. For convenient use in the field, plate 1 is printed in 6 parts.

Figure 5 shows the areal distribution of limestones known to be of value in engineering construction.

The locations of pits and quarries are shown also on plate 1. The symbols indicate (1) whether the pit or quarry is being operated, has been operated, or is a prospect; (2) the type of construction material available at each site; and (3) the estimated 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 materials according to the following plan: the numbering starts in the northeast township and continues west along the same tier to the west boundary of the county; it is continued in the next tier south starting again with the east township and proceeding to the west boundary of the county, and so on. Within a township the sources are numbered in the same sequence as are the sections of the township.

Quaternary system

The most recently deposited sediments in Wabaunsee County are those of the Quaternary system (see fig. 4A), nearly all of which are unconsolidated; exceptions are cemented zones of local extent in the basal parts of some deposits of gravel. These sediments are non-marine in origin and were deposited by wind, streams, glaciers, or by mantle creep. Deposits formed by the wind occur on the tops of some of the interstream areas and along some of the valley sides. Stream-deposited sediments are present along all of the major streams and their tributaries and are usually restricted to the stream valley, but may also occur at higher levels on the valley walls of some of the larger streams. Glacial deposits cover much of the area north of Mill Creek. The materials which were moved by creep or slopewash are present along the sides of most of the valleys and are on some of the rock benches as well.

Alluvium

Areal distribution.--Sediment deposited by a stream on its present floodplain is known as alluvium (see fig. 4A) and is identified on plate 1 by the symbol Qal. Alluvium is present along the Kansas River; its width ranges from a narrow strip in the vicinity of Wamego to a maximum of 1.5 miles in other places; its average width is about 0.5 mile. The floodplain along Mill Creek extends from Maple Hill to a point 1 mile southwest of Volland. The portion of Mill Creek extending from Maple Hill to the Kansas River is deeply incised in a terrace deposit and the alluvium is restricted to the stream channel. Small areas of alluvium are mapped along Mission Creek from a point near Keene eastward to the county line; along Dragoon Creek in the vicinity of Harveyville; and along the southern part of the Marais Des Cygnes River. The average width of alluvium along the smaller streams is about 0.25 mile. These deposits are usually widest on the inner curve of meanders.

General description.--Alluvium deposited in the channel of the Kansas River consists predominantly of particles of sand and gravel size. The material deposited above normal water level is fine sand and silt with some lentils of coarse gravel. The sand is composed principally of quartz, but contains feldspar, acid igneous rocks, and a small amount of chalcedony. The silt is mixed with some clay, and is tan-brown to gray-brown. The gravel lenses are composed of sub-rounded or rounded pebbles of local limestone and chert. Small percentages of clay, fine sand, and silt also are present in the gravel lenses. Sand bars occur near the inner bank of a meander and consist of fine to coarse sand intermixed with some local material of gravel size.

The alluvium of the other streams is composed of gray-brown silt and clay, but commonly contains thin lenses of chert and limestone gravel in the lower part. Bars of limestone and chert gravel occur in some of the stream beds. The gravel particles range in size from granules to boulders, but those of pebble size are the most numerous.

Thickness.--Although accurate determination of the thickness of the alluvium in the various streams could not be made, it is estimated that the maximum thickness of the alluvium of the Kansas River is about 100 feet: of Mill Creek, 50 feet; of Mission Creek, about 30 feet; Dragoon Creek, about 30 feet; and the Marais Des Cygnes River, about 25 feet.

Construction materials.--

Aggregate for concrete.

Road metal.

Travertine

Areal distribution.--Deposits of travertine are formed by the precipitation of calcium carbonate from spring water, and three such deposits were found in Wabaunsee County. (See fig. 4A.) The largest deposit is in the $SE\frac{1}{4}$ sec. 12, T. 12 S., R. 10 E. and the other two are in the $NE\frac{1}{4}$ sec. 21, T. 12 S., R. 10 E. and the $SW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 4, T. 14 S., R. 11 E.

General description.--The material is calcium carbonate and is gray to light gray, soft, and porous. It contains numerous imprints of leaves and twigs. The deposit looks like a badly weathered limestone with its bedding planes steeply inclined. A small spring adjacent to the largest deposit flows from the base of the Neva limestone and probably was the source of the material.

Thickness.--The largest deposit of travertine is about 12 feet thick, but the two other deposits are less than 6 feet thick.

Construction material.--

Calcareous binder.

Terrace deposits

Areal distribution.--Terrace deposits of Quaternary age are mapped in the valleys of most streams in Wabaunsee County. (See fig. 4A and pl. 1.) Two well-defined terrace levels are mapped along the Kansas River. The older (higher) terrace in indicated on plate 1 by the symbol Qt_1 and the lower level, which is more extensive, by the symbol Qt_2. Terrace deposits along streams other than the Kansas River and Mill Creek are shown as Qt on plate 1. The average width of the terrace deposit on the south side of the Kansas River is 3 miles. The width of the Mill Creek terrace does not exceed 1 mile, and those along other streams are not more than 0.5 mile.

General description.--The terrace deposits are composed of materials laid down by present-day streams in earlier cycles of deposition. They consist of predominantly silt- and clay-size particles, but contain some lenses of sand, and chert and limestone gravel. The silts and clays are usually gray to red brown, and grade downward to gray brown. The terrace materials stand in a vertical bank and columnar jointing is commonly displayed. Shells of small snails and clams are abundant in some zones.

The gravel lenses are composed of angular to subangular limestone and chert particles that vary in size from granules to cobbles; pebble-size particles are the most abundant. Sand lenses containing erratics occur in the Kansas River and Mill Creek terraces.

Thickness.--Terrace height above stream level ranges from a few feet along small streams to 80 feet or more along the Kansas River. Exact thickness of the terraces cannot be determined without drill-hole data.

Such data would reveal how much of the Kansas River and Mill Creek terraces is underlain by glacial sediments and what part of the thickness of the terrace is to be ascribed to these sediments.

Construction materials.--

Aggregate for concrete.

Road metal.

Mineral filler.

Sanborn formation

Areal distribution.--The Sanborn formation is the most widely distributed stratigraphic unit that crops out in Wabaunsee County. (See fig. 4A and pl. 1.) Frye and Fent7/ have subdivided the formation into members,

7/ Frye, J. C., and Fend, O. S., Late Pleistocene loesses of Central Kansas: Kansas Geol. Survey Bull. 70, pt. 3, pp. 41-51, 1947.

but this subdivision is not feasible in a construction materials inventory; therefore, the Sanborn formation is treated as an undivided unit in this report.

As defined in this report, the Sanborn formation consists of materials deposited by wind, slopewash, streams, and through the action of soil or mantle creep. This formation occurs on the crests of interstream areas, along the margins of the terraces of the major streams, and in the valleys of their tributaries. It is also found on limestone benches at various levels above the streams.

General description.--Wind-deposited silt (loess) is found in small outcrops in Wabaunsee County. These are probably of two different ages (Loveland and Peorian), but are not mapped separately on plate 1 because their materials characteristics are not markedly unlike. The loess is a gray-brown to red-brown clayey silt. In the SE$\frac{1}{4}$ sec. 22, T. 14 S., R. 12 E. there is a deposit of calcium carbonate 2.5 feet thick beneath 7.5 feet of loess. This deposit is the result of deposition of calcium carbonate on an impermeable fossil soil developed in an underlying layer of still older loess. The part of the Sanborn moved by slopewash and mantle creep is a heterogeneous mixture of silt, clay, and granule to boulder-size fragments of local limestone and shale. The stream-deposited material of the Sanborn formation is composed of gray to red-brown silt and clay with lenses of angular to subangular chert and limestone particles.

An extensive deposit of chert and limestone in the Sanborn formation is located in the NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 26, T. 11 S., R. 11 E. and extends into sec. 25, T. 11 S., R. 12 E. Clay and fine sand are intermixed with the gravel and the former causes some zones to be cemented. Cross-bedding is well displayed in the cemented zones of the deposit. There are some glacial erratics included in the gravel. The total thickness of the deposit is about 10 feet.

There is another large gravel deposit in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 22, T 11 S., R. 12 E. The gravel is composed of chert fragments of pebble size, but cobbles and boulders of limestone, and erratics are also present. Intermixed red-brown silty clay acts as a binder for the gravel particles. There is a firmly cemented conglomerate near the base. The total thickness of this deposit is 9.1 feet. Small tributary valleys contain angular gravels of local limestone, chert, and shale.

Thickness.--The average thickness of the Sanborn formation is 15 feet. It ranges from a feather-edge in some areas to a maximum of 50 feet in the southwestern part of the county.

Construction materials.--

Road metal.

Mineral filler.

Concrete aggregate.

Glacial till

Areal distribution.--Considerable glacial material was deposited in the northern part of the county during the Pleistocene epoch. It is shown by the map symbol Qgt on plate 1 and its characteristics are summarized in fig. 4A. Todd 8/ and other writers believe these deposits were laid down by,

8/ Todd, J. E., Kansas during the Ice age: Kans. Acad. Sci. Trans., vol. 28, pp. 33-47, 1918.

or in association with, the Kansas ice sheet. The till was deposited directly by melting ice, and large areas of it are partly covered by the more recent Sanborn formation. It is difficult to distinguish till from clayey silt of the Sanborn when the latter has been derived from the till.

The area covered by glacial till is north of a line that extends from the northwestern corner of the county to 1.5 miles north of McFarland, follows Mill Creek east to Maple Hill, then swings southeastward to Dover in Shawnee County. This line also marks the maximum advance of the ice sheet. Till exposures are numerous in stream banks in sec. 1, T. 11 S., R. 10 E.

General description.--The unconsolidated sediment referred to in this report as glacial till is a heterogeneous mixture of unstratified clay, silt, and erratics. Clay is the principal constituent of till, but particles the size of silt, sand, granules, pebbles, cobbles and boulders are also present. Lenses of fine, cross-bedded sand occur in some places. Occasionally an erratic-free clay zone is incorporated in the till, but these zones are local and small in size. The till is gray-brown to tan, and much of it is iron-stained. Some fragments of chert, limestone, and petrified wood are present in it.

There are numerous concentrations of boulders within the area covered by glacial till, and they are most conspicuous in areas where the finer materials have been removed by slopewash. (See pl. 1.) They are located on the top and especially on shoulders of the hills, and smaller boulders and cobbles are found abundantly in many of the valleys of small streams. The largest concentration of boulders is in secs. 1, 2, and 3, T. 11 S., R. 10 E. and secs. 24, 26, 34, and 35, T. 10 S., R. 10 E. The boulders are granite and other acid igneous rocks, basic igneous rocks, quartzite, "greenstone" and other metamorphic rocks, and some sandstone. Boulders and cobbles of quartzite are the most numerous erratics. The largest erratic found, a quartzite boulder, measures 18x17x6 feet.

Thickness.--The thickness of the glacial till varies from a featheredge to about 50 feet. Its thickness could not be determined in some places because of the presence of the Sanborn formation.

Construction materials.--

Aggregate for concrete.

Riprap.

Glacial outwash

Areal distribution.--Glacial outwash is the material carried by streams flowing away from or parallel to the ice front. It is possible that some of the alluvium of the Kansas River and Mill Creek is glacial outwash, and that these streams carried away most of the material that was being discharged by the glacier. Much of the outwash deposited in this area is covered by glacial till. The outwash in Wabaunsee County is mapped on plate 1 as (1) a kame-like deposit, Qgk, and (2) a more-or-less typical outwash gravel, Qgo.

The kame-like material is found on several inter-stream areas in secs. 7 and 16, T. 11 S., R. 12 E. and sec. 11, T. 11 S., R. 11 E. The glacial outwash was found only in secs. 9 and 10, T. 12 S., R. 13 E. but probably extends eastward into Shawnee County.

General description.--The kame-like material probably was deposited as a small delta or cone resting against the front of the glacier and collapsed as the ice front melted back. It is a fine to coarse sand with red-brown silt. Various kinds of small erratics occur in these deposits together with numerous clay balls and limestone and chert fragments. These deposits overlie glacial till and are topographically higher than any other glacial sediments in the area.

The glacial outwash is composed of particles ranging in size from fine sand to boulders. Limestone shale and chert fragments are intermixed with a variety of igneous and metamorphic rocks. Some of the limestone particles are foreign to this area and are well rounded, as are most of the erratics. Size sorting and cross-bedding in the gravel is apparent. Zones cemented with calcium carbonate occur at various horizons. The gravels were deposited directly upon the Pennsylvanian units in this area.

Thickness.--The average thickness of the kame-like deposits is 6 feet, and the glacial outwash is about 30 feet.

Construction materials.--

Aggregate for concrete.

Road metal.

Mineral filler.

Older gravels

Areal distribution.--Two kinds of gravels (see fig. 4A) recognized to be older than glacial outwash are mapped as Qog on plate 1. These gravels were stream deposited, are pre-Kansas in age, and may have been deposited during the Nebraskan glacial stage. J. E. Todd 9/ cites similar chert

9/ Todd, J. E., History of Kaw Lake: Kans. Acad. Sci. Trans., vol. 28, pp. 190-191, 1918.

gravels west of Manhattan, Kans., northeast of St. George, and northeast of Lawrence. He believed these gravels to have been deposited before the Kansan ice sheet moved into the area and thought that they might be as old as Pliocene. Thick beds of chert gravel, overlain in most places by glacial till, extend from a point 2 miles southwest of Alma to the Kansas River terrace south of St. Marys, Kans. This chain of chert gravels is about 60 feet above the present stream terraces and, because deposits are restricted in a narrow band, it is assumed that a pre-Kansan channel of Mill Creek extended from Alma to St. Marys.

Two other gravel deposits, these consisting mostly of limestone particles, are located in secs. 26 and 27, T. 11 S., R. 10 E. They are overlain by scattered erratics, but careful examination did not disclose any of the erratics within the beds of gravel. One deposit is located adjacent to, but at a slightly higher level than, Pretty Creek. The other deposit is located about 130 feet above Pretty Creek. The age of these deposits may correspond with that of the chert gravels or they may have been deposited early in the Kansan glacial stage before the ice sheet had reached this vicinity.

General description.--The chert gravels are composed predominantly of fragments of pebble and granule sizes. The particles are subrounded to angular, and are intermixed with red-brown silt and clay. The deposits include some lenses of clay, silt, and very fine sand. The limestone gravels contain well-rounded fragments of limestone and angular chert fragments that range from granules to cobbles in size. Some red-brown silts and clays, fine sand, and particles of gray to gray-green shale are incorporated in the gravels.

Thickness.--The average thickness of the chert gravels is 8 feet, and the maximum is 20 feet. The average thickness of the limestone gravels is 6 feet, and the maximum is 10 feet.

Construction material.--

Road metal.

Permian system

General

The most numerous outcropping stratigraphic units in Wabaunsee County are those of the Permian system of which all are a part of the Wolfcamp series. (See figs. 4A to 4E.) The basal formation of the Wolfcamp series is the Towle shale. The lower part of this shale locally contains a channel sandstone which is defined as the horizon separating the Permian and Pennsylvanian systems in this region. The Wolfcamp series is divided into three groups which are, in descending order, the (1) Chase, (2) Council Grove, and (3) Admire. The areal distribution of the three groups is shown on plate 1 by overprints in distinctive color patterns.

The rocks of the Permian system that outcrop in Wabaunsee County are here discussed according to groups of formations, starting with the youngest (uppermost), the Chase group. Key beds, ones which are more easily identified than other formations, will be indicated in the following descriptions. Those units which are not considered key beds are best identified by their position above or below a key bed.

Chase group

General.--The Chase group is the uppermost group of formations in the Wolfcamp series of the Permian system. (See figs. 4A and 4B.) Each formation and the members of which it is composed will be described separately but outcrop areas of formations are shown on plate 1 according to the following plan:

Map unit	Formation	Member
Pb	Doyle shale	Gage shale
		Towanda limestone
		Holmesville shale
	Barneston limestone	Fort Riley limestone
		Oketo shale
		Florence limestone
Pwr	Matfield shale	Blue Springs shale
		Kinney limestone
		Wymore shale
	Wreford limestone	Schroyer limestone
		Havensville shale
		Threemile limestone

Areal distribution.--Only the lower part of the Chase group outcrops in Wabaunsee County. (See figs. 4A and 5, and pl. 1.) The formations present in this county are, in descending order: the (1) Doyle shale, (2) Barneston limestone, (3) Matfield shale, and (4) Wreford limestone. The two limestones are flint-bearing and form prominent hillside benches in the southwestern part of the county. Two successive formations, a limestone overlain by a shale, are shown as a single map unit on plate 1. The symbol identifying the outcrop area of each map unit is adapted from the name of the limestone.

Limestones known to be sources of construction materials are shown in figure 5 in which the outcrop of each limestone is shown by solid and dashed lines. The solid line indicates places where the limestone can be quarried in quantities of 10,000 cubic yards or more; the dashed line indicates the occurrence of the limestone in quantities less than 10,000 cubic yards. Each limestone is identified by an appropriate symbol.

Doyle shale.--The Doyle shale crops out only in a small area in the southwestern part of the county and is shown on plate 1 as part of the map unit Pb. (See fig. 4A and pl. 1.) This formation is divided into three members which are, in descending order, the (1) Gage shale, (2) Towanda limestone, and (3) Holmesville shale. Only the Holmesville shale member crops out in this County.

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

Barneston limestone.--The Barneston limestone is shown on plate 1 as part of the map unit Pb. It crops out in the southwestern part of the county. It is divided into three members which are, in descending order, the (1) Fort Riley limestone, (2) Oketo shale, and (3) Florence limestone. (See figs. 4A and 4B.)

(1) Fort Riley limestone member. Outcrops of the Fort Riley limestone are conspicuous in the area north and east of Alta Vista. (See Pb on pl. 1 and FR in fig. 6.) The Fort Riley consists of massive layers of limestone, often separated by thin shale partings. A shale parting is commonly present near the base of this member. Some of the limestones weather and erode to form conspicuous ledges whereas others weather in a manner similar to shale. The limestones vary from hard, massive beds to soft, dolomitic beds, and are tan to tan-gray. They are somewhat porous, and contain limonite-stained zones.

There are two "rim rock" ledges present in the Fort Riley limestone in this County, one near the base and the other near the middle, but most of the rim-rock outcrops are those of the lower ledge. A rim rock is a massive limestone and, being very resistant to weathering and erosion, it forms a conspicuous rim on the shoulders of many hillsides. The ledge ranges from 3 to 6 feet thick, and usually becomes porous when weathered. Rim-rock outcrops are prominent on hillsides in sections 27, 28, 29, and 30, T. 13 S., R. 9 E. In this area there are two limestones in the Fort Riley and each has the rim-rock characteristics. Each limestone is 4 feet thick in the eastern outcrop area and thins toward the west. They are separated by 6 feet of calcareous shale. This member is about 25 feet thick and fossils are common.

The Fort Riley limestone is a useful marker bed and is easily recognized by massive blocks weathered from the rim-rock ledge and by its position above the flint-bearing Florence limestone.

(2) Oketo shale member. The Oketo shale crops out in the southwestern part of the county, but is largely obscured by weathered material from the overlying Fort Riley limestone. The Oketo shale is thin-bedded to blocky, silty, and calcareous. It is commonly hard and well cemented, depending on total lime content. Calcite-lined geodes are common in blocky shales. The Oketo is tan-gray to gray, and locally is mottled blue-gray. This shale, in most outcrops, is sparsely fossiliferous. Its thickness ranges from a featheredge, in secs. 18 and 19, T. 13 S., R. 9 E., to 8 feet in sec. 36, T. 13 S., R. 8 E.

The Oketo shale is easily recognized by its position between the underlying flint-bearing Florence limestone and the overlying Fort Riley limestone.

(3) Florence limestone member. The Florence is a prominent and easily recognized flint-bearing limestone forming benches in the area south and southwest of Alma. The benches are characterized by smooth, rounded shoulders covered by chert fragments 3 to 4 inches in diameter. Numerous isolated knolls of Florence limestone between Illinois and South Branch Mill Creeks, rise 50 to 70 feet above the broad, flat bench formed by the Wreford limestone.

The Florence member consists of massive limestone beds containing numerous chert nodules and lenses. The chert is dense, hard and fractures conchoidally. It is usually steel-gray to light-gray, and is often limonite stained on the surface. Chert, more resistant to weathering than the limestone which encloses it, weathers out in small blocks and generally covers the face of the outcrop. The limestone beds are moderately hard, gray, and massive. There are thin lentils of tan-gray shale. Fossils are common in certain shale and limestone beds. The average thickness of this member is 30 feet.

The Florence limestone is easily recognized by the abundance of chert, its thickness, the rounded hillside shoulders it forms, and by its position above the Wreford bench.

Matfield shale.--The Matfield shale is shown on plate 1 as part of the map unit Pwr. It is divided into three members which are, in descending order: the (1) Blue Springs shale, (2) Kinney limestone, and (3) Wymore shale. The Matfield shale is present beneath the prominent benches formed by the Florence limestone but is normally covered by slump and soil. Part of the formation is exposed in road cuts, ditches, stream banks, and at the heads of tributaries that have eroded up to the Florence limestone. The thickness of the Matfield shale is about 70 feet.

(1) Blue Springs shale member. Outcrops of the Blue Springs shale are associated with the Florence limestone exposure. A typical exposure of this shale is in a stream bank in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 19, T. 13 S., R. 9 E. It is a silty and calcareous shale, and includes interbedded tan-gray, green, maroon, and purple layers with the gray and green layers being most conspicuous. No fossils were observed in this member. The average thickness of the Blue Springs shale is 40 feet.

This shale is easily recognized by its vari-colored beds and its position beneath the prominent bench formed by the Florence limestone.

(2) Kinney limestone member. The Kinney limestone outcrops on many hillsides about 40 feet beneath the Florence limestone but rarely does it form a recognizable bench. Knolls capped by the Kinney limestone are in sec. 16, T. 12 S., R. 9 E.; secs. 7 and 32, T. 12 S., R. 10 E.; and secs. 5 and 30, T. 13 S., R. 10 E. A good exposure of the Kinney limestone is in a road cut in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 27, T. 13 S., R. 9 E. This limestone is hard, massive, tan-gray, and weathers into irregular blocks. Clay lentils are common in it. The upper part is

commonly stained red by iron oxide derived from the overlying shale. The Kinney limestone is fossiliferous throughout and microfossils are abundant in the upper part. The average thickness of this member is 2 feet.

The Kinney limestone is easily recognized by its tan-gray color, softness, massiveness, the microfossils occuring in its upper part, and its position about 40 feet beneath the Florence limestone.

(3) Wymore shale member. The Wymore shale constitutes the basal member of the Matfield shale. This shale is exhibited in a stream bank and road cut in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 27, T. 13 S., R. 9 E. It is composed of silt and clay, and is generally calcareous. The shales are tan, gray, green, and maroon in the basal part of the member, and tan in the upper part. A thin bed of limestone occurs in some places in the center of this shale and is commonly overlain by a fossiliferous tan shale. The thickness of the Wymore shale is about 30 feet.

The Wymore shale is best identified by its position above the easily recognized Schroyer limestone member of the Wreford limestone.

Wreford limestone.--The Wreford limestone is the basal formation of the Chase group (see fig. 4B), and is shown on plate 1 as part of the map unit Pwr. Prominent hillside benches formed by this formation crops out in the area south and east of Alma and southwest and west of Eskridge. The Wreford limestone is divided into three members which are, in descending order: the (1) Schroyer limestone, (2) Havensville shale, and the (3) Threemile limestone.

(1) Schroyer limestone member. Outcrops of the Schroyer limestone are closely associated with those of the Threemile limestone. Where these two members are present, the Schroyer limestone usually forms a less conspicuous bench above and farther back on the hillside than the prominent, round-shouldered bench formed by the Threemile limestone. The bench of the Schroyer limestone is generally covered by a thin mantle of Sanborn formation.

The Schroyer limestone consists of alternating thick limestone beds and thin lenses of chert and scattered chert nodules. The limestone is moderately hard, tan-brown to gray, massive, and usually weathers blocky and porous. The chert is dark-gray to light gray, hard and dense. The weathered surface of the Schroyer limestone has an appearance similar to that of the weathered Florence limestone in that it is mantled by numerous chert fragments. Fossils are common in this limestone. The total thickness of this member is about 8.5 feet.

The Schroyer limestone is recognized by the presence of numerous chert lenses and nodules in it and by its position above the tan-gray shales of the Havensville. Outcrops of the easily recognized Threemile limestone commonly occur at a lower level on the same hillside.

(2) Havensville shale member. The Havensville shale is composed predominantly of shale but includes a limestone lens in its upper part. The shales are clayey near the base, and are silty in the upper part. They are gray-green to gray, and are thin-bedded to blocky. Calcium carbonate nodules are present in the middle part of the member. The limestone lens is nearly 2 feet thick, and is hard, tan, and massive. Fossils are present only in the limestone. The average thickness of the Havensville shale is about 18 feet, but in the western part of the county it thins to about 6 feet.

The Havensville shale is easily recognized by its position between the two chert-bearing limestone members of this formation.

(3) Threemile limestone member. The Threemile limestone caps most of the interstream areas south of Mill Creek in the central and south-central parts of the county. This limestone crops out in road cuts and stream banks in this area. This member is composed of layers of limestone, most of which contain nodules and thin lenses of chert. A thick non-cherty limestone bed occurs near the top of the member and generally there is a thin, gray, fossiliferous shale near the base. The basal limestone of this member contains 2 or 3 chert lenses. The limestone beds are white to light-gray, weather gray, and commonly fossiliferous. The average thickness of the member is 10 feet.

A local reef in the Threemile limestone is exposed in a stream bank in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 26, T. 13 S., R. 9 E. The total exposed thickness of the member at this location is 32.95 feet. The upper part of the limestone, 23.4 feet thick, is very massive, soft, and porous. The lower part, 9.55 feet thick, contains massive beds of soft, dolomitic limestone separated by lenses of chert. A very fossiliferous shale occurs near the top of the Threemile limestone in the southern part of the county. Fossils also occur in some of the limestone beds. A somewhat thinner section of the Threemile is exposed in a road cut in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 10, T. 15 S., R. 10 E. This same reef extends southwest into Morris County, but cannot be traced more than a mile north of the location cited.

The Threemile limestone is a good marker bed and is easily recognized by the persistent shale parting near the base, the abundance of chert, and by the presence of the vari-colored Speiser shale beneath it.

<u>Construction materials in the Chase group</u>.--

Structural stone.

Road metal.

Aggregate.

Riprap.

Council Grove group

General.--The Council Grove is the middle group of formations in the Wolfcamp series of the Permian system. (See figs. 4C to 4E.) The group includes the formations from the Foraker limestone up to and including the Speiser shale. The formations and members will be described separately, but their outcrop areas are shown on plate 1 according to the following plan.

Map unit	Formation	Member
Pf	Speiser shale	
	Funston limestone	
Pc	Blue Rapids shale	
	Crouse limestone	
Pba	Easly Creek shale	
	Bader limestone	Middleburg limestone
		Hooser shale
		Eiss limestone
Pbe	Stearns shale	
	Beattie limestone	Morrill limestone
		Florena shale
		Cottonwood limestone
Pg	Eskridge shale	
	Grenola limestone	Neva limestone
		Salem Point shale
		Burr limestone
Pre	Roca shale	
	Red Eagle limestone	Howe limestone
		Bennett shale
		Glenrock limestone
Pfo	Johnson shale	
	Foraker limestone	Long Creek limestone
		Hughes Creek shale
		Americus limestone

Areal distribution.--Outcrops of the Council Grove group are distributed over nearly three-fourths of the area of the county, and are most extensive in the central part. (see pl. 1). The limestone formations form conspicuous hillside terraces and the intervening shales form the nearly vertical slopes between terraces.

Speiser shale.--The Speiser shale is shown on plate 1 as part of the map unit Pf. This is a silty, calcareous, and vari-colored shale. Tan-gray is the dominant color in the upper part, and green and maroon are conspicuous in the basal part, although in some places this formation is composed entirely of tan, gray, and olive-drab zones. A bed of thin, hard, massive limestone occurs near the top and several very thin limestones are present lower in the shale. Fossils are usually abundant in a tan shale that lies between the uppermost bed of limestone and the base of the overlying Threemile limestone member of the Wreford limestone. The average thickness of the Speiser shale is about 16 feet, but the formation locally thins to 4 feet in the western part of the county.

The Speiser shale is readily recognized by its vari-colored beds, the thin limestone in the upper part, and the tan-gray fossiliferous shale above this limestone.

Funston limestone.--The Funston limestone is shown on plate 1 as part of the map unit Pf. This limestone is usually composed of two limestones separated by a shale. The limestones are massive, soft, porous, light-gray, and are fossiliferous. The shale parting is silty, calcareous, tan, thin-bedded, and varies in thickness from 0.5 foot to more than 4 feet. The average thickness of the Funston limestone is about 6 feet.

In sec. 13, T. 12 S., R. 9 E. and sec. 18, T. 12 S., R. 10 E. the Funston limestone is 23.3 feet thick and is composed of numerous thin shale partings separated by thick soft limestones. In this area the limestone forms an unusually prominent bench. A road cut in the SW¼ SE¼ sec. 9, T. 12 S., R. 9 E. shows only 8.7 feet of the Funston limestone, but a section 24.85 feet thick is exhibited in a stream bank in the SE¼ NE¼ NE¼ sec. 24, T. 13 S., R. 9 E. In the latter place, the limestone is soft and massive, and is composed almost entirely of minute fossils. The weathered surface of the limestone develops a cross-bedded appearance which was observed also in some zones of outcrops in the northwestern and southern parts of the county. There is a fossiliferous shale 1.35 feet thick near the base of most sections of this formation. A section of 16.5 feet thick exposed in a road cut in the SW¼ NW¼ sec. 10, T. 15 S., R. 10 E. shows numerous beds of fossiliferous limestone separated by shale partings.

The Funston limestone is characterized by its soft, gray limestones, and by its position beneath the easily recognized Threemile limestone.

Blue Rapids shale.--The Blue Rapids shale is shown on plate 1 as part of the map unit Pc. It is usually a silty, calcareous, gray-brown, and thin-bedded shale. Some maroon and gray-green zones are usually present in the lower part, as well as a hard, massive, lenticular, tan-gray limestone. Fossils occur in some places in the middle part of the shale and in the limestone lens. The average thickness of this formation is about 16 feet.

The Blue Rapids shale is best identified by its position between the Crouse and Funston limestones.

Crouse limestone.--The Crouse limestone is composed of two limestones and a shale, and is shown on plate 1 as part of the map unit Pc. The lower limestone is hard, massive, tan-gray, and fossiliferous. The intervening shale is silty, calcareous, tan-gray, and is usually 7 feet thick. The upper part of this formation consists of numerous thin platy limestones which are separted by thin partings of shale. Small plates weathered from the limestones are scattered over the surface of the prominent bench formed by this formation. Its average thickness is about 13 feet.

The Crouse limestone is readily recognized by its numerous thin limestones which give the platy appearance so typical of its outcrops.

Easly Creek shale.--The Easly Creek shale is shown on plate 1 as part of the map unit Pba. It is usually silty, calcareous, and dark gray in the lower part, and gray-green, green, and maroon in the upper part. Thin beds of limestone usually occur in the lower half of the formation, and include a persistent bed of clayey limestone 1.3 feet thick. As observed in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 24, T. 12 S., R. 10 E. and in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 13, T. 12 S., R. 10 E, this limestone is massive, blocky, and shows wavy bedding near the top. No fossils were observed in this formation, and its average thickness is about 20 feet.

The Easly Creek shale is best identified by its position between the Crouse and Bader limestones.

Bader limestone.--The Bader limestone is shown on plate 1 as part of the map unit Pba. It is composed of three members which are, in descending order: the (1) Middleburg limestone, (2) Hooser shale, and (3) Eiss limestone. (See fig. 4D.) The average thickness of this formation is about 20 feet.

(1) Middleburg limestone member. The Middleburg limestone is composed of two limestones separated by a shale. The limestones are hard, massive, tan-gray to gray-brown, and fossiliferous. The shale is silty, calcareous, and tan-gray. The average thickness of the member is about 6 feet, and it forms a prominent hillside bench only in a few places, as in secs. 19 and 30, T. 12 S., R. 11 E. and secs. 24 and 25, T. 12 S., R. 10 E.

The Middleburg limestone is characterized by the two beds of limestone separated by a shale, and by its position between the easily identified Crouse and Eiss limestones.

(2) Hooser shale member. The Hooser is a usually silty, calcareous, and tan-gray to green shale. Thin maroon zones and fossiliferous lenticular limestones are present in some places. The average thickness of this member is about 6 feet.

The Hooser shale is best identified by its position immediately above the Eiss limestone.

(3) Eiss limestone member. The Eiss is composed of two limestones and a thin intervening layer of shale. The lower limestone is thin, shaly, tan-gray, and usually very fossiliferous. The upper limestone is tan-gray, massive, and forms a prominent hillside bench over most of the area of outcrop. This limestone weathers to form cavity-riddled blocks which measure about a foot on a side. Fossils are common in the limestones and in the lower part of the shale. The total thickness of the Eiss limestone is about 10 feet.

The Eiss limestone is readily recognized by the cavity-riddled blocks of limestone in the top part, and by the fossiliferous shaly limestone at the base.

Stearns shale.--The Stearns shale is shown on plate 1 as part of the map unit Pbe. It is composed of silty, calcareous, tan-gray to olive-drab shales, and one or more thin beds of shaly limestone, in most places in its middle part. This formation is nonfossiliferous, and has an average thickness of about 10 feet.

The Stearns shale can best be recognized by its position between the Bader and Beattie limestones.

Beattie limestone.--The Beattie limestone is composed of three members which are, in descending order: the (1) Morrill limestone, (2) Florena shale, and (3) Cottonwood limestone. Its average thickness is about 20 feet.

(1) Morrill limestone member. The Morrill limestone usually consists of two thin limestones and an intervening shale. The limestones are moderately hard, tan-gray, weather porous to cavernous, and locally show wavy banding. The shale is calcareous, silty, tan-gray, and thin-bedded. In the southeastern part of the outcrop area, the Morrill is a succession of thick beds of massive limestone separated by numerous thin partings of shale. However, in the vicinity of Eskridge, this member is very platy and its weathered surface resembles that of the Crouse limestone. No fossils were observed in this limestone. Its thickness ranges from 3 to 8 feet.

(2) Florena shale member. The Florena is a silty, calcareous, and tan to tan-gray shale. It is thin-bedded in the lower part and blocky in the upper part. Fossils are generally very abundant in the lower one third of the shale. In a few localities, a nonfossiliferous gray-green shale constitutes the upper part of the member. Its average thickness is about 9 feet.

The Florena shale is easily identified by its position above the Cottonwood limestone and by its fossils.

(3) Cottonwood limestone member. Erosion of the Cottonwood limestone develops a very conspicuous hillside bench characterized by massive limestone blocks and a persistent growth of bushes ("bushline") at the base of

the outcrop. This limestone is hard, massive, and tan-gray to light-gray. Two or three thin bands of chert nodules occur in its middle part, and other nodules are scattered throughout the rock. Solution channels have developed in most of the outcrops and may be as much as 6 inches in diameter. Small wheat-shaped fossils (fusulinids) are typical of the upper half of the limestone, but fossils are not numerous in the lower part. The average thickness of the Cottonwood limestone is about 6 feet.

The Cottonwood limestone is a very good marker bed and is easily identified by its thickness, thin bands of chert nodules, abundance of fusulinids, and the conspicuous "bushline" hillside bench it forms.

Eskridge shale.--The Eskridge shale is shown on plate 1 as part of the map unit Pg. It is a predominantly calcareous shale, silty in some zones and clayey in other, and vari-colored. Green and tan zones are typical of the upper part, and maroon, purple, olive-drab, green and gray zones of the remainder of the formation. There is a persistent, thin bed of, hard, massive limestone in the upper part, and several thin lenticular limestones appear locally in the lower part. Fossils are usually present in the limestones. The average thickness of the Eskridge shale is about 32 feet.

The Eskridge shale is readily identified by its thickness, vari-colored beds, and by its position beneath the Cottonwood limestone.

Grenola limestone.--The Grenola limestone is composed of three members which are, in descending order: the (1) Neva limestone, (2) Salem Point shale, and (3) Burr limestone. This formation is mapped on plate 1 as part of the map unit Pg. Its average thickness is about 27 feet.

(1) Neva limestone member. The Neva limestone is composed of thick limestones separated by beds of shale in the upper and lower parts of the member. The beds of limestone near the top and base of the member are hard, dense, and massive, whereas those in the middle part are soft, massive, and become porous when weathered. The uppermost ledge of limestone weathers into thin slabs in some exposures. The shales are silty, calcareous, and tan to blue gray. Fossils are generally numerous in the shales and in most of the limestones. The average thickness of this member is about 15 feet.

The Neva limestone makes a good marker bed. It forms a prominent hillside bench beneath the easily recognized bench of the Cottonwood limestone, and is readily identified by its thickness, shale beds present in upper and lower parts, and by the thick porous limestone in the middle part.

(2) Salem Point shale member. The Salem Point shale is silty, calcareous, olive drab or blue gray, and weathers tan. It includes numerous thin calcareous lenses which weather to small plates that mask part of the surface of an outcrop. This member is fossiliferous. Its average thickness is about 9 feet.

The Salem Point shale is best recognized by its position beneath the Neva limestone.

(3) Burr limestone member. The Burr limestone is composed of two or more beds of limestone separated by thin shales. The limestones are usually soft, massive, and tan to gray brown. The shales are silty, calcareous, and tan. There are fossils in most of the limestones, but not in the shales. The average thickness of this member is about 4 feet.

The Burr limestone is best recognized by its position beneath the Neva limestone and above the Roca shale.

Roca shale.--The Roca shale is shown on plate 1 as part of the map unit Pre. This shale is silty or clayey, calcareous, and tan near the top but green or purple throughout most of its thickness. Locally, the green shale in the middle part is mottled with maroon. A persistent bed of thin, hard, fossiliferous limestone occurs in the upper part. The average thickness of the Roca shale is about 18 feet.

The formation is best identified by its green zones, persistent limestone in the upper part, and its position beneath the Neva limestone.

Red Eagle limestone.--The Red Eagle limestone is shown on plate 1 as part of the map unit Pre. This formation is composed of three members which are, in descending order: the (1) Howe limestone, (2) Bennett shale, and (3) Glenrock limestone. Its average thickness is about 10 feet.

(1) Howe limestone member. Throughout most of its area of outcrop the Howe is a soft, massive, and tan to gray-orange limestone. Crystals of pink or white celestite are numerous in most exposures of this limestone. This member makes no more than a minor hillside bench. Its average thickness is about 4 feet. Fossils are numerous and microfossils occur abundantly in certain zones and are an aid in recognizing this member.

However, in the area south of Eskridge the Howe limestone is thick, hard, tan-gray, and massive. Locally it includes a thin shale parting and scattered nodules of chert, although a lens of chert occurs near the middle of the member in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 36, T. 14 S., R. 11 E. In the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 12, T. 15 S., R. 11 E. the Howe limestone is 13.9 feet thick, massive, contains some fossils, and is noncherty. Numerous limestone sinks are associated with this thickened phase of the member, such as those in secs. 30, 31, 32, and 33, T. 14 S., R. 12 E.; secs. 7 and 18, T. 15 S., R. 12 E.; and sec. 12, T. 15 S., R. 11 E. Also, it forms a very conspicuous hillside bench in these localities. In this development, the limestone ranges from 7 to 14 feet thick.

(2) Bennett shale member. The Bennett is usually a clayey, calcareous, thin-bedded to very thin-bedded, gray-brown to dark-gray shale. A thin lenticular limestone may occur in the middle part. Brown, thin-shelled fossils (Orbiculoidea) are numerous in almost all exposures of

this member, and it ranges from 3 to 7 feet thick.

This member is easily recognized by its dark-gray, thin-bedded shales, and brown, thin-shelled fossils.

(3) Glenrock limestone member. The Glenrock is a hard, massive, blocky, and tan-gray limestone. It is characterized by an abundance of small fusulinids scattered throughout the bed, and has an average thickness of 1.5 feet.

This member is absent in the vicinity of Alma, but the contact between the Bennett and Johnson shales is evident because of the abrupt change from the dark-gray shales of the Bennett to the light gray-green shales of the Johnson.

Johnson shale.--The Johnson shale is mapped on plate 1 as part of the map unit Pfo. This shale is usually silty, calcareous, and is tan to gray in the upper part and olive drab to gray green in the lower part. A thin, lenticular, clayey limestone is sometimes present in the middle part. Some of the harder, more calcareous beds of shale show wavy banding and numerous small folds. No fossils were found in this formation. Its average thickness is 25 feet.

The Johnson shale is identified by its gray-green calcareous shales and its position between the easily recognized Glenrock and Long Creek limestones.

Foraker limestone.--The Foraker limestone is shown on plate 1 as part of the map unit Pfo. This formation is composed of three members which are, in descending order: the (1) Long Creek limestone, (2) Hughes Creek shale, and (3) Americus limestone. Its average thickness is about 40 feet.

(1) Long Creek limestone member. The Long Creek is a soft, dolomitic, massive, gray to gray-orange limestone. Pink crystals of celestite which line geodes and the walls of small fractures are usually present in the upper part of the limestone. Fossils are rare or absent, but in some outcrops there is a shaly limestone composed almost entirely of fusulinids near the base. This member forms a small and poorly developed hillside bench. Its average thickness is 7 feet.

The Long Creek can be recognized by its color, softness, dolomitic character, and by the presence of celestite in the upper part and the bed rich in fusulinids in the basal part.

(2) Hughes Creek shale member. The Hughes Creek shale is silty, calcareous, and gray to dark gray. Lenses of soft, clayey, fusulinid-bearing limestone occur in the upper and middle parts of this member, and fossils are very abundant in most of the beds of shale. The average thickness of the Hughes Creek shale is about 30 feet.

This member is easily recognized by its dark shales and especially by the abundance of fossils it contains.

(3) Americus limestone member. The Americus limestone is composed of two limestones separated by a shale. The limestones are hard, massive, and weather blocky. Their color is gray to dark gray, but usually changes to tan gray upon weathering. The upper limestone is somewhat thicker and more massive than the lower one which, in addition, is shaly in most outcrops. The intervening shale is silty, calcareous, thin-bedded, and gray. Large, checker-like columnals of crinoids, and other fossils are common in the beds of limestones in this member. Its average thickness is nearly constant at 2.8 feet.

This member makes a good marker bed and is easily recognized by its two persistent beds of dark-gray limestone and by the consistency with which the crinoid columnals can be seen in all exposures.

Construction materials in the Council Grove group.--

Aggregate.

Riprap.

Structural stone.

Road metal.

Admire group

General.--The Admire is the basal group of formations in the Wolfcamp series of the Permian system. (See fig. 4E.) The break between the Admire Group and the underlying rocks of the Pennsylvanian system is poorly shown and is not apparent in most places, and is evident only where the Indian Cave sandstone member of the Towle shale is present. The formations which compose the Admire group are:

Map unit	Formation	Member
Pfp	(Hamlin shale ((Five Point limestone	(Oaks shale (Houchen Creek limestone (Stine shale
Pfc	(West Branch shale (Falls City limestone	
Pa	(Hawxby shale (Aspinwall limestone	
Pt	(Towle shale	(Unnamed shale
Pti	(Towle shale	(Indian Cave sandstone

Areal distribution.--The Admire group outcrops in a small area in the northern and eastern parts of the county, principally along both sides of Mill Creek as far west as Alma. (See pl. 1.) Because most of the units do not form prominent hillside benches, they are exposed only in road cuts and stream banks.

Hamlin shale.--Outcrops of the Hamlin shale are shown on plate 1 as part of the map unit Pfp. Moore, Frye, and Jewett 10/ divided the Hamlin

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10/ Op. cit., p. 169

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shale into three members which are, in descending order: the (1) Oaks shale, (2) Houchen Creek limestone, and (3) Stine shale. In parts of the outcrop area of the Hamlin shale in the northwestern part of this county, this formation is regarded as being composed of undifferentiated shales because of the absence of the Houchen Creek limestone member. The total thickness of the Hamlin shale is about 35 feet.

(1) Oaks shale member. As developed in Wabaunsee County, the Oaks shale is very thin and appears to be absent in some places. It is silty, calcareous, gray to dark gray, and is thin-bedded. The thickness of this member is about a foot.

(2) Houchen Creek limestone member. The Houchen Creek limestone is usually a thin-bedded, medium-hard limestone that contains a wavy band of dark-gray, circular plant fossils (algae). The average thickness of this member is 0.8 to 1 foot. In the north-central and southern parts of the outcrop area, it is composed of two or more hard limestones separated by a gray-green shale. The thickness of this member is about 6 feet.

This limestone is easily recognized by the presence of the wavy band of fossil algae.

(3) Stine shale member. The Stine shale is usually silty, calcareous, gray to gray green, but includes some gray and maroon zones in the basal part. Thin beds of limestone and calcium carbonate-filled fractures are sometimes present in its upper part. A sandstone lens in the middle part is exposed in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 4, T. 14 S., R. 13 E. where it is composed of fine sand, thin-bedded, firmly cemented, and numerous leaf imprints. This member is well exposed in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 9, T. 15 S., R. 12 E. The average thickness of the Stine shale is about 30 feet.

Five Point limestone.--The Five Point limestone is shown on plate 1 as part of the map unit Pfp. The upper part of this limestone is hard, massive, gray, and weathers platy. The basal part is hard, massive, tan gray, fossiliferous, and may contain one or more shale partings. Its average thickness is about 6 feet, and the limestone forms a prominent hillside bench over most of its outcrop area.

In a road cut in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 14, T. 13 S., R. 12 E., the Five Point limestone consists of a thick bed of massive limestone underlain successively by thin beds of shale and limestone. The upper limestone is soft, tan-brown, and has the appearance of being composed entirely of fossil shells which impart an "oatmeal" texture to it. The layer forms a prominent hillside bench and large, rectangular blocks weathered from it have slumped onto the underlying West Branch shale. The total thickness of the Five Point limestone is 5.9 feet in this place. This formation, in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 23, T. 14 S., R. 12 E., is composed of numerous beds of limestone separated by thin shales, and its upper part becomes platy upon weathering. Fossils and fossil fragments are abundant in the massive limestone and common in some of the thin limestones of other exposures.

The Five Point limestone is most readily identified by its thickness, "oatmeal" texture, and the presence of a thin bed of coal which is persistent near the top of the West Branch shale.

West Branch shale.--The West Branch shale is shown on plate 1 as part of the map unit Pfc. This formation is predominantly shale but contains one or more thin lenses of limestone and one or more beds of coal. The shale is silty to sandy, contains mica, and is tan-gray to gray brown. The lenticular limestones are clayey, massive, and tan gray. Thin lenses of siltstone and micaceous sandstone occur in the formation. The limestone lenses are fossiliferous, as are some of the shale zones, and plant fragments are also found in the latter. There is a thin, persistent bed of coal a few feet below the Five Point limestone and another thin bed is sometimes present in the lower part of the formation. The average thickness of the West Branch shale is 20 feet.

The West Branch shale is readily recognized by the thin coal in the upper part, its thin sandstones, and its position immediately beneath the Five Point limestone.

Falls City limestone.--The Falls City limestone is shown on plate 1 as part of the map unit Pfc. It is a soft, thin-bedded, tan, cavernous limestone. It contains numerous pelecypods, and forms a minor bench on some hillsides. The average thickness of the Falls City limestone is 4 feet.

This formation can best be identified by its position above the easily recognized Hawxby shale.

Hawxby shale.--The Hawxby shale is shown on plate 1 as part of the map unit Pa. It is composed of numerous beds of shale which are separated by thin lenses of limestone. The shales are usually clayey, calcareous, thin-bedded, and there are fossiliferous zones present in some outcrops. The limestones are hard, clayey, massive, gray to gray-brown, and very fossiliferous. East of Eskridge there is a thick bed of coal in the Hawxby shale. As reported by inhabitants of this locality, the coal is 32 inches thick and was mined, at a depth of 40 feet below the surface, during the early 1920's; however, the coal is not exposed in any of the stream banks near the mine shafts. The thickness of the Hawxby shale is about 28 feet.

The Hawxby shale is easily recognized by its numerous thin limestones which are composed almost entirely of small, elongated clams (pelecypods).

Aspinwall limestone.--The Aspinwall limestone is shown on plate 1 as part of the map unit Pa. It is moderately hard, massive, tan-brown, and fossiliferous. Minute tan and brown specks and a greenish tint are characteristic of this formation. There is a thin parting of shale in the lower part. The limestone weathers blocky to platy, and forms a prominent hillside bench. The thickness of this formation is about 4 feet.

Towle shale.--The Towle shale is composed of two members. (See fig. 4E.) The upper member (1) is an unnamed shale, and the lower (2) is a channel sandstone known as the Indian Cave sandstone. These two units are mapped separately on plate 1.

(1) Unnamed shale member. The unnamed member of the Towle shale is shown as the map unit Pt on plate 1. In some places it rests directly on the Brownville limestone of the underlying Pennsylvanian system, but locally this shale overlies the Indian Cave sandstone member. It is usually a silty, calcareous shale, gray to gray green in the upper and middle parts, and maroon in the basal part. One or more thin, gray, lenticular limestones are usually present near the top. A westward thickening of the uppermost limestone was observed 4 miles east of Paxico. Fossils are abundant in the limestones in some places, and septarian concretions may also be present. The average thickness of this member is 12 feet.

(2) Indian Cave sandstone member. This member of the Towle shale is shown on plate 1 as the map unit Pti. Only one area of outcrop of this channel sandstone was found in this county, the "Echo Cliff" exposure in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 5, T. 13 S., R. 13 E. In the SE$\frac{1}{4}$ sec. 4, T. 13 S., R. 13 E., an extension of this same channel rests on the Dover limestone, but at Echo Cliff the sandstone extends an unknown distance below the Dover horizon. Where this channel sandstone is present, the stratigraphic units from the Brownville limestone down to the floor of the channel are absent. In some areas the Indian Cave sandstone is easily confused with small channel sands that are present in some of the shales of the upper Pennsylvanian system.

The Indian Cave sandstone is composed of fine grains of quartz and mica which have been cemented by pore-space deposits of calcium carbonate or iron oxide. The member varies from a sandy shale to a loosely or firmly cemented sandstone, and contains a firmly cemented conglomerate either near the base or near the top. Numerous carbon and iron stains occur along bedding planes. Thin layers of coal and iron concretions and nodules are present, as well as wood and leaf fragments. Cross-bedding and ripple marks are apparent in some exposures. The maximum exposed thickness of the Indian Cave channel deposit is about 75 feet.

Construction materials in the Admire group.--

Structural stone.

Aggregate.

Road metal.

Riprap.

Pennsylvanian system

Wabaunsee group

General.--The Wabaunsee is the uppermost group of formations in the Virgil series, and the Virgil is the youngest series of rocks in the Pennsylvanian system. (See fig. 4F.) The Wabaunsee group is divided into subgroups which are, in descending order: The Richardson, Nemaha, and Sacfox.11/

11/ Moore, R. C., Divisions of the Pennsylvanian system in Kansas: Kans. Geol. Survey Bull. 83, p. 163, 1949.

Only the Richardson and Nemaha subgroups outcrop in this county. Representative measured sections of the formations in the Wabaunsee group are given in the Appendix.

The formations of this group are shown on plate 1 as the following map units:

Map unit		Formation	Member
Cbr		(Brownville limestone	
Ccv		(Pony Creek shale (Caneyville limestone	(Grayhorse limestone (Unnamed shale (Nebraska City limestone
Ccf	Richardson subgroup	(Pony Creek, French Creek, and Friedrich shales (undifferentiated) (Caneyville limestone and French Creek shale	
Cjc	Richardson subgroup	(French Creek shale (Jim Creek limestone	
Cgh	Richardson subgroup	(Friedrich shale (Grandhaven limestone	
Cdo	Richardson subgroup	(Dry shale (Dover limestone	
Cmh	Richardson subgroup	(Langdon shale (Maple Hill limestone	
Ct	Richardson subgroup	(Wamego shale (Tarkio limestone	
Cc	Nemaha subgroup	(Willard shale (Elmont limestone	
Cr	Nemaha subgroup	(Harveyville shale (Reading limestone	
Cwa	Nemaha subgroup	(Auburn shale	

<u>Areal distribution</u>.--The outcrop areas of the Wabaunsee group are in the northern part of the county along the south side of the valley of the Kansas River and along the eastern border of the county as far south as the southeastern corner. (See pl. 1.) The thickness of that part of the Wabaunsee group exposed in this county is about 225 feet.

Richardson subgroup

General.--The Richardson is the uppermost subgroup of the Wabaunsee group and includes the formations from the Brownville limestone down to the Wamego shale. The average thickness of this subgroup is about 150 feet.

Brownville limestone.--This limestone is shown on plate 1 as the map unit Cbr. It is usually a massive limestone, but locally is composed of two limestones separated by a thin shale. The limestone is moderately hard, massive, but weathers nodular. It is gray brown with a greenish tint, and weathers brown to tan brown, but the weathered surface is usually covered by a maroon stain derived from the overlying Towle shale. Two distinctive fossils are present in the Brownville limestone and are an aid in its identification. One is small, white, bi-globular shell (Marginifera), and the other is flat and wing-shaped (Chonetes). The average thickness of the formation is about 2.5 feet, and it forms a distinct hillside bench over most of its outcrop area.

The Brownville limestone is a very good marker bed and is easily identified by its fossils, thickness, color, and nodular weathered surface.

Pony Creek shale.--The Pony Creek shale is shown on plate 1 as part of the map unit Ccv. It is usually clayey, noncalcareous, gray to gray-brown, but contains a maroon zone in the middle and lower parts in some places. In the SE$\frac{1}{4}$ sec. 11, T. 11 S., R. 9 E., and in other parts of the county, a bed of micaceous sandstone occurs in the middle part, and there is a fossiliferous shale near the top. The thickness of the Pony Creek shale is about 15 feet.

Caneyville limestone.--The Caneyville limestone is shown on plate 1 as part of the map unit Ccv. The Caneyville limestone is composed of three members which are, in descending order, (1) Grayhorse limestone, (2) unnamed shale, and the (3) Nebraska City limestone. The average thickness of the Caneyville limestone is 10 feet.

(1) Grayhorse limestone member. The Grayhorse is a hard, massive, and gray-orange limestone. Limonite stains and nodules, small clay balls, and numerous fossils are characteristic of this unit. This member forms a small hillside bench over most of its outcrop area, and its average thickness is about a foot.

The Grayhorse limestone is easily identified by its color, abundance of limonite nodules, fossils, and by its position between the easily recognized Brownville and Nebraska City limestones.

(2) Unnamed shale member. The unnamed shale member is sandy, micaceous, gray to tan gray, and locally contains some maroon beds in the middle part. Its average thickness is about 9 feet.

(3) Nebraska City limestone member. This member, as developed in this county, is usually a very fossiliferous and calcareous shale. Elsewhere in the state, however, it may be a soft, massive limestone. Its average thickness is about 1.5 feet.

The Nebraska City is easily recognized by the abundance of fossils, thickness, shaly appearance, and by its position above the Lorton coal.

Pony Creek and French Creek shales.--These two shales are shown as the map unit Cpf; their outcrop areas are south of the city of Wabaunsee in sec. 7, T. 11 S., R. 10 E., and southwest of Maple Hill. In these places the Caneyville and Jim Creek limestones are absent. A total thickness of 58.8 feet of shale is exposed in a stream bank in the area south of Wabaunsee. The shales are sandy, micaceous, thin-bedded, and gray brown to blue gray. They include numerous lenses of sandstone and conglomerate, and septarian concretions; thin fossiliferous limestones and fossiliferous shale zones occur near the top. Zones of fossil leaves and wood may also be present.

Caneyville limestone and French Creek shale.--The Caneyville limestone and French Creek shale are shown on plate 1 as the map unit Ccf. This map unit was devised to show the channel phase of the Caneyville limestone. This channel originates in the unnamed shale member of the Caneyville limestone and extends downward into the French Creek shale, and may be cut into the Dry shale. This channel material is sandy shale, cross-bedded sandstone, and conglomerate. The sandstone and shales are tan to tan brown, and contain very fine sand and mica flakes. Wood, leaves, and carbon-stained zones are not uncommon. The conglomerate is similar to the conglomerates in the Indian Cave sandstone member of the Towle shale, and is composed of calcium carbonate cemented, subangular fragments of limestone and shale, and some limonite nodules and clay balls. The particles range in size from sand to pebbles. In a road cut in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 27, T. 11 S., R. 12 E. the upper part of this channel phase is composed of silty, micaceous to sandy, tan and maroon shales. The maroon shales were observed to pinch in and out laterally within short distances.

The maximum thickness of this channel is about 60 feet.

French Creek shale.--The French Creek shale is shown on plate 1 as part of the map unit Cjc. It varies from clayey to sandy, is noncalcareous, and gray to blue gray. The Lorton coal bed is usually present at or near the top of this formation, and there may be another thin coal lens a few feet below the top. The shale is characterized by numerous plates of limonite that cover weathered surfaces, and by numerous iron nodules and stains. No fossils were found in French Creek shale. Its thickness is about 20 feet.

This formation is readily identified by the presence of the Lorton coal bed, and by its position beneath the Caneyville limestone.

Jim Creek limestone.--The Jim Creek limestone is shown on plate 1 as part of the map unit Cjc. It is hard, massive, weathers to irregular chips, and is dark gray to brown with a somewhat purplish tint. Fossils are abundant in this formation. The thickness of this limestone is constant at about a foot, and its topographic expression is subdued.

The Jim Creek limestone is easily identified by its thickness, fossils, color and tint, and by its weathered appearance.

Friedrich shale.--The Friedrich shale is shown on plate 1 as part of the map unit Cgh. It is clayey, usually noncalcareous, olive drab to blue gray, and sometimes contains a maroon zone in the middle part. Locally a thin calcareous lens occurs near the base, and the basal part of the shale is usually fossiliferous. There is a thin bed of coal in the upper part of the formation just beneath the Jim Creek limestone in the northern part of the outcrop area. The thickness of this formation is about 13 feet.

This shale is best identified by its position between the Jim Creek and Grandhaven limestones.

Grandhaven limestone.--This limestone is shown on plate 1 as part of the map unit Cgh. The Grandhaven limestone, in the northern part of the county, is a single layer of limestone which is hard, massive, brown, and weathers brown to tan. A shale zone, 4 feet thick, underlying this thin massive limestone is believed to be part of the Grandhaven limestone and not of the Dry shale. It is silty, calcareous, olive drab to blue gray, and contains numerous calcareous lenses. Fossils, crinoid columnals for the most part, are common in the limestone zone of the formation. The average thickness of this formation in the northern part of the outcrop area is 6 feet.

The Grandhaven limestone in the southern part of the county is composed of two fossiliferous limestones separated by a thick shale. The lower limestone, which is thought to be missing farther north, is about a foot thick, hard, gray brown, and weathers tan to brown. The upper limestone is also a foot thick, hard, dense, and is tan gray. The shale zone is 5 feet thick, gray, and contains a thin maroon band. The average thickness of the Grandhaven limestone in this area is 7 feet.

This limestone can be identified by its brown color, abundance of crinoid columnals, and by its position above the easily recognized Dover limestone.

Dry shale.--The Dry shale is shown on plate 1 as part of the map unit Cdo. This shale is usually sandy, contains flakes of mica, and is gray, blue gray, or tan brown. In the southeastern part of the county, the weathered surface of the middle zone of the shale is bright tan yellow, and a thin lens of sandstone occurs near the top of the formation. No fossils were found in this shale, and its thickness is about 20 feet.

The Dry shale is easily recognized by its position above the Dover limestone.

Dover limestone.--The Dover limestone is shown on plate 1 as part of the map unit Cdo. This formation is usually composed of two layers of limestone separated by a thin, calcareous shale. The upper limestone is massive, moderately hard, weathers into irregular blocks, and is gray brown. The lower limestone is light gray to brown, soft, massive, and weathers to a shaly appearance. The upper limestone contains numerous nodules of algae, whereas the lower limestone is composed almost entirely of large fusulinids. The Dover limestone becomes thinner in the area north of Harveyville. It forms a hillside bench over most of its area of outcrop, and its thickness is about 3 feet.

The Dover limestone is a very good marker bed and is easily recognized by its fossils, light gray color, and thickness.

Langdon shale.--The Langdon shale is shown as part of the map unit Cmh on plate 1. It is thin-bedded to blocky, blue gray to tan, and there are thin lenses of sandstone in the upper part. This shale becomes extremely sandy in the vicinity of Harveyville. Large fusulinids are very abundant in the uppermost part. Its average thickness is 35 feet, and its maximum thickness is 55 feet.

The formation can best be recognized by its position beneath the Dover limestone.

Maple Hill limestone.--The Maple Hill limestone is shown on plate 1 as part of the map unit Cmh. It is a single bed of limestone which is hard, massive, gray, and weathers light gray to tan gray. The weathered surface of the limestone has the appearance of an I-beam. Fossils are common throughout this formation. Its average thickness is 1.2 feet.

This limestone is easily identified by its thickness, color, I-beam appearance, and fossils.

Wamego shale.--The Wamego shale is shown on plate 1 as part of the map unit Ct. The shale is clayey to silty, and is predominantly calcareous. It is gray brown to blue gray, and usually weathers tan gray. Limonite stains are common, and limonite plates are abundant on the weathered surface. Fossils are numerous in the lower zones, but only in the southern part of the outcrop area. The thickness ranges from 8 to 25 feet.

This shale can be recognized by its color, abundance of limonite plates, and its position above the easily recognized Tarkio limestone.

Nemaha subgroup

Tarkio limestone.--The Tarkio limestone is shown on plate 1 as part of the map unit Ct. It is usually composed of two limestones separated by a thin shale. The limestones are hard, massive, and dark brown. The shale is silty, calcareous, and tan gray.

The lower limestone forms a conspicuous bench on many hillsides, but the upper limestone usually erodes farther back on the hillside and is concealed beneath colluvium and soil. This peculiarity of erosion creates the impression that the Tarkio is a single bed of limestone. Large blocks of the lower ledge often slump down and conceal the face of the underlying Willard shale. Near the southeastern corner of the county, the Tarkio limestone is actually only one bed which is hard, slightly sandy, and contains some flakes of mica. It is massive, gray orange to gray, and weathers gray brown. The bedding is irregular and wavy, and the upper part of the layer weathers platy in most exposures. The thickness of the Tarkio limestone ranges from 2.3 feet in the southern part of the county to 10 feet in the vicinity of Maple Hill. Large fusulinids are abundant in this formation except in the southern part of the county where they are somewhat less numerous.

This limestone is a very good marker bed and is readily identified by its color, abundance of large fusulinids, thickness, and by the prominent bench it forms.

Willard shale.--The Willard shale is shown on plate 1 as part of the map unit Ce. It is usually silty, calcareous, blue gray to gray brown, and weathers tan. Locally the shale is sandy, contains some sandstone lenses, and is micaceous. The thickness of this shale is about 32 feet.

The Willard shale is readily identified by its position beneath the easily recognized Tarkio limestone.

Elmont limestone.--The Elmont limestone is shown on plate 1 as part of the map unit Ce. It is a hard, massive, dark blue-gray, fossiliferous limestone. The weathered rock is tan gray, massive, and breaks into rectangular blocks which reflect the characteristic fracture pattern of almost all exposures of the Elmont limestone. The formation is conglomeratic and porous at the base, and usually has a veneer of limonite plates over the top. The thickness of this limestone is about 1.8 feet.

The Elmont limestone is readily recognized by its dark blue-gray color, massiveness, fracture pattern, and by its position beneath the easily identified Tarkio limestone.

Harveyville shale.--The Harveyville shale is shown on plate 1 as part of the map unit Cr. It is clayey, slightly calcareous, thin-bedded, and usually contains some mica. It is tan gray and weathers gray. The average thickness of this shale is 21 feet.

This formation can best be recognized by its position between the Reading and Elmont limestones.

Reading limestone.--The Reading limestone is shown on plate 1 as part of the map unit Cr. and it outcrops only in the northwestern part of the county. It is hard, dense, blue gray, and weathers tan gray to tan brown. The limestone is massive and usually weathers to three dense beds which are of equal thickness. Fossils occur throughout the formation. Its average thickness is about 2 feet.

The Reading limestone can be identified by the three dark blue-gray, fossiliferous limestones, and by its thickness.

Auburn shale.--The Auburn shale is shown on plate 1 as the map unit Cwa. It is the oldest formation exposed in Wabaunsee County, and outcrops only in the northwestern part. This shale is silty, tan gray, and weathers tan. It is nonfossiliferous, and only about 6 feet of its total thickness is exposed at the surface.

Construction materials in the Wabaunsee group.--

Aggregate.

Structural stone.

Riprap.

Roadmetal.

INVENTORY OF CONSTRUCTION MATERIALS

General

The objectives of this inventory of construction materials in Wabaunsee County are to define the construction materials as they are classified in this report and to relate the materials to the map units in which they occur.

Whenever available, laboratory test data have been introduced into the report to aid the reader in his evaluation of the materials. The information given in table 1 is based on standard testing procedures of the State Highway Commission of Kansas 12/ and the American Association of

12/ State Highway Commission of Kansas, Standard specifications for State road and bridge construction: 512 pp., 1945.

Gradation factor, p. 16

Sieve analysis, pp. 333-334.

Soundness, pp. 335-336.

of State Highway Officials.13/ It is expected that prospects listed in this

13/ American Association of State Highway Officials, Standard specifications for highway materials and methods of sampling and testing: pt. 2, 5th ed., 361 pp., 1947.

Absorption, pp. 251-252.

Compressive strength, pp. 257-258.

Deval abrasion, pp. 235-236.

Liquid limit, pp. 198-201.

Los Angeles abrasion, pp. 237-239.

Plasticity index, pp. 202-204.

Specific gravity, pp. 249-250.

Toughness, pp. 204-241.

Weight per cubic foot, pp. 253-254.

report 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 numerous prospect pits and quarries were located, no attempt was made to complete an exhaustive survey of all possible sources of materials. If the construction materials that are available in Wabaunsee County can be related to the geologic formations mapped on plate 1, then the use of that map will aid the field man in his 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 table 1 and on plate 1. 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. The material is classified as a coarse aggregate if the coarse fraction is 15 percent or more by weight of the whole sample; as a mixed aggregate if the coarse fraction is between 5 and 14 percent; and as a fine aggregate if the coarse fraction is less than 5 percent. The three aggregates will be considered together because of the standard practice of bringing the grading to specifications by sweetening or screening.

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 economically developed. Deposits that are overlain by thick or consolidated beds, or 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.--The following stratigraphic units are active or potential sources of aggregate for concrete:

(1) Alluvium. Two samples of mixed aggregate (ma 1 and 2) were collected from alluvial deposits of Quaternary age. These samples were obtained from the Kansas River at Wamego, Kans. and the test data are given on table 1. This material is composed of granitic and siliceous particles of sand and gravel size. As shown on plate 1, two samples of ma 1 were taken from the Kansas River at the same location. None of the samples tested was accepted by the State Highway Commission as a mixed aggregate for concrete. As stated under Remarks in table 1, this material is acceptable as aggregate for bituminous surface course, cover material, and for surfacing or resurfacing. Most of the samples of alluvium from the Kansas River contain a high percentage of chert or chalcedony.

The quantity of mixed aggregate which can be obtained from the Kansas River is almost unlimited. This material can be pumped from the alluvium at numerous locations along the river. The alluvium along other streams in the county is composed predominantly of clay and silt.

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

(2) Sanborn formation. Wind-deposited clay and silt are considered by Plummer and Hladik 14/ to be of prime importance as raw materials

14/ Plummer, N., and Hladik, W. B., The manufacture of ceramic railroad ballast and constructional aggregates from Kansas clays and silts: Kansas Geol. Survey Bull. 76, pt. 4, pp. 57-111, 1948.

for the manufacture of ceramic slag for railroad ballast and constructional aggregate. They report that tests of ceramic-slag aggregate by the Road Materials Laboratory of the Kansas Highway Commission indicate that the material is a superior aggregate and that its low density is decidedly in its favor.

(3) Glacial deposits. Lenses of fine sand occur in the glacial till but they occur in very small quantities. However, there are other glacial sediments in which sand and/or gravel occur in producible quantities. (See Qgo and Qkg on pl. 1, and ca 1 and ca 2 in table 1.) Ca 1, glacial outwash, is classified as a coarse aggregate but does not meet the specifications for coarse aggregate for concrete. This material is composed of particles of chert, and fragments of limestone and glacial erratics ranging from sand to boulder size; silt- and clay-size particles are intermixed in it. It is acceptable as a surfacing material and has been used extensively on nearby county roads in Wabaunsee and Shawnee Counties.

Ca 2 was collected from a glacial sediment that resembles a kame deposit. The sample contains a small percentage of chert fragments, together with fragments of igneous and metamorphic rocks and a large percentage of silt and clay. It has been used as surfacing material for township roads.

The high percentage of clay in glacial till makes it potentially useful as a ceramic material. Tests by Plummer and Hladik 15/ show the

15/ Idem, pp. 82 and 83.

specific gravity of a sample of Kansan till to be 2.06, and that it is suitable for use as ceramic railroad ballast and constructional aggregate.

(4) Limestones of the Permian and Pennsylvanian systems. A number of limestones have been accepted as rock to be crushed for the coarse fraction in aggregate for concrete. The limestones sampled and tested are shown in table 1 and are: ls 17, Funston limestone; ls 18,

Threemile limestone member of the Wreford limestone; ls 20, near the top of the Neva limestone member of the Grenola limestone; ls 21 and 22, Cottonwood limestone member of the Beattie limestone; ls 24, top of the Threemile limestone member of the Wreford limestone; ls 25, Fort Riley limestone member of the Barneston limestone; ls 34, 35, and 37, Howe limestone member of the Red Eagle limestone; ls 40, Aspinwall limestone; and ls 41, Neva limestone member of the Grenola limestone. The limestones rejected as coarse aggregate for concrete were: ls 6 and 13, Cottonwood limestone member of the Beattie limestone; ls 20, Neva limestone member of the Grenola limestone; ls 23, Cottonwood limestone member of the Beattie limestone; ls 25, Fort Riley limestone of the Barneston limestone; ls 27, Florence limestone member of the Barneston limestone; and ls 23, Five Point limestone. The Neva limestone member of the Grenola limestone is composed of numerous beds of limestone which are usually separated by shale partings. The test data indicate that each bed of limestone should be sampled for testing. Ls 20 shows that the top bed of the Neva limestone is not acceptable for any construction use, whereas the bed of limestone beneath it is acceptable for numerous uses. The Cottonwood limestone member of the Beattie limestone is one thick bed of limestone and its test characteristics are presumed to be constant throughout the area of its outcrop. But this limestone was sampled at 7 different places in Wabaunsee County and 3 of the 7 samples were rejected as construction stone. The other 4 samples were accepted for numerous material uses which include use as coarse aggregate for concrete.

Chert gravel

Engineering and geologic characteristics.--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 silt-size particles. This material may also contain subrounded to rounded gravel-size fragments of local limestones and occasional pebbles, cobbles, or boulders of erratic rocks. The matrix may contain a minor percentage of fine sand and/or clay.

Stratigraphic sources and performance characteristics.--

(1) Alluvium. Test data for a sample of chert gravel, cg 7, are given in table 1. This material came from a creek bed and is commonly known as "creek gravel." (Because of the map scale, it was necessary to map this unit as terrace.) The count of the coarse fraction shows that almost all particles are chert and that there is only a trace of limestone. In comparison with other gravels, this material is unusually coarse, although it contains a small amount of "wash." The abrasion loss in the Los Angeles test is low.

There are similar terrace deposits along Mill Creek from Alma to Alta Vista, Middle Branch Creek, Illinois Creek, and Spring Creek. The valleys of Horse and Rock Creeks contain small quantities of chert gravel.

(2) Sanborn formation. Two samples of chert gravel (cg 1 and cg 8) were obtained from the Sanborn formation. (See table 1 and pl. 1.) Tests of cg 1 show that the material is sound and that its abrasion loss in the Los Angeles test is low. The sieve analysis shows that the gravel is relatively coarse, but that it contains a large amount of wash.

The mineral count of the coarse fraction of cg 8 shows all particles are chert and that they do not exceed pebble size. The wash material is red-brown silt and clay and is but a small percentage of the total sample. The abrasion loss in the Los Angeles test is low.

Similar deposits of chert gravel are present in that part of the Sanborn formation which is adjacent to the tributaries of Mill Creek. The gravel is usually concentrated on the western and northern slopes of Mill Creek; on the west slope of Illinois Creek; and in the upper regions of Middle Branch, Mill, and Spring Creeks. Gravel deposits occur in the basal part of the Sanborn formation near Horse and Rock Creeks.

(3) Older gravels. There were 5 samples of older chert gravels collected for laboratory testing. (See cg 2, 3, 4, 5, and 6 in table 1 and on pl. 1.) Four of the 5 samples (cg 2, 3, 4, and 6) are composed predominantly of chert, whereas one, cg 5, contains a high percentage of limestone fragments. (Cg 2, 3, 4, and 6 were accepted by the Road Materials Laboratory of the State Highway Commission of Kansas) as material for calcareous binder and base course and as secondary metal on light-traffic roads. Cg 5 is composed of 85 percent limestone, 5 percent chert, and 10 percent silt. There are similar deposits in a strip one mile wide extending from Alma to St. Marys.

Mineral filler

Engineering and geologic characteristics.--Material composed predominantly of silt-size mineral particles (50 percent or more of the material passing the No. 200 sieve) is classified in this report as mineral filler. It has no more than a trace of sticks or other 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 (personal communication) that material will qualify for mineral filler only if laboratory tests indicate a low coefficient of cementation.

Stratigraphic sources and performance characteristics.--Only one sample to be tested for use as mineral filler was collected in Wabaunsee County. (See mf 1 in table 1 and on pl. 1.) This material did not meet the requirements for mineral filler because of the high coefficient of cementation. Other possible sources, such as terrace deposits and the Sanborn formation, were investigated but in all cases the quantity of clay was sufficient to indicate that the coefficient of cementation would be too high.

A more exhaustive search of the terrace deposits should reveal small quantities of mineral filler. It is doubtful that the Sanborn formation or any of the glacial deposits in Wabaunsee County contain material that is acceptable for this use.

Riprap

Engineering and geologic characteristics.--Riprap, as defined in this report, is any 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 freeze-and-thaw. 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.

Stratigraphic sources and performance characteristics.--

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

(2) Permian system. Many limestones of the Permian system have been accepted for use as riprap. (See table 1 and pl. 1.) Ledges of acceptable rock are included in the Cottonwood limestone member of the Beattie limestone (ls 7); Eiss limestone member of the Bader limestone (ls 15); Funston limestone (ls 17); Five Point limestone (ls 19); Fort Riley limestone member of the Barneston limestone (ls 30); Howe limestone member of the Red Eagle limestone (ls 36 and 37); and the Neva limestone member of the Grenola limestone (ls 38).

The upper part of the Neva limestone (ls 11) is acceptable as stone for riprap on the basis of most of its physical tests but because it is platy, and thus does not meet the size requirement, it is usually rejected for that use. The Cottonwood limestone, as discussed previously, shows some variation in test characteristics but generally fulfills the requirements for riprap. The Five Point limestone meets some of the requirements, but has a low specific gravity (2.05) and the wear test indicates 46 percent loss. The thick beds of the Funston and Threemile limestones have a very low specific gravity and a high percentage of loss in the Los Angeles abrasion test. The Neva limestone member of the Grenola limestone (ls 38) was accepted for use as riprap by the State Highway Commission and was used on the upstream face of the dam at Lake Wabaunsee. The Cottonwood limestone member of the Beattie limestone and the Threemile limestone member of the Wreford limestone were also used as riprap on the dam and in the construction of the spillway at Lake Wabaunsee. Only the uppermost 5 feet, the non-cherty zone, of the Threemile limestone was so used. Extensive use of the Cottonwood limestone as riprap along stream banks has been made by the Rock Island Railroad.

(3) Pennsylvanian system. Of the limestones in the Pennsylvanian system outcropping in Wabaunsee County, (see fig. 4F) only the Tarkio limestone (ls 1 and 2 in table 1) is considered adequate for riprap. It has been installed as riprap along the Kansas River, and has also been used in the county as riprap in spillways and on the upstream faces of dams. Field observation indicates that it is entirely suitable and laboratory tests show that it is sound, has a relatively high specific gravity, and is wear-resistant.

The Maple Hill limestone (ls 3), Grayhorse limestone member of the Caneyville limestone (ls 7), and Brownville limestone (ls 12) qualify as riprap on the basis of laboratory tests. But the Maple Hill and Caneyville limestones are thin (only slightly more than a foot thick) and therefore would not be economical to quarry for riprap. The Brownville limestone (ls 12) has been accepted on the basis of meeting the minimum requirements, but field observation indicates that the limestone disintegrates rapidly.

Structural stone

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

Stratigraphic sources and performance characteristics.--

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

(2) Limestones of the Permian and Pennsylvanian systems. Many of the limestones outcropping in the county have been used as structural stone. However, their use has been governed principally by the accessibility of quarries. Some structural stone has been brought into the

county from other areas, and an appreciable quantity has been shipped from the county. The following limestones have been used as structural stone:

(a) The Fort Riley limestone member of the Barneston limestone has been used extensively in the vicinity of Alta Vista. Many quarries south of this city have produced large quantities of rock for building stone, crushed rock for road metal, and for railroad ballast. Most of the civic buildings of Alta Vista were constructed of the Fort Riley limestone. The stone in these structures, which are 50 or more years old, shows only slight weathering effects, although some of the blocks have become porous and are stained dark gray to yellow brown. The Fort Riley limestone has been used as a structural stone in the abutment and span of a single-arch bridge in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 6, T. 13 S., R. 9 E. The stone shows no marked effects of weathering at the water line or in other parts of the bridge.

(b) The Crouse limestone has been used locally as structural stone. A two-story farm house in the vicinity of Volland was constructed of rock from the bed of massive limestone which occurs in the lower part of the formation. The house is about 80 years old and the limestone blocks show no serious deterioration by weathering. In an unweathered condition, this stone is soft enough to be cut and trimmed. The platy part of the Crouse limestone is used as flagstone for the construction of sidewalks and stone fences.

(c) The Cottonwood limestone member of the Beattie limestone is the source of most of the structural stone used in this area, and has been used in the construction of buildings, abutments, piers, retaining walls, and as riprap. Most of the public buildings in Alma have been constructed of it. Many houses, barns, and schoolhouses in the vicinity of Alma and Eskridge have been constructed of the Cottonwood limestone, but both the Cottonwood and Neva limestones have been used in some of the buildings. Observation indicates that this stone is little affected by weathering, and that its appearance is generally a pleasing one. Abutments, piers, and the span of a double-arch bridge in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 30, T. 12 S., R. 10 E. were constructed in 1891 of the Cottonwood and Neva limestones. The Cottonwood limestone has withstood weathering in all parts of the structure, but the blocks of Neva limestone in the abutments had to be replaced in 1946.

(d) The Neva limestone member of the Grenola limestone has been used as structural stone in the vicinity of Alma. Observations of this stone indicate that it may be weakened by the action of freeze and thaw. Tests of two ledges of Neva limestone (ls 20, table 1) show that portions of this limestone are not suitable for use as structural stone.

(e) The Five Point limestone was used in only one structure, the church in Newbury. Field observation indicates that the Five Point limestone has adequate bearing strength for use in foundations and that it is acceptable as trim stone. Where the Five Point occurs as a platy limestone, it is a source of flagstones for sidewalks and fences.

(f) The Aspinwall limestone was used in the construction of a 2-story stone house which is located in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 23, T. 11 S., R. 12 E. Field observation indicates that this limestone reacts slightly with mortar, and that its weathered appearance is not too pleasing.

(g) The Grayhorse limestone member of the Caneyville limestone was used in the construction of a bridge in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 15, T. 12 S., R. 13 E. Observation indicates that weathering affects this limestone very little.

(h) Use of the Tarkio limestone as a structural stone was not observed in Wabaunsee County. However, test data (see table 1) indicate that it would be acceptable for this use, although the chocolate-brown color it develops upon weathering is not pleasing.

Road metal

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

Stratigraphic sources and performance characteristics.--

(1) Sources of aggregate for concrete. Mixed aggregate from alluvial deposits along the Kansas River has been used in large quantities as road metal in Wabaunsee County. It has been used extensively on the state highways, and some of the county roads are metalled with a mixture of this material and crushed stone. As judged by field observation, this method of combining mixed aggregate and crushed rock seems to be successful. Rutting, washing, and washboarding are almost eliminated, whereas on a road where mixed aggregate is used alone, these do develop. Mixed aggregate was also used in the bituminous-mat placed on the streets in Alma. Ma 2, and fa 1 and 2 in table 1 qualify as aggregate for bituminous-mat construction.

(2) Chert gravel. Chert gravel from the older gravels, Sanborn formation, 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. Field observation indicates that the older chert gravels are best for road metal inasmuch as they contain clay binder, and the particles of chert are slightly rounded. Creek gravel appears to be the least desirable because of the wide range in size of the constituent particles and the difficulty in gaining access to the deposit. Commercial quantities of older chert gravels can be obtained

from an old creek channel which extends from Alma to St. Marys. Creek gravel and older gravels can be obtained from the southern part of the Mill Creek watershed.

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

(4) Glacial gravels. The glacial gravels are classified as two different types of deposits, glacial outwash (Qgo) and kames (Qgk), and both of these materials are used as metal on light-traffic roads. Glacial outwash has been extensively used in both Wabaunsee and Shawnee Counties, but to fulfill the specifications for road metal, the gravel must be screened to reduce the amount of oversize material present in it. Field observation indicates that this material makes an excellent road metal.

(5) Crushed rock. The limestones of the Permian and Pennsylvanian systems were discussed in the sections on riprap and structural stone. The Fort Riley, Cottonwood, and Howe limestones have been used extensively as crushed stone for road metal. Other limestones in this county that have been used for this purpose are: Aspinwall limestone, Threemile limestone, Neva limestone, the Florence limestone, and the Americus and Houchen Creek limestones which are quarried together because of the very thin shale interval between them. All these limestones appear to be suitable for use on light-traffic roads.

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

Subgrade and embankment material

Engineering and geologic characteristics.--This definition of subgrade and embankment material is adapted from the specifications compiled for the A. A. S. H. O. 16/ Suitable geologic materials for this kind of construc-

16/ Amer. Assoc. State Highway Officials, Highway materials: pt. 1, Specifications; pp. 37-38, 1937.

tion are:

(1) Fine-granular unconsolidated sediments, including soil, of which 50 percent or more pass 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 materials listed above are available in Wabaunsee County for the construction of subgrades and embankments and are the product of the excavation along the alignment of the structure or can be obtained 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. Glacial till is composed predominantly of clay, although a minor amount of silt does occur in it in some places.

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

(3) Broken or crushed rock. Most limestones of the Pennsylvanian and Permian systems are durable and resist crumbling and solution.

The shales of the Pennsylvanian and Permian systems vary in their physical characteristics. The Hughes Creek, Johnson, and Florena shales have been used in the construction of embankments. These three shales are silty and calcareous. Silty shales which might prove acceptable for this use are:

- Permian system
  - Chase group
    - Oketo shale member of the Barneston limestone.
    - Matfield shale.--Includes both clayey and silty zones.
    - Havensville shale member of the Wreford limestone.
  - Council Grove group
    - Speiser shale.--Usually clayey in upper part.
    - Blue Rapids shale.--Includes both clayey and silty zones.
    - Easly Creek shale.
    - Stearns shale.--Silty in the lower part.
    - Florena shale member of the Beattie limestone.
    - Eskridge shale.--Silty but with some clay zones.
    - Roca shale.--Includes both clayey and silty zones.
    - Johnson shale.
    - Hughes Creek shale member of the Foraker limestone.

Admire Group
Hamlin shale.
West Branch shale.--Silty to sandy with minor amount of clay.
Towle shale.--Silty to sand.
Pennsylvanian system
Wabaunsee group
Richardson subgroup
French Creek-Pony Creek shales.--Silty to sandy.
French Creek shale.--Contains minor amount of clay.
Dry shale.--Silty to sandy.
Langdon shale.--Sandy in the upper part.
Wamego shale.--Silty with some clay.
Nemaha subgroup
Willard shale.

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

Permian system
Chase group
Holmesville shale member of Gage shale.
Council Grove group
Hooser shale member of the Bader limestone.
Bennett shale member of the Red Eagle limestone.
Admire group
Hawxby shale.
Pennsylvanian system
Wabaunsee group.
Richardson subgroup
Pony Creek shale.
Friedrich shale.
Nemaha subgroup
Harveyville shale.
Auburn shale.

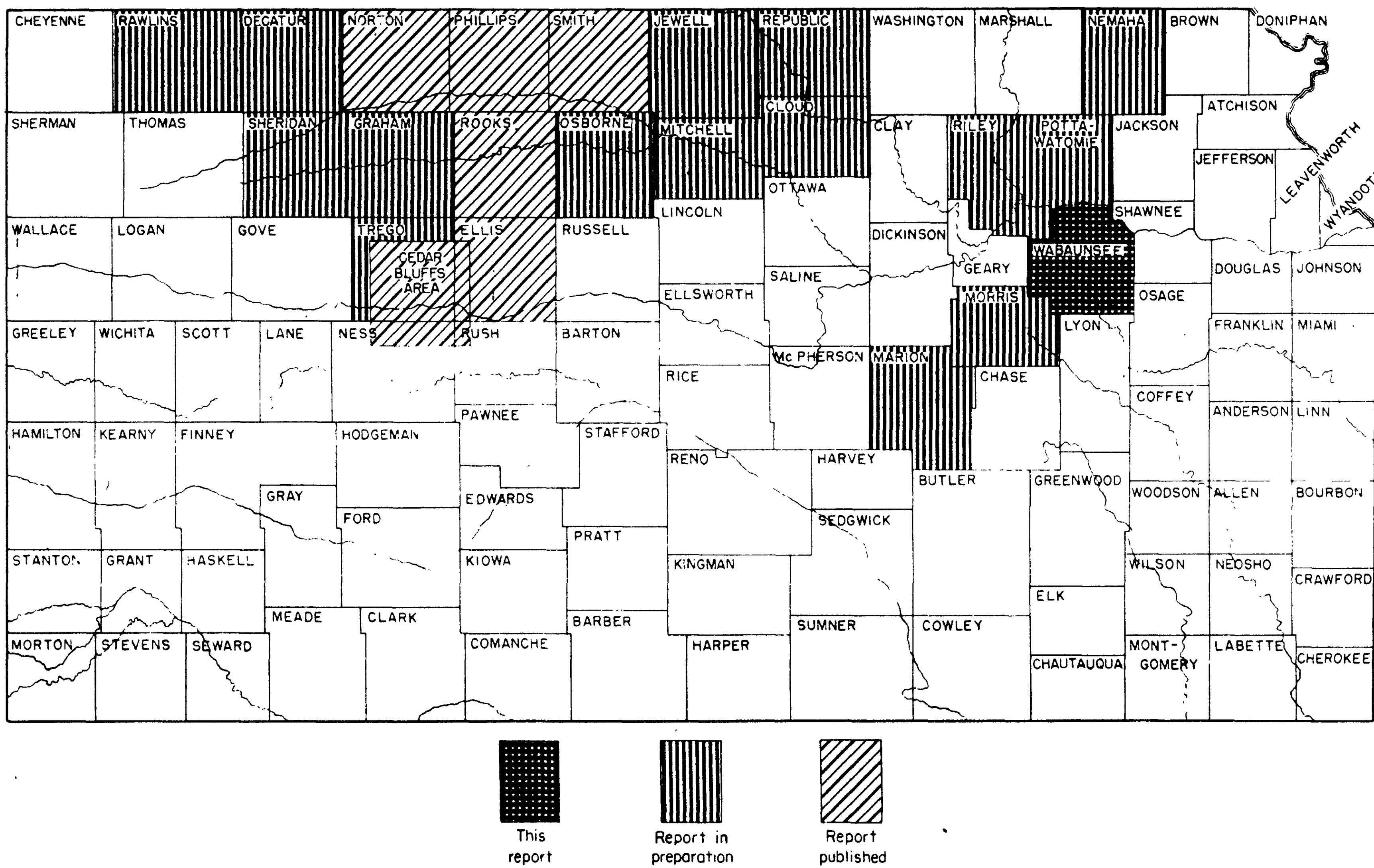


Figure I.—Index map of Kansas showing areas covered by this report and by other construction materials investigations

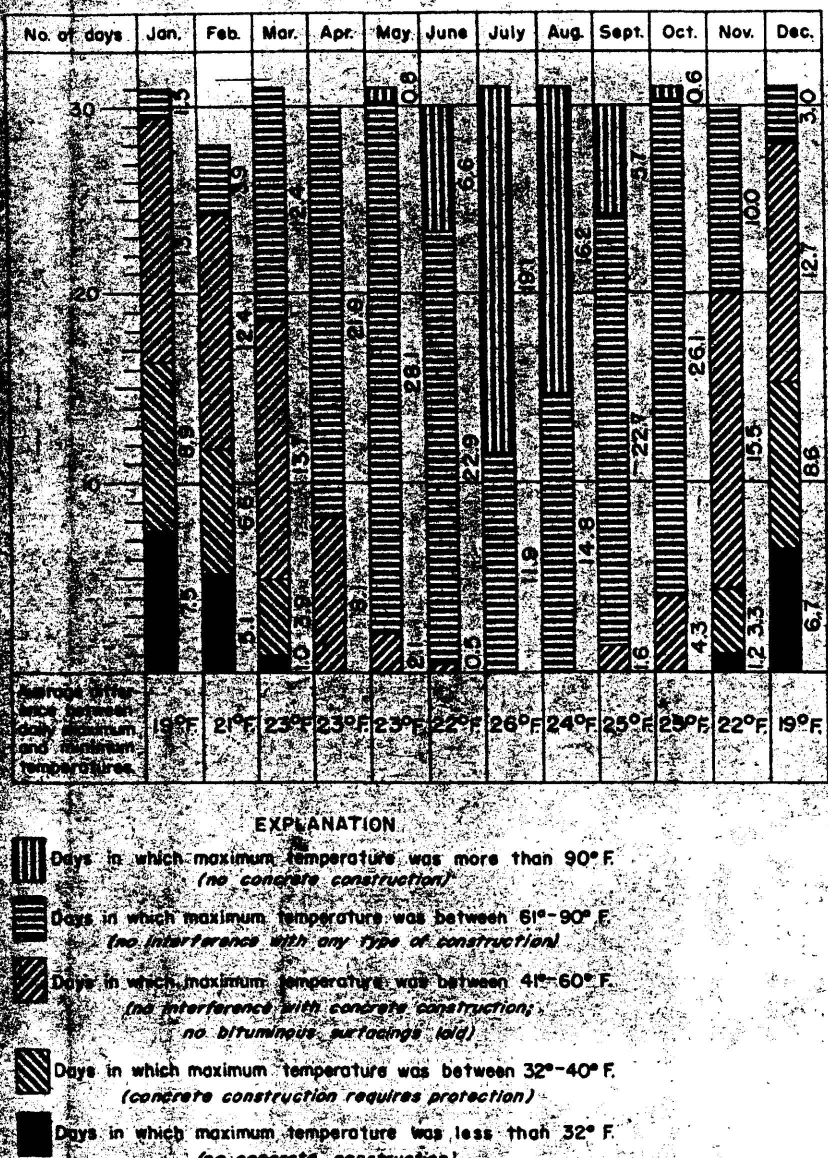


Figure 2._Chart showing temperature ranges at Eskridge, Kansas.

Data for both charts compiled from Climatological Data Kansas Section for years 1937 to 1946, inclusive. Issued by Weather Bureau United States Department of Commerce

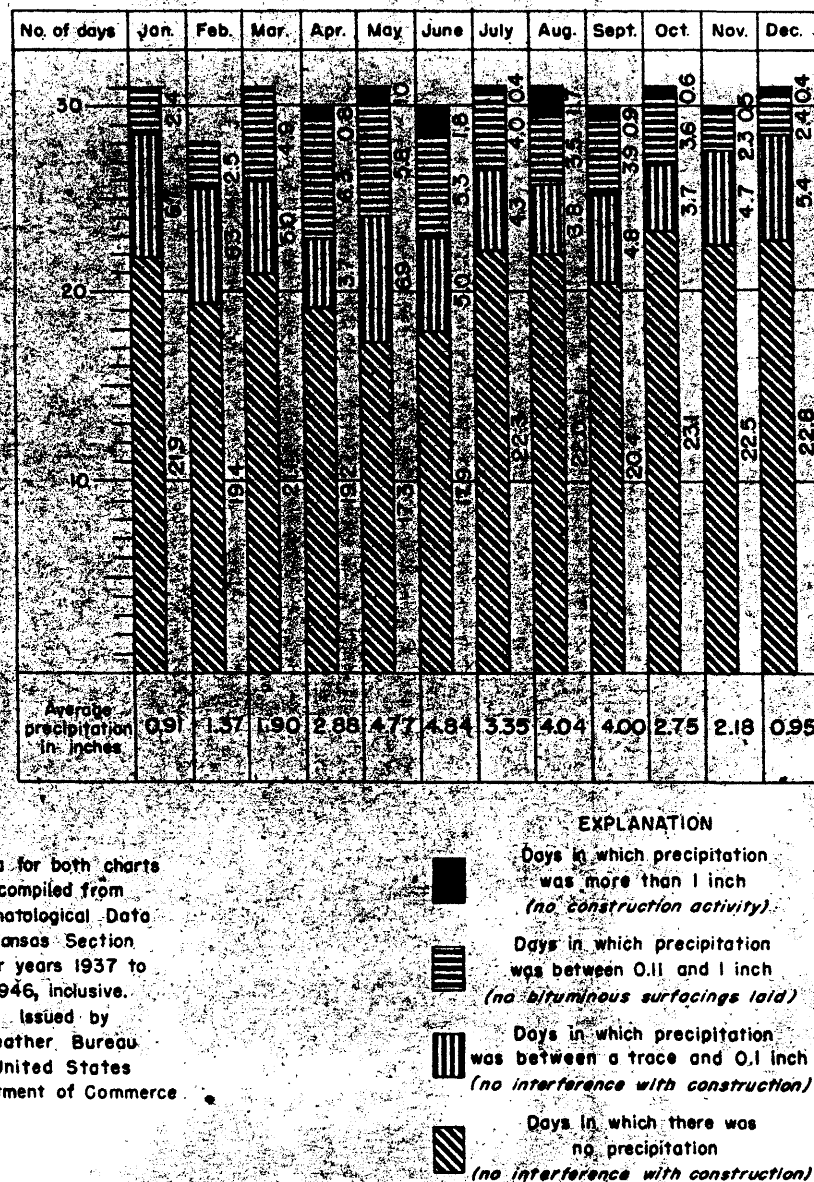


Figure 3._Chart showing precipitation ranges at Eskridge, Kansas.

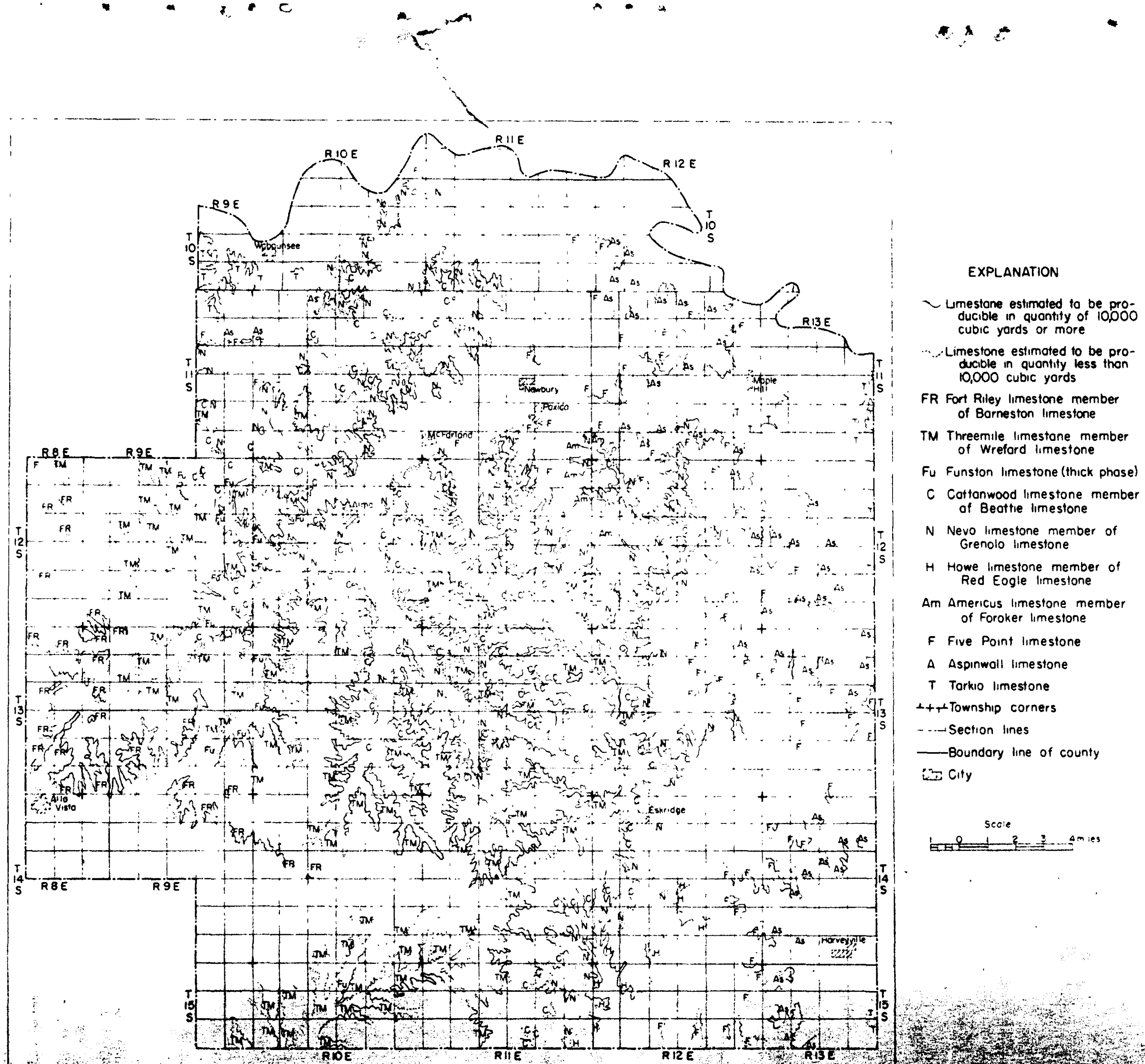


Figure 5.—Map showing outcrops in Wabaunsee County, Kans. of limestones of use in engineering construction.

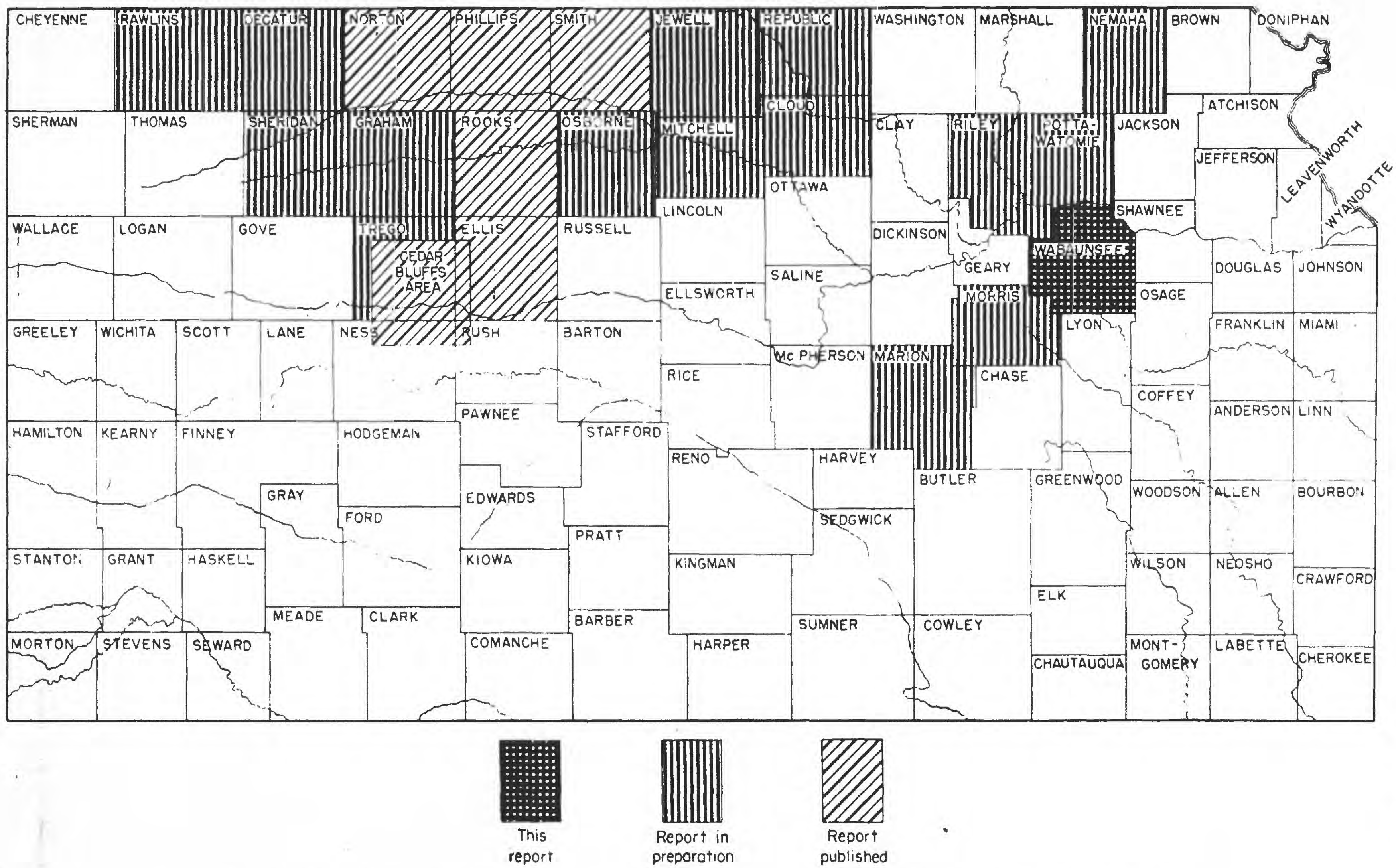
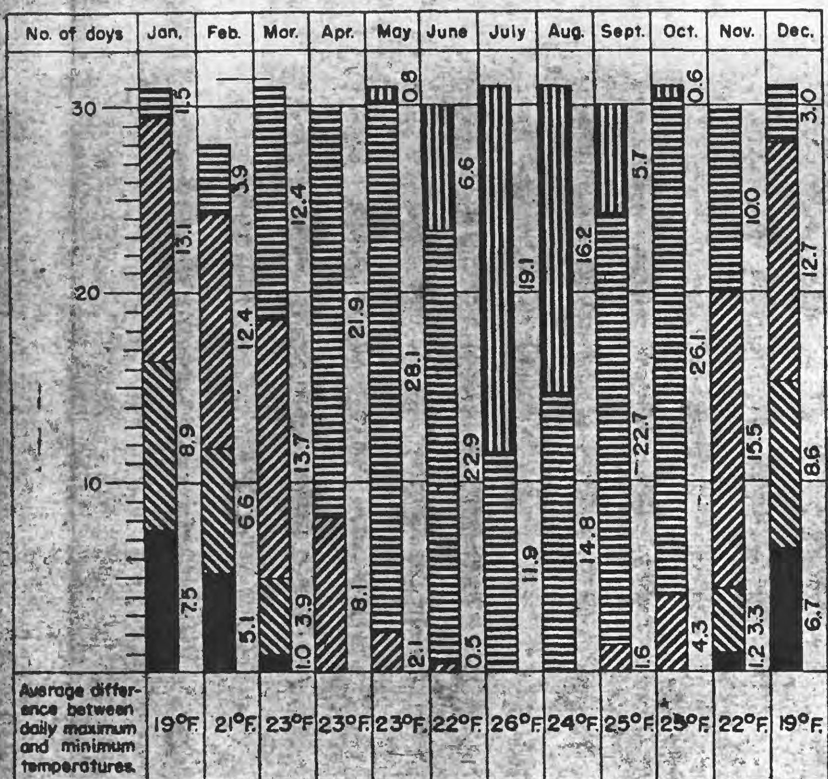


Figure I.—Index map of Kansas showing areas covered by this report and by other construction materials investigations



EXPLANATION

Days in which maximum temperature was more than 90° F. *(no concrete construction)*

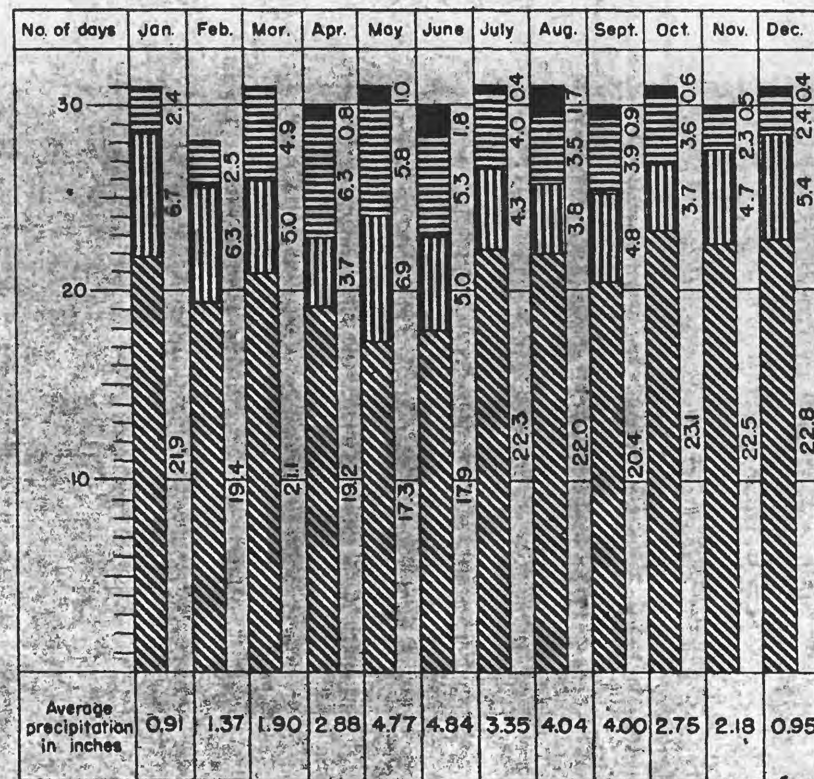
Days in which maximum temperature was between 61°-90° F. *(no interference with any type of construction)*

Days in which maximum temperature was between 41°-60° F. *(no interference with concrete construction; no bituminous surfacings laid)*

Days in which maximum temperature was between 32°-40° F. *(concrete construction requires protection)*

Days in which maximum temperature was less than 32° F. *(no concrete construction)*

Figure 2.—Chart showing temperature ranges at Eskridge, Kansas.



Data for both charts compiled from Climatological Data Kansas Section for years 1937 to 1946, inclusive, issued by Weather Bureau United States Department of Commerce

EXPLANATION

Days in which precipitation was more than 1 inch *(no construction activity)*

Days in which precipitation was between 0.11 and 1 inch *(no bituminous surfacings laid)*

Days in which precipitation was between a trace and 0.1 inch *(no interference with construction)*

Days in which there was no precipitation *(no interference with construction)*

Figure 3.—Chart showing precipitation ranges at Eskridge, Kansas.

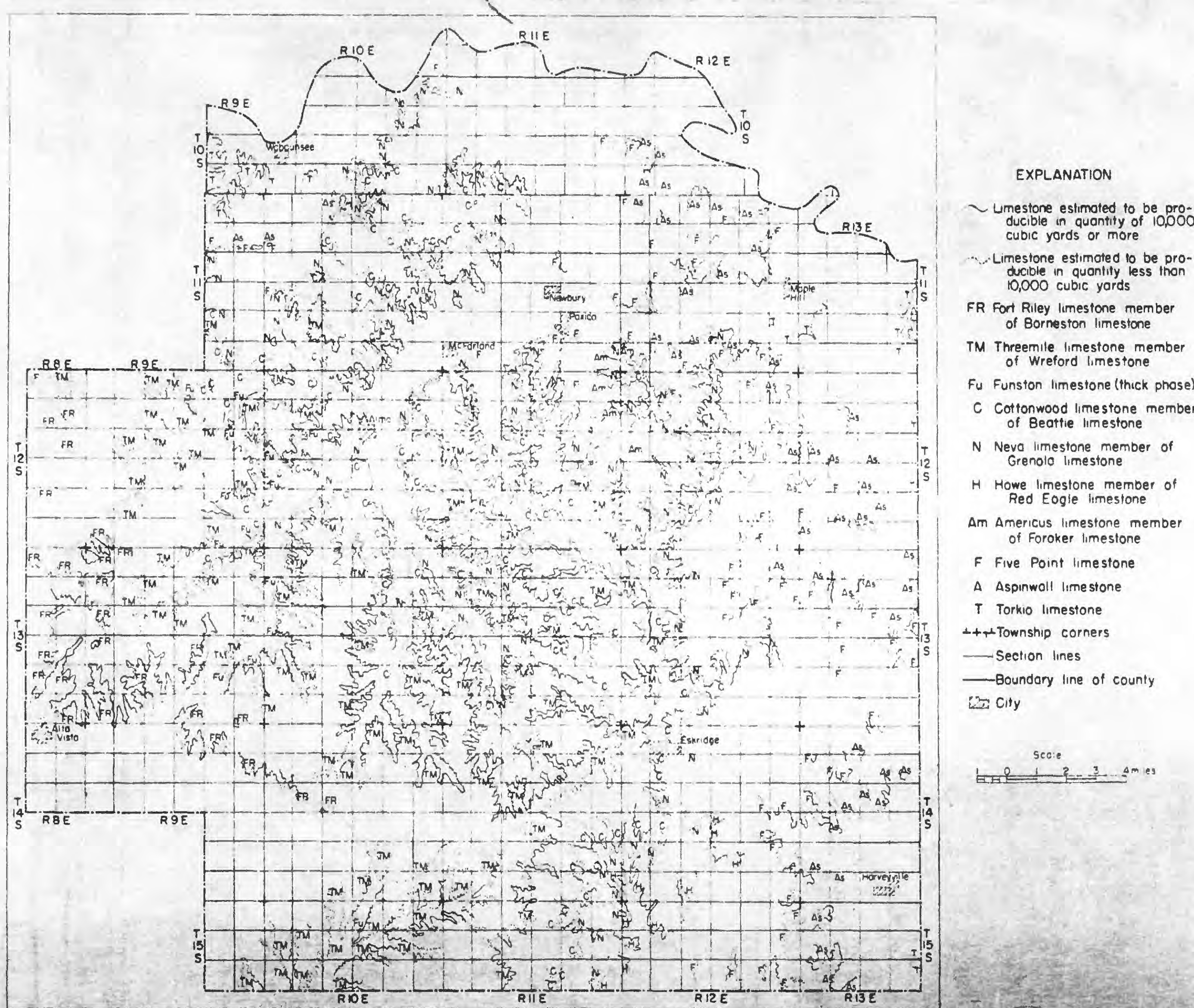


Figure 5.—Map showing outcrops in Wabaunsee County, Kans. of limestones of use in engineering construction

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System	Series	Group	Section	Average thickness (feet)	Symbol on plate 1	Geologic formation	Geologic member	Description	Construction materials
Quaternary	Pleistocene and Recent			20	Qal	Alluvium	These formations are not subdivided into members	Tan brown to gray-brown silt and clay with sand and gravel in lower part.	Aggregate Road metal
				0-12	Qtr	Travertine		Gray to light gray deposit of dense, porous calcium carbonate. Contains leaf and wood fragments.	Calcareous binder
				5-20	Qt Qt$_1$ Qt$_2$	Terrace deposits		Predominantly red-brown silt and clay; tends to stand in vertical banks; lenses of chert and limestone gravel occur in basal part.	Aggregate Road metal Mineral filler
				10	Qs	Sanborn formation		Gray brown to red-brown silt and clay Chert and limestones gravels in basal part; gravity-moved material of local rock.	Road metal Mineral filler
				2-30	Qgt	Glacial till		Non-stratified, light gray to gray-brown clay with some silt, sand, and erratics; erratics range in size from sand to boulders 5 feet or more in diameter.	Structural stone Riprap
				6	Qgk	Kame-like deposits		Fine and coarse sand with red-brown silt and clay; various kinds of small erratics abundant; some limestone and chert fragments.	Aggregate Road metal Mineral filler
				30	Qgo	Glacial outwash		Various sizes of material ranging from fine sand to boulders; great variety of igneous and metamorphic rocks; limestone and chert fragments common; some clay inclusions; usually shows bedding and crossbedding.	Road metal
				8	Qog	Older gravels		Thick beds of chert gravel and red-brown clay overlain in most cases by glacial till. Limestone gravels containing some chert, limestones well rounded, chert semi-angular, size varies from sand to pebbles with some cobbles.	Road metal
Permian	Leonard	Sumner		8	Pb	Doyle shale	Holmesville shale	Silty, calcareous, tan gray to gray shale, has a blocky to thin-bedded structure.	Aggregate Structural stone Riprap Road metal
				25		Barneston limestone	Fort Riley limestone	Massive to shaly, beds vary from hard to soft dolomitic limestones, shale partings near base and in center, limestones tan to tan gray; lower limestone forms conspicuous "rimrock" outcrop.	

Figure 4A.—Outcropping stratigraphic units in Wabaunsee County, Kans., and their construction materials.

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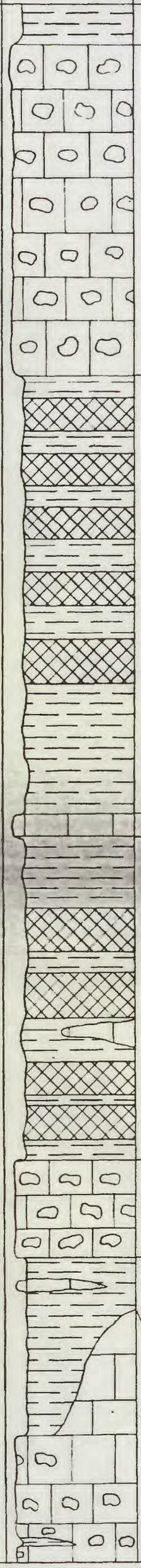

System	Series	Group	Section	Average thickness (feet)	Symbol on plate 1	Geologic formation	Geologic member	Description	Construction materials
Permian	Wolfcamp	Chase		4		Barneston limestone	Oketo shale	Silty, calcareous, tan gray to gray, locally blue gray. Shale sparsely fossiliferous to nonfossiliferous.	Aggregate Structural stone Riprap Road metal
				30	Pb		Florence limestone	Massive beds of hard, gray to light gray limestones containing numerous chert nodules and lenses; fossiliferous; forms a conspicuous, rounded shoulder on a hillside which is covered by an abundance of chert fragments.	
				40		Matfield shale	Blue Springs shale	Predominantly silty and calcareous, shale tan gray, green, maroon, and purple zones in upper part, tan gray in lower part. Fossils are present in the lower part in some places.	
				2			Kinney limestone	One or more thin, tan gray, massive limestones; microfossils abundant in upper part.	
				30	Pwr		Wymore shale	Silty and clayey, calcareous shales with tan-gray beds in upper part and gray green, tan, and maroon shales in lower part. Thin limestones and fossiliferous shales occur in lower part in some places.	
				8.5		Wreford limestone	Schroyer limestone	Massive, hard, fossiliferous, light gray limestone containing numerous chert lenses and nodules; forms subdued hillside bench.	
				10-18			Havensville shale	Shale, clayey in lower part and silty in upper part, gray green to gray, thin limestone lens near top.	
				10-30			Threemile limestone	Massive, hard, light gray, fossiliferous beds of limestone which contain chert lenses and nodules in all but the uppermost bed. A fossiliferous shale is usually present near the base. In some places the limestone is very thick, soft, and massive with the chert lenses restricted to the basal part.	

Figure 4B.— Outcropping stratigraphic units in Wabaunsee County, Kans., and their construction materials (continued).

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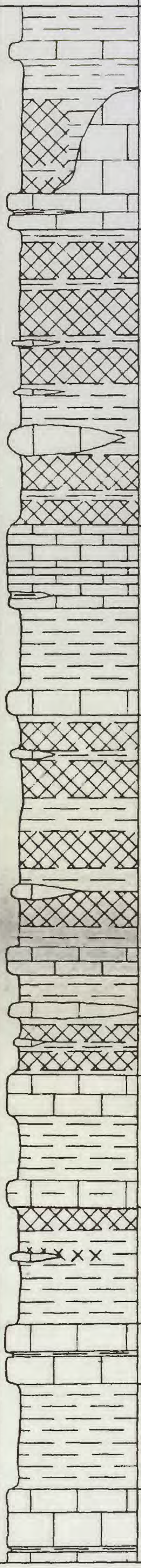
System	Series	Group	Section	Average thickness (feet)	Symbol on plate 1	Geologic formation	Geologic member	Description	Construction materials
Permian	Wolfcamp	Chase		16	Pf	Speiser shale		Silty, calcareous shale, usually vari-colored, tan gray predominant in upper part, maroon and gray green in lower part, locally may be only tan or tan gray; persistent bed of limestone present in upper part.	Aggregate Structural stone Riprap Road metal
				3-22		Funston limestone		Beds of soft, massive, fossiliferous limestone separated by one or more shale; very thick and highly fossiliferous in beds of some places.	
				25	Pc	Blue Rapids shale		Predominantly silty and calcareous shale; gray brown with some gray green and maroon zones; locally, beds of hard, massive limestone are present.	
				16		Crouse limestone		Two or more hard limestones separated by a thick tan-gray shale; uppermost limestone weathers platy with a massive ledge near base; lower limestone hard and massive; some fossils occur in limestones. Platy bed forms a broad, flat, hillside bench.	
				20		Easly Creek shale		Predominantly silty and calcareous shale, gray in lower part with gray green, green, and maroon zones composing remainder.	
				6	Pba	Bader limestone	Middleburg limestone	Two hard, massive, fossiliferous limestones separated by a shaly, calcareous, tan-gray shale.	
				6			Hooser shale	Predominantly silty and calcareous shale, tan gray to green; locally, thin, maroon beds and limestone lenses are present.	
				10			Eiss limestone	Two limestones separated by a gray silty, calcareous fossiliferous shale. The upper limestone is hard, massive, porous, and forms a hillside bench; lower limestone is shaly, tan gray and fossiliferous.	
				10	Pbe	Stearns shale		Predominantly silty and calcareous shale, tan gray to olive drab; thin, clayey limestone lens near middle.	
				5		Beattie limestone	Morrill limestone	Two or more thin limestones separated by shale partings; limestones tan gray and porous to cavernous.	
				9			Florena shale	Silty, calcareous, tan gray and fossiliferous shale; locally, a gray-green zone occurs in upper part; fossils absent in some places	
				6			Cottonwood limestone	Hard, massive, gray, fossiliferous limestone with some chert nodules and lenses; forms prominent hillside bench marked by bush line.	

Figure 4C.—Outcropping stratigraphic units in Wabaunsee County, Kans., and their construction materials (continued).

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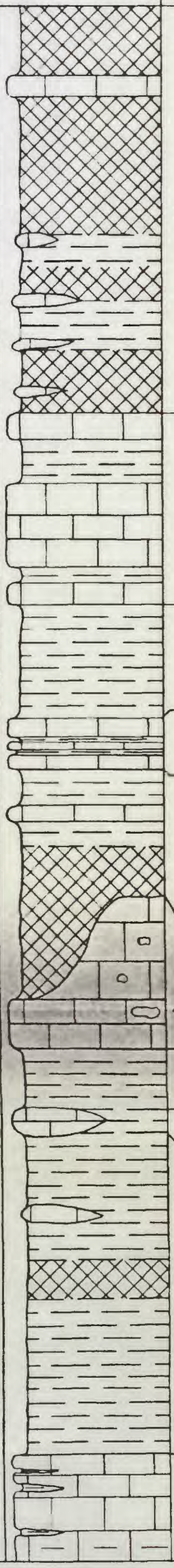

System	Series	Group	Section	Average thickness (feet)	Symbol on plate 1	Geologic formation	Geologic member	Description	Construction materials
Permian	Wolfcamp	Council Grove		32	Pg	Eskridge shale		Silty to clayey, predominantly calcareous, gray green, olive drab, maroon, and purple shales with some gray and tan-gray zones in the lower part; beds of massive, hard limestone in upper part; one or more thin lenticular limestones in lower part; limestones usually fossiliferous.	Aggregate Structural stone Riprap Road metal
				15		Grenola limestone	Neva limestone	Massive beds of limestone separated by two or more calcareous, tan-gray shales; limestone in middle part, soft, porous to cavernous; shales and limestones fossiliferous.	
				9			Salem Point shale	Silty, calcareous, olive drab to blue-gray shales; numerous calcareous plates on weathered surface.	
				4			Burr limestone	Soft, massive, gray brown, fossiliferous limestones separated by thin, calcareous shales.	
				18	Pre	Roca shale		Silty to clayey, calcareous shale, tan in upper part, green and gray green with some maroon zones in lower part; persistent thin bed of limestone in upper part.	
				4-12		Red Eagle limestone	Howe limestone	Soft, massive, tan to gray orange, fossiliferous limestone; thick, hard, and massive in some places and may contain chert nodules or a chert lens.	
				3-7			Bennett shale	Clayey, calcareous, gray brown to dark gray, thin-bedded shales; usually fossiliferous.	
				0-2			Glenrock limestone	Hard, massive, fossiliferous limestone; absent in some places.	
				25	Pfo	Johnson shale		Predominantly silty and calcareous, tan to tan-gray shale with some thin gray-green zones in lower part; calcareous lenses in upper part.	
				8		Foraker limestone	Long Creek limestone	Soft, massive, tan to gray-orange limestone, locally contains one or more partings of thin-bedded, gray shale in upper part and a very fossiliferous limestone in basal part.	

Figure 4D.—Outcropping stratigraphic units in Wabaunsee County, Kans., and their construction materials (continued).

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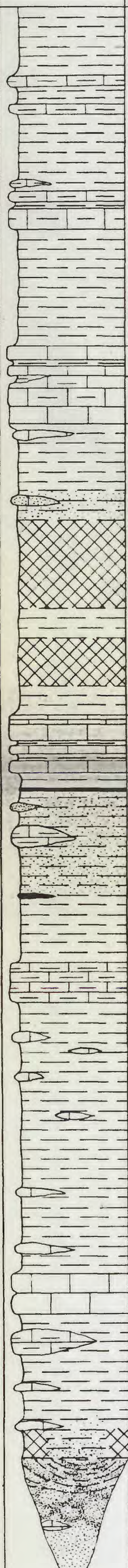
System	Series	Group	Section	Average thickness (feet)	Symbol on plate I	Geologic formation	Geologic member	Description	Construction materials
Permian	Wolfcamp	Council Grove		35	Pfo	Foraker limestone	Hughes Creek shale	Silty, calcareous, gray to dark gray, very fossiliferous shale containing two clayey limestones in the upper part and one or more clayey limestones in the middle part.	Aggregate Structural stone Riprap Road metal
				3			Americus limestone	Two hard, dense, dark gray, fossiliferous limestones separated by a silty, calcareous, gray shale.	
		Admire		3-5	Pfp	Hamlin shale	Houchen Creek limestone	Hard, dense, gray limestones locally separated by one or more thin shales. Contains large algal masses.	
				30			Stine shale	Predominately silty, calcareous shales, gray to gray green in upper part, gray green and maroon in lower part; thin sandstone lens near middle.	
				6		Five Point limestone		Two or more hard, gray limestones separated by one or more calcareous shales; uppermost limestone platy or massive, and fossiliferous.	
				20	Pfc	West Branch shale		Silty, slightly sandy, tan, gray, and gray-brown shale with a thick lens of clayey limestone in upper part. Persistent thin coal near top and a lenticular coal bed in lower part.	
				4		Falls City limestone		Soft, thin-bedded, tan, cavernous limestone.	
				28	Pa	Hawxby shale		Predominately silty and calcareous, olive drab and gray-brown shale with numerous thin, fossiliferous limestone lenses.	
				4		Aspinwall limestone		Hard, gray to tan brown, massive limestone; contains numerous small brown specks.	
				15	Pt	Towle shale	Unnamed shale	Predominately silty, calcareous, and gray-brown shale; contains some thin limestones and maroon zones; thin, clayey limestone present near top.	
				0-75	Pti		Indian Cave sandstone	Fine-grained, tan to tan brown, cross-bedded sandstone; composed of grains of quartz and mica cemented by iron oxide and, locally, calcium carbonate, conglomerate near top and middle, occurs in local channels cut into underlying formations of Pennsylvanian age.	

Figure 4E.—Outcropping stratigraphic units in Wabaunsee County, Kans., and their construction materials (continued).

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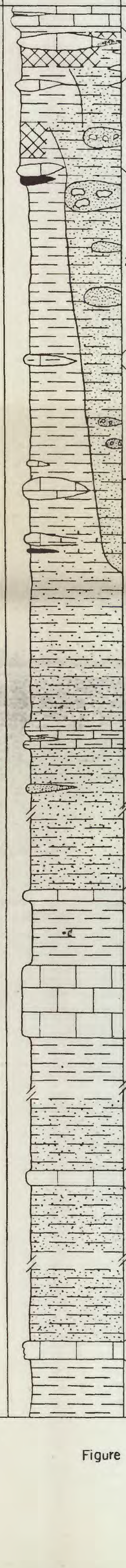

System	Series	Group	Average thickness (feet)	Symbol on plate 1	Geologic formation	Geologic member	Description	Construction materials
Pennsylvanian	Virgil	Wabaunsee	2.5	Cbr	Brownville limestone		Blocky, tan gray to brown, fossiliferous limestone; local shale parting.	Aggregate Structural stone Riprap Road metal
			6 (55)	Cpf	Pony Creek shale (French Creek-Pony Creek shale)		Silty, calcareous, gray and gray green. Limestone lenses in upper part, maroon in some places. French Creek-Pony Creek shales.-- Varies from silty to sandy, tan to blue gray shale, locally contains numerous lenses of limestone. Conglomerates and septarian. Concretions occur in some places.	
			10	Ccv	Caneyville limestone (French Creek-Pony Creek shale)	Grayhorse limestone	Hard, massive, gray orange, fossiliferous limestone.	
						Unnamed shale	Sandy, micaceous, gray to gray green shale; local maroon zones.	
						Nebraska City limestone	Very fossiliferous, gray, shaly limestone.	
			20	Cjc	French Creek shale (French Creek-Pony Creek shale)		Clayey, noncalcareous, tan-gray to blue-gray shale, micaceous in lower part; coal lens in upper part.	
			1		Jim Creek ls (Caneyville limestone-French Creek shale)		Hard, dark gray, fossiliferous, shaly limestone.	
			13	Cgh	Friedrich shale (Caneyville limestone-French Creek shale)		Clayey, olive drab, to blue-gray shale, calcareous lenses in lower part in some places. Caneyville limestone and French Creek shale.--Sandy shale, cross-bedded to massive sandstones, and conglomerates tan to tan brown, fine micaceous sand with some wood and leaf fragments.	
			7	Ccf	Grandhoven limestone (Caneyville limestone-French Creek shale)		Two limestones separated by a sandy, tan gray to olive drab shale. Upper limestone hard, fossiliferous and brown, lower limestone shaly and locally is a calcareous shale.	
			20	Cda	Dry shale		Tan gray to olive drab, sandy shale. Locally a thin lens of coal in upper part.	
			3		Dover limestone		Two limestones, locally separated by a shale; limestones are massive to nodular, brown to light gray, fossiliferous.	
			35	Cmh	Langdon shale		Tan gray to blue gray, sandy shale, sandstone lenses in upper part.	
			1.2		Maple Hill limestone		Massive, hard, gray, fossiliferous limestone.	
			8-25	Ct	Wamego shale		Silty, calcareous, gray-brown shale, contains some fossils locally.	
			3-12		Tarkio limestone		Massive, hard, dense, very fossiliferous limestone which becomes sparsely fossiliferous and sandy in southern part of outcrop area.	
			32	Ce	Willard shale		Silty to sandy, gray brown to gray shales; upper part thin-bedded, lower part blocky.	
			1.8		Elmont limestone		Massive, hard, dark gray, fossiliferous limestone.	
			21	Cr	Harveyville shale		Tan gray to blue gray, thin-bedded sandy shale.	
			2		Reading limestone		Hard, dense, dark gray to brown, fossiliferous; usually weathers into three distinct beds.	
			6	Cwa	Auburn shale		Clayey, tan gray, thin-bedded shale.	

Figure 4F.— Outcropping stratigraphic units in Wabaunsee County, Kans., and their construction materials (concluded).