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PRELIMINARY REPORT AND MAP ON THE GEOLOGIC CONSTRUCTION MATERIAL RESOURCES IN RILEY COUNTY, KANSAS

By

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INTRODUCTION

Purpose of the investigation

The State Highway Commission of Kansas and the United States Geological Survey are cooperating in the compilation of State-wide construction materials inventory. This report on Riley County, Kansas is a part of the Department of Interiors' program for the development of the Missouri River Basin in connection with geologic mapping and mineral resource investigations. 1/ A field party of the United States Geological Survey started its investigations of sources of engineering construction materials in Riley County in the fall of 1947. The investigation was continued in the spring and fall of 1948 and concluded in the spring of 1949. It also included the compilation of a map to show the geologic occurrence of the construction materials.

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

The primary objective of the investigation was to accumulate all field and laboratory data pertaining to the geologic materials in Riley County that would be of use in the construction of dams, highways, railways, airports, and other engineering structures. Additional geologic data are included in this report but only to the extent of providing information useful in the development of the prospects reported in the inventory or for the location of other materials required for future engineering needs.

Geography

Area covered by the investigation.--Riley County is in the second tier of Kansas counties south of the Nebraska border and in the fourth tier west of Missouri. (See fig. 1.)

Topography.--Riley County is near the western boundary of the Central Lowlands physiographic province in the subdivision known as the Flint Hills. These hills have been carved by streams, principally, from alternating beds of shale and flint bearing limestone. Many of the limestones form conspicuous hillside benches. The shales are more rapidly eroded than the limestones and form the steep slopes between adjacent benches.

Deposits of glacial sediments, both till (deposited directly by glacial ice) and outwash (deposited by melt-water from a glacier), occur in the eastern part of the county. Terrace deposits are found along almost all of the streams, and extensive deposits of silt in some places 20 or more feet thick, occupy the tops of many divides.

Drainage.--The principal stream in Riley County is the Kansas River which is formed by the junction of the Republican and Smoky Hill Rivers a short distance from the southwestern corner of the county. (See pl. 1.) It is joined by the next most important stream, the Blue River, near the city of Manhattan. Wildcat Creek, and other large tributaries, rises in the western part of the county and joins the Kansas River about 1 mile south of Manhattan. Minor tributaries of the Kansas River are MacDowell, Deep, Threemile, and Sevenmile Creeks. The larger tributaries of the Blue River are Mill, Fancy, and Swede Creeks.

Climate.--Riley 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 low of about 29° F. in January to a high of about 80° F. in July. On the average there are 85 cloudy days, 95 partly cloudy days, and 185 clear days a year. The average date of the first killing frost in the fall is October 12, the average date of the last killing frost in spring is April 23.[2]

2/ Flora, S. D., The Climate of Kansas: Kansas State Board Agric., vol. 67, no. 285, 1948.

Figure 2, a chart showing temperature ranges at Manhattan, Kans., was compiled from Climatological Data[3] for the years 1937 and 1946,

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

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inclusive, to provide a basis for evaluating the temperature factor in terms of days in which construction may be carried on without detriment to the engineering structure. The chart indicates, for the 10-year period, the number of days each month in which the maximum daily temperature fell within ranges arbitrarily based on temperatures important in various phases of engineering construction.

For most concrete construction the minimum allowable temperature is 32° F.; the minimum temperature for laying concrete without protection is 40° F.; and the maximum temperature at which concrete may be poured without being subjected to undue evaporation loss is 90° F. Bituminous construction should not be undertaken if the temperature drops below 60° F.

Days in which the maximum temperature does not exceed 32° F. occur only from November to March, inclusive, with the maximum incidence of 7.3 days in January. July is the warmest month of the year, with an average of 21 days having maximum temperatures above 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 October; and the least difference, 20° F., is in January.

Inasmuch as precipitation also conditions the number of working days in engineering construction, figure 3, a chart showing precipitation ranges at Manhattan, Kans., is presented to show the effect of this climatic factor. The ranges in precipitation were selected arbitrarily. Grading and concrete construction may be carried on, with perhaps only short interruptions in the work, if no more than one inch of rain falls; bituminous surfacings probably should not be laid if the rainfall has exceeded 0.1 inch; and most construction work should cease if there has been more than 1 inch of rain.

As based on a 10-year average (Climatological Summary, Kansas section, 1937-1946) there are 17 days in June, for example, in which no measurable precipitation fell; 5.6 days in which the precipitation ranged from a trace to 0.1 inch; 5.5 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 fall, for the most part, in the late spring and early fall and other rainfall is generally in the form of showers of short duration. The normal annual precipitation is 32.03 inches.

Railways.--Riley County is served by two railroads. (See pl. 1.) The Chicago, Rock Island and Pacific Railway enters from the east and parallels the Kansas River to Manhattan. It then follows the valley of Wildcat Creek toward the northwest. The main line in Kansas of the Union Pacific Railroad enters Riley County from the east at Manhattan and continues toward the southwest in the valley of the Kansas River. The Blue Valley branch of the Union Pacific Railroad leaves the main line at Manhattan and follows the Blue River northward along the eastern edge of the county.

Roads.--U. S. Highways No. 24 and No. 40 enter the county at Manhattan. (See pl. 1 and highway map at end of report.) U. S. Highway No. 24 trends toward the northwest and No. 40 toward the southwest. U. S. Highway No. 77 enters at the southwest corner of the county and trends northward. Kansas Highway No. 29 enters the county from the east and follows the valley of the Kansas River to Manhattan. Kansas Highway No. 13 enters from the south and, after passing through Manhattan, follows the valley of the Blue River to Garrison Crossing, a few miles south of Randolph.

Roads follow section lines in the relatively flat upland areas. Where the topographic relief is too great, however, the roads have been located along stream valleys. Roads are relatively few in the hilly eastern part of the county. The U. S. and State highways are constructed of concrete or bituminous materials or are metalled with local materials; county and 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 to 3 inches equal 1 mile) provided by the State Highway Commission of Kansas. The photographs were also used in the placement of the contact lines between adjacent stratigraphic units. Some of the mapped units are single 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 4/ and the Kansas Geological

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

Survey. 5/ The principal emphasis of this report is on construction

5/ 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.

materials. Geologic problems not critically related to construction materials, therefore, are considered to be of secondary importance.

An effort was made to accumulate all existing data pertaining to construction materials in the county. Existing data on construction materials together with sources, are incorporated in this report. In addition, the field party collected samples of construction materials not reported previously. The samples were subjected to routine laboratory tests in the Road Materials Laboratory of the State Highway Commission of Kansas, Manhattan, Kans. A portion of each sample of aggregate material was analyzed under a binocular microscope in the laboratory of the Department of Geology, Kansas State College, and the constituent rock and mineral grains determined. The laboratory tests and mineralogical analyses, together with information on the pit or quarry site, are presented in table 1, a summary of materials tests.

Acknowledgments

Appreciation is expressed to the following for their aid in contributing information used in the compilation of the geologic map or the construction materials data included in this report: the State Highway Commission of Kansas at Topeka and Manhattan, Kans., R. D. Finney, engineer of materials, and W. E. Gibson, engineer of tests; the Kansas office of the Ground Water Division,

United States Geological Survey, V. C. Fishel, district engineer; the State Geological Survey of Kansas at Lawrence, Kans., J. C. Frye, executive director, and J. M. Jewett, geologist; and W. Kipper, the county engineer. An earlier report by Jewett 6/ on the geology of Riley and Geary Counties, in which a somewhat different type of geologic map is included, was a valuable guide to field investigations.

6/ Jewett, J. M., Geology of Riley and Geary Counties, Kans.: Kansas Geol. Survey Bull. 39, 164 pp., 1941.

This report, in manuscript form, was reviewed by various members of the State Highway Commission of Kansas and the United States Geological Survey.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

Introduction

This discussion of the outcropping stratigraphic units of Riley 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 4G. The areal distribution of the local stratigraphic units is shown on plate 1, a map of Riley County. Each mapped unit is indicated by an identifying symbol and groups of formations of Pennsylvanian and Permian age and formations of Cretaceous and Quaternary age are shown by distinctive patterns overprinted in color. Locations of operated and prospective pits and quarries are also shown. For more convenient use in the field, plate 1 is printed in three parts.

As an aid to the identification of the local geologic formations in the field, figure 5, a chart showing the location of representative sections of outcropping stratigraphic units, is included in this report. Figure 6, summarizes 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 whether (1) 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 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 the sources of construction materials are listed in table 1, Summary of materials tests, and are numbered within each classification of materials according to the following plan: the numbering starts in the northeasternmost township and continues along the same tier to the west boundary of the county; it is continued in the next tier south starting again with the township in the easternmost range and proceeding to the 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

General

The most recently deposited sediments in Riley County are those of the Quaternary system (see fig. 4A), almost all of which are unconsolidated (see fig. 5), that is, they only rarely exhibit an appreciable amount of cementation or compaction. The Quaternary formations are of nonmarine origin and were deposited by wind, streams, gravity, and glaciers. Glacial sediments occur in the eastern part of the county on the tops of some of the divides and in the valley bottoms. Stream-deposited sediments are limited to the valleys but some of them occur as terraces well above the level of the present-day streams. Wind-deposited sediments are found both in the valleys and on the tops of divides. Sediments moved by creek or slopewash mantle the lower part of the walls of many stream valleys.

Alluvium

Areal distribution.--The deposits (see fig. 4A) formed by streams in their present floodplains are mapped as alluvium (Qal) on plate 1. The floodplain is the area, adjacent to the stream channel, which is covered by water during normal flood stage. On plate 1 alluvium is mapped in the valleys of the Kansas and Blue Rivers, and Deep, MacDowell, Wildcat, and Fancy Creeks. Less extensive deposits of alluvium occupy the lower parts of the valleys of smaller tributaries but may not be shown on the map. The alluvium deposited by the Kansas River is, in some places, as much as 1.25 miles wide although its average width is about 0.25 mile. The average width of the alluvium in the valley of the Blue River is about 0.25 mile and that of the alluvium of the smaller streams is about 0.1 mile. The alluvial deposits are widest on the inner curves of meanders.

General description.--The alluvium deposited by the Kansas and Blue Rivers consists predominantly of sand and gravel-size particles in the zone near river level, and of particles of silt and fine sand in the upper part of the deposit. Thin lenses of water-rounded fragments of local cherts occur occasionally in the silty upper part of the alluvium. This part is generally red brown and exhibits a strong tendency to stand in vertical banks. The sand-gravel basal zone is usually light gray or tan.

The alluvial deposits in the valleys of other streams in the county are composed predominantly of red-brown silt. They often contain an appreciable percentage of intermixed clay-size particles, and local lenses of gravel-size particles of limestone and chert. The lenses are most numerous in the lower part of the alluvium.

Thickness.--Accurate determinations of thickness of the alluvium could not be made in the absence of precise test-hole data. It is estimated that the maximum thickness of the alluvium in the valley of the Kansas River is about 100 feet; of the Blue River, about 80 feet; of Wildcat Creek, about 50 feet; and of the smaller tributaries, about 25 feet.

Construction materials.--

Aggregate for concrete.

Road metal.

Dune sand

Areal distribution.--Dune sand of Quaternary age (see fig. 4A) occurs only in the valley of the Kansas River. (See Qds on pl. 1.) A large area of dune sand is in sec. 4, T. 11 S., R. 7 E., for the most part, but extends for short distances into adjacent sections. The only other area mapped as dune sand is in the eastern part of sec. 36, T. 10 S., R. 7 E. and the western part of sec. 31, T. 10 S., R. 8 E. Areas in which alluvial sands have been reworked by the wind were noted elsewhere in the valley of the Kansas River but were too small to be mapped on plate 1.

Dunes are the deposits of mineral particles of sand size that have been deposited by the wind. Areas of sand dunes are characterized by a hummocky topography, and the sand composing the dunes is typically cross-bedded. The deposits are tan-gray. The two largest areas of dunes occur along the north side of the river and along the inner sides of meander curves. Though they lie on terraces as much as 15 feet above the present stream level, the sand particles undoubtedly were eroded from alluvium by the wind, carried up onto the terrace, and there deposited as dunes. The dunes occur only along the north side of the river because the winds blow prevailingly from the southwest during the hot, dry summer months when the low moisture content of the alluvial sand makes the deposit most likely to be wind eroded. A covering of vegetation has developed to anchor the dunes rather effectively.

Thickness.--The thickness of the dunes varies from a featheredge to a maximum of about 25 feet. Their average height is about 10 feet.

Construction materials.--

Mineral filler.

Road metal.

Terrace deposits

Areal distribution.--Terrace deposits of Quaternary age are mapped in the valleys of most streams in Riley County. (See fig. 4A and pl. 1.) Two well-defined terrace levels are mapped on plate 1 along the Kansas and Blue Rivers. The older and higher level is indicated by the symbol Qt_1 and the lower level, which is much less extensive, by Qt_2. Terrace deposits in the valleys of other streams are not differentiated and are indicated by the map symbol Qt on plate 1. The terrace deposits along the Kansas River average about 3 miles wide; those along the Blue River vary from about 2 miles wide in the vicinity of Manhattan to less than 1 mile wide near Cleburne. Terrace deposits in the valleys of other streams in the county are seldom more than 0.5 mile wide.

General description.--The terrace deposits are composed of materials laid down by present-day streams in earlier cycles of deposition. They consist predominantly of silt-size particles, but also contain lenticular sandy zones and numerous lenses of gravel made up of local limestone and chert. The silts are red-brown, show a marked tendency to stand in vertical banks, and often develop crude columnar structure. Fossilized remains of elephants and other mammals of the Ice Age are often found in the terrace deposits.

Thickness.--The height of the terrace level above the present floodplain of the streams ranges from about 4 feet along some of the smaller streams to a maximum of about 25 feet along the Kansas River. Their average height is about 10 feet. Data from water wells and test holes drilled in the valleys of the Kansas and Blue Rivers indicate that the full thickness of the sediments deposited in these valleys are probably in excess of 85 feet. Without more precise data than are now available, however, it is not possible to tell what part of this thickness is to be ascribed to older glacial sediments.

Construction materials.--

Aggregate for concrete.

Road metal.

Mineral filler.

Sanborn formation

Areal distribution.--The Sanborn formation of Quaternary age is the most widely distributed stratigraphic unit that outcrops in Riley County. (See fig. 4A and pl. 1.) It occurs principally on the tops of divides, but is also present in the headward portions of small tributary valleys and along the base of the walls of the valleys of somewhat larger tributaries. Frye and Fent 7/ have subdivided the

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

formation into members, but it was not feasible to attempt the mapping of such members in the field work on which this report is based. To do so would have required a greatly expanded field program, including test drilling. The treatment of the Sanborn as an undivided unit seemed adequate to serve the purpose of a construction materials inventory.

As defined in this report, the Sanborn formation consists of materials deposited by the wind (other than sand dunes), slopewash, and through the action of soil creep. Wind-deposited silts (loess) named the Loveland and Peorian have been recognized in Riley County but are not mapped as subdivisions of the Sanborn formation. Their characteristics, insofar as engineering properties are concerned, do not warrant the additional field work that would be required to distinguish them on plate 1.

General description.--The Sanborn formation is composed predominantly of rust-gray to red-brown silt. In almost all places in the county it contains a relatively high percentage of clay. Although the A horizon and the upper part of the B horizon of the soil profile have been thoroughly leached of soluble constituents, the basal part of the B horizon and the underlying C horizon contain fairly heavy concentrations of calcium carbonate either disseminated throughout or concentrated in the form of nodules or stringers. Locally, in the basal part of the formation, there are thin lenses of gravel composed of fragments of local limestone and chert. Occasional clay balls, sometimes as large as 5 inches in diameter, are found in the formation. The silt of the Sanborn tends to stand in vertical banks, and often exhibits columnar structure.

Thickness.--The average thickness of the Sanborn formation is about 10 feet; it ranges from a featheredge to an estimated maximum thickness of about 20 feet in the northwestern part of the county.

Construction materials.--

Road metal.

Mineral filler.

Glacial deposits

Several deposits associated with the glacier or glaciers that advanced into northeastern Kansas during the Pleistocene epoch (the Great Ice Age) of the Quaternary period are mapped on plate 1 and their characteristics are summarized in fig. 4A. The sediments deposited directly by melting glacial ice are mapped as glacial till (Qgt); those deposited by meltwaters coming from the ice, or by streams flowing toward the ice are mapped as glacio-fluvial sediments (Qgf); and one deposit of glacially transported boulders (erratics) is mapped as glacial boulders (Qgb). The sediments composing these three stratigraphic units were probably deposited at nearly the same time. In many places in the eastern part of the county it was difficult to draw an exact line of demarcation between the Sanborn formation and glacial till or glacio-fluvial sediments.

(1) Glacial till

Areal distribution.--Outcrops of glacial till have been identified only in the northeastern part of Riley County. The outcrops are discontinuous and occur only in road ditches or where streams, in their headward portions, have cut through the overlying mantle of Sanborn formation. Essentially all of the outcrops of this material thus far discovered are confined to T. 6 S., R. 7 E. The outcrops are most numerous in sec. 1 of this township but the largest single area of exposure is in secs. 29 and 30.

General description.--The material designated in this report as glacial till is a nonstratified deposit consisting predominantly of clay with intermixed particles of silt, sand, granules, pebbles, and boulders. The larger particles are readily identifiable as having been derived from rock units that outcrop at least several hundred miles toward the northeast. The most conspicuous of these foreign materials are cobbles and boulders (glacial erratics of quartzite, dark-colored igneous rocks, and banded and green metamorphic rocks.) Of these, the quartzite erratics are the most numerous and often measure 3 feet or more across. The clay matrix in which the larger particles are imbedded is usually either yellowish green or maroon in color. Only occasional limestone and chert fragments of recognizable local origin are found in the glacial till.

Thickness.--The thickness of the glacial till ranges from a featheredge along the shoulders of the divides to an estimated maximum of 10 feet at their crests.

Construction materials.--Glacial till in this county is not a source of construction materials.

(2) Glacial boulders

Areal distribution.--One area heavily mantled with glacial boulders (see fig. 4A) is mapped on plate 1 in sec. 25, T. 10 S., R. 9 E. about 1.5 miles southeast of Zeandale. The erratics in this area show no direct relationship to deposits of glacial till or outwash. They lie on a divide underlain by rocks of Pennsylvanian age. Two somewhat similar occurrences of glacial boulders were noted in secs. 23 and 25, T. 9 S., R. 7 E., but are not mapped on plate 1 because the erratics are small (cobble size) and only sparsely scattered over the two divides. Occasional erratic boulders have also been found on Bluemont Hill just north of Manhattan, on College Hill on the campus of Kansas State College, and on Stagg Hill about 2 miles west of Manhattan.

General description.--Almost all of the glacial boulders concentrated on the hilltop near Zeandale are quartzite. Occasional erratics of other kinds of rocks, such as granite and dark-colored igneous rock are also found. The average diameter of the erratics is about 4 feet, but some are double that size. The erratics on the hilltops north of Manhattan are seldom more than 5 or 6 inches across and are usually platelike rather than rounded or quadrangular, as are the larger erratics elsewhere. The erratics found on Bluemont, College, and Stagg Hills are about the same size as those in the Zeandale area.

The erratic field near Zeandale is about 5 miles west of the nearest known outcrop of glacial till (in Wabaunsee County). Further, it contains no indication of the fine matrix of clay and silt that is almost invariably associated with glacial till. For these two reasons, therefore, this concentration of erratics is shown on plate 1 as a separate map unit. It is possible that this deposit represents boulders dropped by icebergs stranded in considerable number near the spillway of a hypothetical glacial Kaw lake, as first suggested by Smyth. 8/ Such erratics are said to be "rafted" by

8/ Smyth, B. B., Buried moraine of the Shunganunga: Kansas Acad. Sci. Trans. 15, pp. 45-104, 1898.

icebergs detached from the main mass of the glacier and moved by wind and water currents over the surface of the glacial lake. The other isolated deposits of glacial erratics may well have had the same origin.

Thickness.--The glacial boulders are merely scattered over the surface and hence have no measurable thickness as a stratigraphic unit.

Construction materials.--

Structural stone.

Riprap.

(3) Glacio-fluvial deposits

Areal distribution.--Glacio-fluvial sediments are widespread over Riley County. (See fig. 4A and plate 1.) They are thickest and most widely distributed in the valleys of the Kansas and Blue Rivers, but important occurrences of these materials are mapped in the valleys of Wildcat, Deep, MacDowell, and Fancy Creeks.

General description.--As defined in this report, the glacial-fluvial sediments include materials carried toward the west, southwest, and south by meltwaters draining from the glacier (glacial outwash), and materials carried toward the east, northeast, and north by streams not fed by the melting ice (glacial inwash). The ice-sheet type of glacier that covered northeastern Kansas in early Quaternary times very probably dammed the eastflowing Kansas River and created a temporary lake (Kaw Lake). If such a lake did exist, the glacial outwash presumably would have been deposited as an outwash delta in the eastern part of the basin. Each of the streams draining into the lake from the west, southwest, and south would then have deposited its sediments as a series of inwash deltas around the western and southern margins of the lake basin.

Materials carried into northeastern Kansas by the glacier predominate in the glacio-fluvial outwash deposits. The basal part of a typical deposit consists largely of granitic sand and gravel in which sand-size particles of quartz and feldspar and gravel-size particles of granite are most numerous, but fragments of other minerals and rocks, such as quartzite, metamorphic rocks, dark-colored igneous rocks, and chert are also found. The basal phase of the glacio-fluvial outwash is well-displayed in Pottawatomie County in the so-called "Sand Hills" area north of St. George. Apparently similar material has been found on the top of Stagg Hill in the NW$\frac{1}{4}$ sec. 25, T. 10 S., R. 7 E.; in the excavation for the Field House on the Campus of Kansas State College; in an auger hole drilled in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 6, T. 10 S., R. 8 E.; and on the top of the north end of Bluemont Hill in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 6, T. 10 S., R. 8 E. Such outwash sands and gravels as these usually show well-developed stratification.

The basal part of a glacio-fluvial inwash deposit consists usually of lenses, often fairly extensive and quite thick, of local gravels in which fragments of limestone and chert predominate. In some places sand-size particles of quartz and chert are intermixed with the gravel. A thick and fairly extensive deposit of sand-size particles of quartz, feldspar, and brown iron oxide (limonite) was found in the SE$\frac{1}{4}$ sec. 35, T. 10 S., R. 6 E. No particles of gravel size were found in this deposit and no stratification is apparent; it is possible, therefore, that this deposit of sand represents an old area of dunes that has subsequently lost the characteristic hummocky topographic expression. The deposit, however, lies well above the present first terrace level in the valley of the Kansas River and may be a somewhat wind-reworked deltaic sand deposited in Kaw Lake at the mouth of Seven Mile Creek.

In the valleys of Deep, MacDowell, Wildcat, and Fancy Creeks, and basal zone in the glacio-fluvial inwash is typified generally by the abundance of particles of somewhat water-rounded pebbles of local chert. However, occasional rounded pebble-and cobble-size particles of limestone are found.

The basal zone in the glacio-fluvial inwash in the valleys of Deep, MacDowell, Wildcat, and Fancy Creeks is typified generally by the absence of any particles other than somewhat water-rounded pebbles of local chert. Only occasional, rounded pebble- and cobble-size particles of limestone are found in these deposits in some localities.

An intermixing of outwash and inwash sediments has been observed at several places in the county. High on the south wall of the valley of Wildcat Creek in the NW$\frac{1}{4}$ sec. 14, T. 10 S., R, 7 E. is a deposit composed principally of gravel-size fragments of chert intermixed with some sand-size particles of quartz and a few cobble- and boulder-size erratics. A similar deposit was noted on the top of a knoll just north of U. S. Highway 24 in the NW$\frac{1}{4}$ sec. 10, T. 10 S., R. 7 E. C. W. Matthews and V. B. Coombs found a gravel deposit in the SE$\frac{1}{4}$ sec. 3, T. 11 S., R. 7 E. on the south wall of the valley of the Kansas River about 80 feet above the level of the present stream. The deposit consists of pebbles of local chert, and cobbles of quartzite, granite, green metamorphic rocks and brown sandstone.

The upper part of a glacio-fluvial deposit, whether outwash or inwash, consists of a red-brown, somewhat clayey silt. No well-defined break was found between the gravelly basal phase and the silty upper phase. The silt particles may have been brought into the area by winds blowing from the ice sheet or may represent finer sediments carried by meltwater and streams at the time the ice front retreated from the area.

Thickness.--The average thickness of the glacio-fluvial sediments is estimated, on the basis of a limited number of test holes, to be about 50 feet. The sediments undoubtedly are much thicker than this in the valleys of the Kansas and Blue Rivers.

Construction materials.--

Aggregate for concrete.

Road metal.

Mineral filler.

Cretaceous system

Igneous rocks

Areal distribution.--Three small outcrops of dark-colored igneous rocks thought by Moore, Frye, and Jewett 9/ to be possibly of

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9/ Moore, R. C., Frye, J. C., and Jewett, J. M., Tabular description of outcropping rocks in Kansas: Kansas Geol. Survey Bull. 52, pt. 4, p. 151, 1944.

Cretaceous age have been found in Riley County. (See fig. 4A and pl. 1.) The largest of these is near Bala in the NW¼ NW¼ sec. 6, T. 9 S., R. 5 E. A smaller outcrop is in the NW¼ SE¼ sec. 23, T. 8 S., R. 6 E. in a shallow tributary valley about 5 miles northwest of Stockdale. The smallest of the three exposures is in the SE¼ NW¼ sec. 22, T. 8 S., R. 5 E. about 1.4 miles south of Leonardville. It is probable that other masses of igneous rocks occur in the county, but are concealed beneath the mantle of Sanborn formation.

General description.--The three occurrences represent small intrusions of basic igneous rock into the Permian strata that occupy this part of the county. The Bala intrusive is a somewhat metamorphosed (serpentinized), inequigranular (porphyritic), basic igneous rock in which are numerous metamorphosed fragments of the Permian shales and limestones through which the igneous material migrated toward the surface. The igneous rock forms a small knoll about 15 feet high and about 200 feet long. Inclusions of limestone, shale, and chert fragments are more numerous in the other two occurrences, which are further characterized by the presence of small, crushed garnets. Neither of these two occurrences has a marked topographic expression.

Thickness.--A core-drill test of the Bala instrusion by the State Highway commission of Kansas penetrated about 150 feet of the igneous rock before the test hole was abandoned. All three of the instrusive masses probably extended to a considerable depth below the present-day land surface. There is nothing to suggest that any one of them is a lava flow.

Construction materials.--

Road metal.

Dakota sandstone

Areal distribution.--Outcrops of the Dakota sandstone are limited to the northwestern part of the county. (See fig. 4A and 5 and pl. 1.) The most extensive outcrop lies along the line between secs. 1 and 2, T. 6 S., R. 4 E. Several smaller outcrops also occur in sec. 2 and one of them projects a short distance into sec. 11 of the same township. Erosional breaks (unconformities) separate this formation from the overlying Sanborn formation and the underlying Wellington shale.

General description.--This formation is represented in Riley County by sandstones and conglomerates; the beds of clay so characteristic of it farther west in Kansas are absent here. The Dakota sandstone is composed predominantly of fine to coarse sand-size grains of quartz which have been cemented by calcium carbonate and iron oxide laid down in the pore spaces. The zones of conglomerate are composed of ironstone concretions and clay balls enclosed in a matrix of sand-size grains which have been cemented by iron oxide. The sandstone and conglomerate are dark brown, typically exhibit cross bedding, and occur in massive ledges but weathering breaks them down to small blocks and nodules.

Thickness.--The Dakota sandstone average about 4 feet thick and ranges in thickness from 2 to 5 feet.

Construction materials.--

Road metal.

Permian system

General

The most numerous outcropping stratigraphic units in Riley County are those of the Permian system. (See figs. 4A to 4F.) Two series of rocks of Permian age are recognized in this county;

the younger, the Leonard, is represented only by its basal formations, the Wellington shale of the Sumner group, but the underlying 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 of the Wolfcamp series and the Sumner group of the Leonard series shown on plate 1.

The discussion of the rocks of the Permian system that outcrop in Riley County will be organized on the basis of groups of formations starting with the youngest (uppermost), the Sumner.

Sumner group

Areal distribution.--Only the basal formation of the Sumner group, the Wellington shale (symbol: Pwe), outcrops in Riley County. (See figs. 4A and 5 and pl. 1.) One series of outcrops of this formation lies in the area between Leonardville and Walsburg; a second area of outcrop extends more or less parallel to the west county line for several miles north from Lasita; and the third area of outcrop is near the northwest corner of the county, a mile or so west of Bodaville.

Wellington shale.--Thin-bedded to blocky, usually silty and calcareous shales compose the greater part of this formation. Only the lower part of the formation outcrops locally. The shales are nonfossiliferous and are tan-gray in the lowermost zone; maroon, gray, and green in the middle zone; and tan-gray in the uppermost zone. At the top of most outcrops of the Wellington shale is a bed of tan-brown limestone. The limestone is hard and massive but becomes porous or breaks down into small plates when weathered. It is usually about 1 foot thick. The name "Hollenberg limestone" is sometimes applied to this bed. The Wellington shale varies in thickness from a featheredge to a maximum of about 50 feet; its average thickness is about 25 feet.

Construction materials.--The Wellington shale may be accepted as material for fill and embankments.

Chase group

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

Map unit	Formation	Members
Pn	(Nolans limestone	(Herington limestone (Paddock shale (Krider limestone
Pwi	(Odell shale ((Winfield limestone	(Cresswell limestone (Grant shale (Stovall limestone

Map unit	Formation	Members
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.--The Chase group of formations outcrops extensively in all parts of Riley County although toward the southeastern corner the outcrops occur only on the highest divides. (See fig. 5 and pl. 1.)

Limestones known to be sources of construction material are shown in figure 6 in which the outcrop of each limestone is shown by solid and dashed lines. The solid-line outcrops indicate places where the limestone can be produced 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.

Nolans limestone.--The Nolans limestone outcrops only in the western part of the county. (See fig. 4B and pl. 1.) It is divided into three members which are, in descending order, the (1) Herington limestone, (2) Paddock shale, and (3) Krider limestone. The average thickness of the Nolans limestone is about 21 feet.

(1) Herington limestone member. Outcrops of the Herington limestone member are identified in figure 6 by the symbol, H. The Herington is a rather hard, somewhat dolomitic limestone which contains numerous thin partings of tan shale. The limestone occurs generally in rather massive ledges which weather to form blocks and plates. Its texture is sugary, and the rock is somewhat porous. The limestone is fairly fossiliferous. Its average thickness is about 7 feet, and it forms a conspicuous hillside bench by which it is easily recognized.

(2) Paddock shale member. The Paddock is a thin-bedded to blocky, gray to olive-drab shale that usually weathers tan. Some zones are composed of noncalcareous silt. Occasional fossils occur along the bedding planes. The average thickness is about 13 feet.

(3) Krider limestone member. The physical characteristics of the Krider are about the same as those of the Herington limestone member, but the Krider is thinner than the Herington and, because it is relatively soft, does not form a hillside bench as conspicuous as that formed by the Herington. The Krider is a soft, tan-gray, sugary limestone, and is usually composed of two thin limestone layers separated by a thin shale bed. Locally, however, the Krider is a single, massive bed of limestone. Fossils are fairly numerous, and its average thickness is about 1 foot.

<u>Odell shale</u>.--Outcrops of the Odell shale are mapped with those of the underlying Winfield limestone (Pwi) on Plate 1. However, the upper part of this shale usually is found beneath outcrops of the Nolans limestone. The lower part of the Odell shale is gray-green or maroon, and the upper part is tan gray or gray green. The shale is generally a noncalcareous silt but some zones are composed of clay-size particles. Its average thickness is about 25 feet.

Winfield limestone.--The three members that compose the Winfield limestone (see fig. 4B and 5) are, in descending order, the (1) Cresswell limestone, (2) Grant shale, and (3) Stovall limestone. The average thickness of this formation is about 22 feet.

(1) Cresswell limestone member. The Cresswell limestone outcrops conspicuously in the northern third of Riley County. (See Cr in fig. 6.) It is a massive, fairly hard, somewhat dolomitic limestone. Weathering of the lower part forms fairly large blocks, and smaller blocks and plates result upon the weathering of its upper part. The upper part, when badly weathered, becomes porous and cavernous and often contains small cavities filled with calcite (geodes). The Cresswell limestone varies from tan-brown to light gray and usually weathers tan gray. The lower part of the limestone is easily identified by the abundance of thin tabular fossils (echinoid spines and crinoid columnals) that characterize it. The average thickness is about 12 feet, and the limestone forms a prominent hillside bench. In one place, in the SW$\frac{1}{4}$ sec. 6, T. 9 S., R. 6 E., the Cresswell has been eroded by percolating subsurface waters to form a number of limestone sinks.

(2) Grant shale member. The Grant shale is silty, calcareous, thin-bedded to blocky, and tan gray. Because it is highly fossiliferous, its exact identification is easily made. The average thickness is about 9 feet, although it varies from a minimum of about 8 feet near the northern boundary of the county to a maximum of about 11.5 feet near the southwest corner.

(3) Stovall limestone member. The Stovall is a hard, dense, massive limestone, but weathers into fairly large blocks. It is gray to tan gray and is characterized especially by a band of chert that forms the middle zone. The limestone is fairly fossiliferous. The average thickness is about 1 foot although it ranges from 0.25 foot

near May Day to 2.5 feet in the southern part of its outcrop area.

Doyle shale.--The Doyle shale together with the underlying Barneston limestone (see figs. 4B and 5) is mapped as Pb on plate 1. The three members into which the Doyle shale is divided are, in descending order: (1) Gage shale, (2) Towanda limestone, and (3) Holmesville shale. The average thickness of this formation is about 69 feet.

(1) Gage shale member. The upper third of the Gage is a tan-gray and gray-green shale, whereas the lower two-thirds is predominantly maroon. The maroon part is usually mottled with green and is noncalcareous. The upper zone is at least slightly calcareous and includes thin limestone lenses in the eastern part of its outcrop area. The Gage shale is composed largely of silt-size particles but includes some zones of clay-size particles. Fossils are fairly numerous in the upper tan-gray zone. The average thickness is about 38 feet.

(2) Towanda limestone member. The Towanda limestone outcrops extensively in the northern half of the county (see T in fig. 6), and forms a easily identified hillside bench. The Towanda is a hard, dense, massive, essentially nonfossiliferous limestone that weathers to form small blocks and plates. It is gray orange to tan brown, and limonite stains and nodules are abundant on weathered surfaces. Very thin partings of shale occur locally. This member is characterized by local crumpling of the limestone ledges that compose it, absence of large fossils, and the hillside bench it forms. The average thickness is about 12 feet.

(3) Holmesville shale member. Outcrops of the Holmesville shale almost invariably are found beneath those of the Towanda limestone member. The Holmesville is a somewhat clayey, generally calcareous, silt shale, and contains well-defined color zones of gray, gray green, olive drab, and occasionally, maroon. If present, the maroon zone usually is in the middle part of the member. One or two thin lenses of soft, clayey, locally sandy limestone occur in the lower and middle parts of the member. The average thickness is about 19 feet.

Barneston limestone.--This formation is divided into three members, which are, in descending order: the (1) Fort Riley limestone, (2) Oketo shale, and (3) Florence limestone. (See fig. 4C.) The thickness of the formation is about 66 feet.

(1) Fort Riley limestone member. The Fort Riley limestone member outcrops most conspicuously in the central part of Riley County (see FR in fig. 6.) and consists of limestone layers, either massive or platy, interrupted at frequent intervals by shale partings and beds. The limestones usually are tan or gray-orange in fresh exposures and weather tan gray.

Two "rimrock" zones are characteristic of most outcrops of the Fort Riley in Riley County. The lower zone forms the base of the member, ranges from 3 to 6 feet thick, and is massive and quite hard although, upon weathering, it becomes porous. Because it is more resistant to weathering and erosion than the rocks above and below, the basal rimrock forms a very easily traced rim on the shoulders of many valley walls. The second rimrock ledge, near the middle part of the member, develops a less conspicuous rim. This member contains many fossils. Its average thickness is about 35 feet. The Fort Riley is easily recognized by its rimrock outcrops, thickness, and the hillside bench it forms.

(2) Oketo shale member. The Oketo shale member is usually masked by float weathered from the overlying Fort Riley, and outcrops of it are not numerous in Riley County. The Oketo is a thin-bedded, calcareous, fossiliferous, tan to blue-gray shale. Several thin lenses of limestone usually are present in the upper part. This member is consistently about 9 feet thick, and is easily recognized by its distinctive color and the abundance of fossils it contains.

(3) Florence limestone member. The Florence limestone member of the Barneston limestone is one of the most easily recognized of all the stratigraphic units in Riley County. This member outcrops extensively east of a line through Leonardville, and forms a conspicuous, rounded, hillside shoulder usually a short distance below the basal rimrock of the Fort Riley. The Florence is composed of massive limestone beds which contain numerous chert bands and nodules. Weathering causes an abundance of chert nodules to accumulate around the base of outcrops. The chert usually is light gray, as is the limestone. One or more thin partings of tan-gray or gray shale occur near the top of the member. Fossils are fairly abundant in the limestone layers but are even more abundant in the shale partings. The average thickness is about 22 feet. This member is easily recognized by its outcrop expression, and the abundance of chert it contains.

Matfield shale.--The Matfield shale and the underlying Wreford limestone (see fig. 4C) were mapped as Pwr on plate 1. The Matfield shale is divided into three members which are, in descending order: the (1) Blue Springs shale, (2) Kinney limestone, and (3) Wymore shale. The average thickness of the Matfield shale is about 73 feet.

(1) Blue Springs shale member. The Blue Springs shale member usually outcrops in close association with the overlying Florence limestone member of the Barneston limestone. The Blue Springs is usually a calcareous, clay shale. The lower part is composed of maroon and green zones, and the upper part of gray, green, and sometimes tan zones. Lenses of hard, massive, tan-gray limestone commonly occur near the top. The shale is nonfossiliferous. It averages about 28 feet thick.

(2) Kinney limestone member. The Kinney is a soft, massive, light-gray or tan limestone. Locally it includes clay balls or nodules of chert. Relatively few fossils occur in this member. The average thickness of the Kinney limestone is about 2 feet, and in only a few places does it form an identifiable hillside bench.

(3) Wymore shale member. The Wymore is a blocky, thin-bedded, calcareous, and usually platy shale. Tan-gray, gray-green, and maroon zones predominate in the lower part of the member, and gray-green, olive-drab, and sometimes maroon zones in the upper part. Two, thin, fossiliferous limestones are present in most outcrops. Very fossiliferous shale occurs in the upper part but only in the southeastern part of the outcrop area. The average thickness is about 43 feet.

Wreford limestone.--The Wreford limestone is the basal formation in the Chase group. (See fig. 4D.) This formation outcrops extensively in the eastern third of Riley County where it forms two conspicuous, easily recognized, hillside benches underlain by cherty limestones. The three members that compose the Wreford limestone are, in descending order: the (1) Schroyer limestone, (2) Havensville shale, and (3) Threemile limestone. The average thickness is about 37 feet.

(1) Schroyer limestone member. The Schroyer forms a somewhat subdued bench above and farther back on the hillsides than that formed by the lowermost member of the formation, the Threemile limestone. The Schroyer is usually a massive limestone in which thin chert bands and shale partings are interbedded. Chert nodules are scattered throughout the limestone, which is usually light gray, hard, and dense. It is quite fossiliferous. Its average thickness is about 8 feet.

(2) Havensville shale. The Havensville is a thin-bedded, olive-drab to dark-gray, calcareous, clay shale. Several limestone beds of variable thickness occur in the upper part, and one bed, near Winkler, is about 6 feet thick. The Havensville usually contains some fossils. Its average thickness is about 21 feet.

(3) Threemile limestone member. The Threemile limestone usually consists of a thick, nonflinty zone in the upper part and a very flinty bed in the lower part, although, in some exposures, chert nodules and lenses are scattered throughout its whole thickness. A thin parting of gray or dark-gray, fossiliferous shale characteristically occurs 1 or 2 feet above the base. The limestone beds are light gray and massive but weather to form small blocks. Fragments of chert weathered from the limestone usually mantle the hillsides below its outcrop. The average thickness is about 8 feet.

Construction materials of the Chase group.--

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. 4D to 4F.) It is composed of seven shale formations each underlain by a limestone formation. The formations and members of which it is composed will be described separately but their outcrop areas are shown on plate 1 according to the following system:

Map unit	Formation	Members
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 Foraker limestone	Long Creek limestone Hughes Creek shale Americus limestone

Areal distribution.--The Council Grove group outcrops most extensively in the southern third of Riley County (see sheet 3 of pl. 1) where it forms the lower divides and the valley walls of the larger streams and their tributaries. Hillsides eroded into the Council Grove group are characteristically terraced, that is, the limestones form hillside benches and the intervening shales form the steep slopes between adjacent benches. In the central third of Riley County (see sheet 2 of pl. 1), the Council Grove group outcrops only along the valley wall of the Blue River and in the lower portions of tributary valleys. In the northern third of the county (see sheet 1 of pl. 1), this group outcrops along the valley wall of the Blue River from a point about 1 mile northeast of Randolph to the north county line.

Speiser shale.--Outcrops of the Speiser shale are mapped with those of the underlying Funston limestone as Pf on Plate 1. The shale is varicolored, that is, it consists of interbedded tan gray, gray, green, purple, and maroon zones. It is thin-bedded to blocky, silty in some zones and clayey in others; and most of the zones are calcareous. The shale in the upper part of the formation is usually fossiliferous. A persistent foot-thick limestone occurs about 3 feet below the top of the member, is hard, massive, and gray to gray orange. A second thin layer of limestone was found in some exposures just below the base of the Threemile limestone member of the Wreford limestone. The average thickness of the formation is about 15 feet.

Funston limestone.--The Funston is composed of limestone layers interbedded with one or two relatively thin, calcareous, tan, silty shales in the middle and lower parts. The limestone layers are massive but relatively soft and weather to form blocks or small plates. The unweathered stone is tan or gray brown, but outcrop surfaces usually are stained by a veneer of maroon iron oxide washed down from the overlying Speiser shale. The average thickness of this formation is about 9 feet. It forms a well-defined hillside bench just below the prominent one formed by the Threemile limestone member of the Wreford limestone.

Blue Rapids shale.--The Blue Rapids shale is mapped with the underlying Crouse limestone as Pc on plate 1. The shale is predominantly gray to tan, but maroon and green zones appear in its middle part. This formation is thin-bedded to blocky, and thin lenses of sandy limestone were noted near the top in the northern part of its outcrop area. The shale is nonfossiliferous. Its average thickness is about 20 feet.

Crouse limestone.--The Crouse limestone forms a hillside bench comparable to that formed by the Funston limestone. The upper part of the Crouse consists of layers of thin-bedded limestone separated by numerous partings of tan-gray shale. The lower part of the formation is a single, massive bed of limestone. The limestones are hard, dense, and weather to form small blocks and plates; they are gray or brown when unweathered and weather tan or gray. This limestone contains only a very few fragments of fossils. Its average thickness is about 7 feet.

Easly Creek shale.-- The Easly Creek shale is mapped with the underlying Bader limestone as Pba on plate 1. It is a vari-colored shale in which zones of gray, gray green, and maroon predominate. The upper part is gray green to gray, and the lower part is mostly maroon. The Easly Creek is a thin-bedded to blocky, calcareous, silt shale. One or two relatively thin layers of hard, massive limestone occur locally near the top of the formation. The Easly Creek shale is nonfossiliferous. The average thickness is about 20 feet.

Bader limestone.--The Bader limestone 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 17 feet.

(1) Middleburg limestone member. The Middleburg limestone is composed of two limestone layers separated by a layer of calcareous, thin-bedded, gray to black, silty shale. The limestones are massive, hard, dense, and are crystalline in some zones. They are gray to olive drab and usually weather light gray; however, in most exposures the weathered surface is stained maroon by wash from overlying red shales. Fossils are fairly common in the lower limestone layer. The Middleburg seldom forms an identifiable hillside bench. Its average thickness is about 4 feet.

(2) Hooser shale member. The Hooser shale is vari-colored, including maroon, green, gray, and olive-drab zones. The shale is blocky and calcareous. Some zones are composed predominantly of silt and others of clay. The shale is nonfossiliferous. Its average thickness is about 8 feet.

(3) Eiss limestone member. The Eiss is composed of two limestones separated by a thin-bedded, tan or tan-gray, calcareous shale. The limestone layers are hard and massive but weather to form blocks or to become quite porous. They are gray or tan gray and contain numerous fossils. The average thickness is about 5 feet. The Eiss limestone forms the first prominent hillside bench above the one formed by the Cottonwood limestone member of the Beattie limestone.

Stearns shale.--The Stearns shale is mapped with the underlying Beattie limestone as Pbe on plate 1. The Stearns is a calcareous silt shale, gray to olive drab when unweathered but light gray or tan when weathered. It is thin-bedded to blocky, and thin calcareous lenses are usually present near the base. Bedding planes in the shale are frequently coated by deposits of red iron oxide. This formation is nonfossiliferous. Its average thickness is about 14 feet.

Beattie limestone.--The Beattie limestone is divided into three members; in descending order, these are: the (1) Morrill limestone, (2) Florena shale, and (3) Cottonwood limestone. (See fig. 4D.) This formation outcrops conspicuously in the vicinity of Manhattan and along the valley walls of the Kansas and Blue Rivers and MacDowell and Wildcat Creeks. The average thickness of the Beattie limestone is about 14 feet.

(1) Morrill limestone member. The Morrill seldom forms an identifiable hillside bench. It is a massive limestone when unweathered but weathers quite rapidly and becomes very porous or cavernous. Some zones are quite soft and others are relatively hard. The limestone is tan gray or gray orange, and is nonfossiliferous. Its average thickness is about 2 feet.

(2) Florena shale member. The Florena is a thin-bedded to blocky, calcareous, clay shale. It is tan, gray, or olive drab. This shale is perhaps the most fossiliferous of all the stratigraphic units outcropping in Riley County. In most exposures fossils are distributed throughout the whole thickness of the member, but in some outcrops they are restricted to the lower half. A flat fossil shell about 1 inch long is especially characteristic and in many places is so abundant that it forms an easily recognized shell bed in the basal part. The average thickness is about 7 feet.

(3) Cottonwood limestone member. The Cottonwood forms a prominent hillside bench characterized by a line of bushes growing at its base. (See C in fig. 6.) This "bushline" is well displayed on many hillsides in the vicinity of Manhattan. The Cottonwood is a single, massive limestone layer, except for the basal 0.5 foot which is usually platy and carries the water that supplies the vegetation of the bushline. Two or three thin zones of chert nodules are usually present in the massive part of the limestone, and solution channels may be found in some places. The limestone is gray weathers tan gray, and contains a great number of wheat-shaped fossils (fusulinids). This member is easily identified by its conspicuous hillside bench and bushline, abundance of fusulinids, and thin zones of chert nodules. In most places it is slightly more than 5 feet thick.

Eskridge shale.--The Eskridge shale usually outcrops conspicuously immediately beneath the Cottonwood limestone, but is mapped with the underlying Grenola limestone as Pg on plate 1. There are many excellent exposures of this formation in roadcuts and stream banks in the vicinity of Manhattan. The Eskridge is calcareous in some zones and noncalcareeous in others. The lower three-fourths of the formation is vari-colored with maroon, purple, green, and tan-gray zones predominating. The upper part is usually tan or gray. Limestone beds varying in thickness from 0.1 to 1 foot occur at various levels. The limestones are lenticular, hard, dense, and massive. Some fossils are found on the upper and lower surfaces of the limestone lenses and, less commonly, in the shale zones. The average thickness is about 35 feet.

Grenola limestone.--The three members which compose the Grenola limestone are, in descending order: the (1) Neva limestone, (2) Salem Point shale, and (3) Burr limestone. (See fig. 4E.) This formation outcrops extensively in the vicinity of Manhattan and forms a conspicuous hillside bench, or two benches in some places, just below that formed by the Cottonwood limestone member of the Beattie limestone. The formation is about 32 feet thick.

(1) Neva limestone member. The Neva limestone is composed of a series of thick layers of limestone interrupted by a persistent shale bed near the base and by somewhat thinner, less persistent shales in the middle and upper parts. The Neva limestone forms the first prominent hillside bench below that of the Cottonwood limestone member. (See N in fig. 6.) The limestones are tan or tan gray, weather light gray, are hard in the upper part and relatively soft in the lower part. While some ledges remain massive in weathered exposures, most of the limestones break down to form small blocks and plates. The interbedded shales range from gray to black. Although the Neva limestone contains some fossils, it is not characterized, as was the Cottonwood, by an especial abundance of any one kind. The average thickness is about 16 feet. It is easily identified by its thickness, massive and platy zones, interbedded shales, and the position of its hillside bench relative to that formed by the Cottonwood limestone.

(2) Salem Point shale member. Outcrops of the Salem Point shale can generally be seen immediately below those of the overlying Neva limestone member. The Salem Point is a thin-bedded, usually silty, calcareous shale. A thin lens of limestone is present locally. The shale is tan or gray green and is nonfossiliferous. Its average thickness is about 8 feet.

(3) Burr limestone member. The Burr limestone forms a less well-developed bench than does the Neva limestone member of the same formation. Although the Burr is essentially a limestone, it contains interbedded, thin layers of gray, clay shales. Some of the limestones are hard, dense, and massive; others are soft and porous. They are usually tan gray and are somewhat fossiliferous. The average thickness is about 8 feet.

Roca shale.--The Roca shale and the underlying Red Eagle limestone are mapped as Pre on plate 1. This formation has about the same appearance as the Eskridge shale. The two formations, however, may be readily distinguished by their positions relative to the intervening Grenola limestone. Green and gray shales predominate, but maroon and tan zones occur locally. There is a thin layer of limestone in the upper part of the formation and, in some places, a very thin but massive limestone near the base. The formation is nonfossiliferous. It averages about 24 feet thick.

Red Eagle limestone.--The three members which compose the Red Eagle limestone, in descending order, are: the (1) Howe limestone, (2) Bennett shale, and (3) Glenrock limestone. (See fig. 4 E.) Outcrops of this formation are confined for the most part to the vicinity of Manhattan and usually develop no more than small hillside benches. The average thickness for the formation is about 11 feet.

(1) Howe limestone member. The Howe is a tan, soft, massive limestone that weathers to become very porous and develop a "rotten" appearance. In most exposures, its surface is covered with a veneer

of iron oxide derived from the overlying Roca shale. Only occasional, large fossils were noted. Its average thickness is about 4 feet.

(2) Bennett shale member. The Bennett is dark-gray, very thin-bedded, calcareous, clay shale. Its dark color is related to the large amount of disseminated carbon it contains. The shale is easily identified by the numerous fossils included in it, particularly glistening white shells that are about 0.5 inch high and wide and 0.75 inch long. The Bennett shale is about 5 feet thick.

(3) Glenrock limestone member. The Glenrock develops a small, hillside bench in the vicinity of Manhattan. It is a hard, massive, gray-brown limestone, which usually weathers tan. This member, as is the Cottonwood limestone member of the Beattie limestone, easily identified by its fusulinids. The average thickness is about 2 feet.

Johnson shale.--Outcrops of the Johnson shale are not numerous in Riley County and are found only in the immediate vicinity of Manhattan. The Johnson shale and the underlying Foraker limestone are mapped as Pfo on plate 1. The Johnson is a silty, calcareous shale with numerous interbedded layers and lenses of clayey limestone. It is thin-bedded to blocky, and gray green or olive drab. Fairly thick layers of limestone near the base of the formation usually exhibit many close-spaced small folds which are not reflected in the shale zones above and below the limestones. This formation is nonfossiliferous. It is about 25 feet thick.

Foraker limestone.--Three members compose the Foraker limestone; these are, in descending order: the (1) Long Creek limestone, (2) Hughes Creek shale, and (3) Americus limestone. (See fig. 4F.) Outcrops of the Foraker limestone are most conspicuous in the area east and south of Manhattan. The average thickness of this formation is about 52 feet.

(1) Long Creek limestone member. The Long Creek is a soft, fine-grained, massive limestone, and usually contains thin shale partings. The limestones are tan to gray-orange, and the shales are dark gray and thin-bedded. It is sparsely fossiliferous. The average thickness is about 9 feet.

(2) Hughes Creek shale member. The Hughes Creek shale, the thickest member in the Foraker limestone, is well exposed in the valley walls of the Blue and Kansas Rivers in the vicinity of Manhattan, along both sides of Deep Creek, and south and west of Zeandale. It is principally a calcareous silt shale with numerous interbedded thin lenses of fossiliferous limestone. Although most of the shales are gray, some are tan, and others are olive drab or black. They are very thin-bedded to blocky, and are characterized by an unusual abundance of fossils. The upper part of the member is easily identified by the great number of fusulinids in both the shale and limestone beds. The average thickness is about 40 feet.

(3) Americus limestone member. The Americus is composed of two layers of similar limestone separated by a shale layer. This is one of the most certainly recognized stratigraphic units in Riley County. The two limestone beds are hard, dense, and dark gray to blue gray. The limestone is massive but weathers to form fairly large blocks. The intervening shale bed is clayey, noncalcareous, and thin-bedded to very thin-bedded. It is brown, dark gray, or black, and nonfossiliferous. Fossils, however, are fairly numerous in the limestone layers. This member forms a fairly conspicuous hillside bench which is characterized by a zone of rounded, light-gray, field stones mantling the hillsides below its outcrop. The average thickness is about 3 feet.

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. 4F.) The formations which compose, together with their map symbols on plate 1, are:

Map symbol	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 formations of the Admire group generally are found outcropping on the lower slopes of hillsides in the southeastern part of the county. (See sheet 3 of pl. 1.) They cap only a few low hills in the area. The locations of representative sections of these formations are given in figure 5.

Hamlin shale.--Outcrops of the Hamlin shale are mapped with those of the underlying Five Point limestone as Pfp on plate 1. Moore, Frye, and Jewett 10/ divide this formation into three members. In descending

10/ op. cit., p. 169.

order, they are: the (1) Oaks shale, (2) Houchen Creek limestone, and (3) Stine shale. Inasmuch as the Houchen Creek limestone was not found outcropping in Riley County, the Hamlin is not divided into members in this report because the two shales, the Oaks and the Stine, are difficult to separate when the intervening limestone member is missing. For the most part, the Hamlin is a calcareous silt shale, but the basal zone is clayey, and there are sandy zones in the middle part. Its color is gray to gray green. The lower part of the Hamlin is thin-bedded, but the remainder of the formation is blocky. Lenses of very calcareous shale or limestone are present near the top of the formation, and stains and nodules of iron oxide are common near the base. The average thickness is about 27 feet.

Five Point limestone.--The Five Point limestone forms a minor bench low on some of the hillsides south and southwest of Zeandale. It is a hard, highly fossiliferous, massive limestone near the base, but is platy and clayey in its upper part. The limestone is gray and usually weathers tan gray. It is the basal part which forms the hillside bench. The total thickness is about 4 feet.

West Branch shale.--The West Branch is mapped with the underlying Falls City limestone as Pfc on plate 1. It is a clay shale, but includes scattered silty zones and a sandy zone near the middle of the formation. A thin lens of massive limestone occurs in the upper part of the West Branch, and a thin, well-defined sandstone lens occur locally in the middle part. The formation ranges from gray to gray brown and weathers tan gray to tan brown. It is thin-bedded, and the bedding planes are often stained with iron oxide. Leaves and wood fragments of fossil plants occur in the middle part of the formation, and other fossils were found in the thin lens of limestone near the top. The average thickness is about 20 feet.

Falls City limestone.--Only two outcrops of the Falls City limestone were observed in Riley County, one in sec. 8, and the other in sec. 9, T. 11 S., R. 9 E. This limestone is soft, porous, and has a fibrous appearance. It is gray brown and weathers tan. Thin partings of shale are present locally. A few fossils were found in the basal zone. The formation forms a small, poorly developed hillside bench. Its average thickness is about 2 feet.

Hawxby shale.--Many outcrops of the Hawxby shale were found in the southeastern part of Riley County; they are mapped with those of the underlying Aspinwall limestone as Pa on plate 1. The Hawxby is a clay shale, calcareous in some zones, and noncalcareous in others. Although usually gray, locally it may be gray green or tan. Thin lenses of hard, dense, massive highly fossiliferous limestone occur at irregular intervals in the shale. Iron stains are usually present along the bedding planes of the shales and the joint planes of the limestone lenses. The average thickness is about 28 feet.

Aspinwall limestone.--The Aspinwall forms a small bench on some of the hillsides in the area south and southwest of Zeandale. The Aspinwall is hard, somewhat crystalline limestone; locally it exhibits a crushed (brecciated) appearance. Fresh outcrops are massive and gray orange, and weathered outcrops are blocky and gray. Stains and nodules of iron oxide and balls and zones of clay are distributed throughout. Only a few fossils were found. The average thickness is about 2 feet.

Towle shale.--The Towle shale is composed of two members. (See fig. 4F.) The upper one (1) is a shale which carries no identifying name, and the other one (2) is a channel deposit known as the Indian Cave sandstone member. The two members are distinguished as separate units (Pt and Pti, respectively) on plate 1.

(1) Unnamed shale member. The unnamed member of the Towle shale in some places rests on the Brownville limestone of the underlying Pennsylvanian system and, in other places, on the Indian Cave sandstone member of the same formation. It is a clay shale, calcareous in some zones and noncalcareous in others, tan gray to blue gray, and weathers tan. The shale is thin-bedded, and may contain one or more thin zones of highly calcareous shale or limestone. A thin lens of impure coal sometimes occurs near the base of the shale. Stains and nodules of iron oxide are usually present on weathered surfaces. The average thickness is about 9 feet.

(2) Indian Cave sandstone member. The Indian Cave sandstone member of the Towle shale is a channel deposit, therefore, is not universally present throughout the area of outcrop of the Towle shale. Exposures of this channel sandstone, however, are fairly numerous in southeastern Riley County. (See sheet 3 of pl. 1.) Where the Indian Cave sandstone member is absent, the upper shale member rests directly on the Brownville limestone. The Brownville limestone, and additional underlying stratigraphic units as well, are absent where the Indian Cave sandstone occurs. It is apparent that this sandstone was deposited in channels eroded into the underlying formations.

The Indian Cave sandstone member is composed of fine grains of quartz and mica which have been cemented generally by iron oxide, and locally by calcium carbonate. The sandstone is cross-bedded and contains numerous concretions of iron oxide. Some zones are shaly, others are loosely cemented sands, and still others are firmly cemented sands. Fossil leaves and wood fragments are occasionally found in the sandstone. The maximum thickness observed in Riley County is about 75 feet; its average thickness is about 20 feet.

Construction materials in the Admire group.--

Structural stone.

Aggregate.

Road metal.

Riprap.

Pennsylvanian system

Wabaunsee group

General.--The Virgil is the uppermost series in the Pennsylvanian system in Kansas (see fig. 4G.), and the Wabaunsee is the uppermost group of formations in that series. The locations of representative sections of formations in this group are shown in figure 5. The channel sandstone of the Indian Cave is the only indication of a definable break between the rocks of the Pennsylvanian and Permian systems.

Outcrops of the formations are combined into the following map units on plate 1:

Map unit	Formation
Cbr	(Brownville limestone
Ccv	(Pony Creek shale (Caneyville limestone
Cjc	(French Creek shale (Jim Creek limestone
Cgh	(Friedrich shale (Grandhaven limestone
Cdo	(Dry shale (Dover limestone
Cmh	(Langdon shale (Maple Hill limestone
Ct	(Wamego shale (Tarkio limestone
Ce	(Willard shale (Elmont limestone
Cr	(Harveyville shale (Reading limestone
Cwa	(Auburn shale

Areal distribution.--In Riley County, formations of the Wabaunsee group outcrop only in the southern part of T. 10 S., R. 9 E. and the northern part of T. 11 S., R. 9 E. (See sheet 3 of pl. 1.)

Brownville limestone.--Outcrop areas of the Brownville are mapped as Cbr on plate 1. It is a fairly hard, somewhat clayey, blocky limestone. This formation is tan or brown, weathers gray, and stains of iron oxide are usually present on fracture planes. The Brownville is a fairly fossiliferous limestone. It is about 2 feet thick.

Pony Creek shale.--Outcrops of the Pony Creek shale and the underlying Caneyville limestone are mapped as Ccv on plate 1. The Pony Creek is a calcareous silt shale, blue gray to tan, thin-bedded, and nonfossiliferous. Bedding planes are commonly stained with iron oxide. The average thickness is about 7 feet.

Caneyville limestone.--The Caneyville limestone as it is exposed in Riley County is not typical of the formation in other parts of Kansas as described by Moore, Frye, and Jewett. 11/ As defined in this report, the

11/ op. cit., p. 172.

Caneyville consists of a limestone layer underlain by shale. The limestone is massive, weathers blocky, is hard, tan or brown, and weathers tan gray. Limonite nodules and fossil fragments are abundant in it. The shale is clayey, calcareous, thin-bedded, and gray. There is a thin, calcareous zone near the middle of the shale and a thin carbonaceous zone which contains numerous wood fragments near the top. Nodules and concretions of iron oxide covered with fine flakes of mica are characteristic of weathered surfaces. The average thickness of this formation is about 9 feet.

French Creek shale.--The French Creek shale and the underlying Jim Creek limestone are mapped together as Cjc on plate 1. The French Creek is a noncalcareous, somewhat sandy, clay shale. It is thin-bedded to blocky, gray to tan gray, and weathers tan yellow. A lens of impure coal about 0.4 foot thick occurs near the top. This bed has been named the "Lorton coal" and is overlain by a very calcareous, fossiliferous shale zone. The French Creek is readily identified by the presence of the Lorton coal and the overlying fossiliferous zone. Nodules and plates of iron oxide are usually present on weathered surfaces. The average thickness of the French Creek is about 20 feet.

Jim Creek limestone.--This limestone is hard, dense, gray with somewhat of a purplish tint, and weathers gray. A zone of concentrated iron oxide is usually found at or near the top of the limestone. The unweathered rock is massive, but upon weathering, it breaks into blocks and small chips. Fossils, including fusulinids, are numerous. The average thickness is slightly more than 1 foot.

Friedrich shale.--Outcrops of the Friedrich shale are mapped with those of the underlying Grandhaven limestone as Cgh on plate 1. In Riley County, this formation in represented only by erosional remnants, usually no more than 2 or 3 feet thick, that reset on the Grandhaven limestone. The Friedrich is a clay shale, calcareous in some zones and noncalcareous in others. It is gray green to gray and weathers tan to tan gray. The upper half locally weathers to develop a characteristic yellow tint. The shale is thin-bedded to blocky, nonfossiliferous, and nodules of calcium carbonate and stains of iron oxide occur. Its average thickness is about 12 feet.

Grandhaven limestone.--The Grandhaven limestone caps many of the low hills south of Zeandale. This formation consists of two limestones separated by a shale. The limestones are hard, dense, somewhat clayey, brown to gray, and weather light brown to light gray. Weathered exposures have broken down to irregular blocks and small plates. The intervening shale bed is usually clayey, calcareous, and grav green. It contains a few fossils, including fusulinids. The average thickness is 2 feet.

Dry shale.--Outcrops of the Dry shale and the underlying Dover limestone are mapped as Cdo on plate 1. The lower part of the Dry is a silty, calcareous shale, and the upper part is clayey and noncalcareous. It is thin-bedded, gray green to yellow gray, and weathers tan or yellow in the lower part and gray in the upper part. The formation is nonfossiliferous. Its average thickness is about 7 feet.

Dover limestone.--The Dover limestone forms a small hillside bench and numerous knolls in the southeastern part of the county, especially in the area south of the Hillsbury Crossing of Deep Creek. The upper and lower parts of the Dover are composed of massive beds of soft, clayey limestone; in the middle part, however, the limestone is hard and dense. The formation is gray green to gray, weathers light gray, and a brown zone appears locally near the middle. Abundant large fusulinids are the most characteristic fossils in the Dover limestone, although smaller fusulinids and other fossils occur also. Its average thickness is about 2.5 feet.

Langdon shale.--The Langdon shale and the underlying Maple Hill limestone are mapped as Cmh on plate 1. The Langdon is usually a noncalcareous, thin-bedded to blocky, blue-gray to gray-green shale, which weathers gray green to tan gray. Stains and small plates of iron oxide are present on most weathered surfaces. The formation is nonfossiliferous. Its average thickness is about 7 feet.

Maple Hill limestone.--Although hard and massive, the Maple Hill limestone develops only a poor outcrop expression. Fusulinids are abundant in this formation, and other kinds of fossils occur also. The limestone is gray to gray brown, weathers tan. Its average thickness is about 1 foot.

Wamego shale.--Outcrops of the Wamego shale and the underlying Tarkio limestone are mapped as Ct on plate 1. The shale is clayey in some zone and silty in others; it is noncalcareous in the northeastern part of its outcrop area but calcareous elsewhere. It is tan gray to blue gray, weathers tan to tan gray, and is thin-bedded to blocky. Numerous zones and plates of iron oxide occur in it. The formation is nonfossiliferous, and its average thickness is about 13 feet.

Tarkio limestone.--The Tarkio limestone forms the most conspicuous of the hillside benches in the area south and southeast of Zeandale. (See Ta in fig. 6.) The Tarkio is composed of two thick limestones usually separated by a thin shale. The limestones are massive, hard, dense, gray orange to gray brown, and weather brown to gray brown. The shale is olive drab, silty, and calcareous. Large fusulinids are very abundant in this formation, and other fossils are also present. The average thickness is about 12 feet. It is easily recognized by its strong outcrop expression, brown color, and large fusulinids.

Willard shale.--Outcrops of the Willard shale and the underlying Elmont limestone are mapped as Ce on plate 1. The Willard is a somewhat silty, usually calcareous, clay shale. It is thin-bedded in the upper part, but becomes blocky near the base. It is blue gray to tan gray, nonfossiliferous. Its average thickness is about 28 feet.

Elmont limestone.--The Elmont is a hard, dense, massive, blue-gray to gray limestone which weathers tan to tan gray. This formation exhibits a well-developed fracture pattern which apparently causes it to form large rectangular blocks when weathered. A thin but persistent zone of iron oxide occurs near the top, and iron stains are often present along the fracture planes. Large and small fusulinids are abundant, and other fossils are also present. Its average thickness is about 2 feet.

Harveyville shale.--Outcrops of the Harveyville shale and the underlying Reading limestone are mapped as Cr on plate 1. The Harveyville is a slightly calcareous clay shale. It is thin-bedded to blocky, nonfossiliferous, gray green, and weathers light gray green. Its average thickness is about 15 feet.

Reading limestone.--The Reading limestone outcrops at several places east and south of Zeandale. It is a hard, dense, gray limestone which, in unweathered exposures, appears as a single, massive ledge. In weathered outcrops it is tan and breaks down into several distinct zones of irregularly shaped, small blocks. Stains and specks of iron oxide are abundant throughout the formation. The Reading limestone contains numerous fossils. Its average thickness is about 2 feet.

Auburn shale.--The Auburn shale is the oldest stratigraphic unit outcropping in Riley County and is mapped as Cwa on plate 1. Only the upper part of the formation outcrops in the county. The Auburn is a somewhat silty clay shale, calcareous in some zones and noncalcareous in others. It is gray to gray green, weathers gray, and is thin-bedded to blocky.

Stains of iron oxide and carbon often appear on the bedding planes. The formation is nonfossiliferous. About 6.5 feet of it is exposed in the county.

Construction materials in the Wabaunsee group.--

Aggregate.

Structural stone.

Riprap.

Road metal.

INVENTORY OF CONSTRUCTION MATERIALS

General

The objectives of this inventory of construction materials in Riley 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 the 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 State Highway Officials. 13/ It is expected that prospects listed in this 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.

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.

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. 249-450.
Toughness, pp. 240-241.
Weight per cubic foot. pp. 253-254.

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 Riley 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. It will eliminate the non-productive areas from the search and, at the same time, will indicate the areas in the county in which the needed materials are most likely to occur.

Aggregate for concrete

Engineering and geologic characteristics.--Aggregate for concrete is distinguished as fine aggregate and mixed aggregate in table 1 and on plate 1. 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 mixed aggregate if the coarse fraction is 5 percent or more by weight of the whole sample; as a fine aggregate if the coarse fraction is less than 5 percent. Fine and mixed aggregate will be considered together because the grading of almost any aggregate material can be changed by sweetening or screening to conform to required specifications.

Aggregate for concrete consists of fragments of hard, durable minerals or rocks of sand and gravel size. The constituent particles are free from adherent coatings that would interfere with the bonding of cement with the particles. The presence of the following deleterious substances, if in quantities thought to be excessive, is noted under Remarks in table 1: material passing the No. 200 sieve (wash); shaly, soft, or flaky fragments; sticks or other organic debris; clay lumps; and minerals which, because of their chemical composition, may react with the cement to the detriment of the concrete.

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 that are relatively inaccessible, usually are not included in this inventory because of the additional expense involved in their removal or transportion.

The test characteristics of some of the materials included in this classification indicate that they are not suited for use in portland cement concrete. The same materials, though, might be acceptable for other uses, such as aggregate for bituminous concrete, cover materials, and surfacing or resurfacing material.

Stratigraphic sources and performance characteristics.--The following stratigraphic units are actual or potential sources of aggregate for concrete:

(1) Alluvium. Four samples of mixed aggregate (ma 1 to 4) were collected from alluvial deposits of Quaternary age. Two of the samles, ma 1 and 2, are of alluvium of the Blue River. These are granitic sand-gravels, that is, they are composed predominantly of sand- and gravel-size praticles of the minerals quartz and feldspar, and the igneous rock granite. The petrographic analysis of sample ma 1 shows that deleterious mineral or rock fragments are not present in quantities sufficient to affect standard portland cement concrete. As noted in the Remarks column of table 1, sample ma 2 was accepted as mixed aggregate by the Testing Laboratory of the State Highway Commission under the requirements of sec. 67 of the Standard Specifications (ed. 1937).

The samples designated as ma 3 and 4 were collected from the alluvium of the Kansas River. Another sample of material from the same source as ma 3 was collected by the U. S. Geological Survey and examined under a binocular microscope to determine its mineral and rock composition. Sample ma 3, although acceptable for use under several sections of the Kansas Highway Standard Specifications (see table 1, Remarks), contains a high percentage of fragments of chert or chalcedony. These materials are suspect as the cause of injurious reactions between the aggregate particles and the portland cement matrix. It may be that the map cracking reported by Rhoades and Mielenz 14/ for portland cement concrete in which aggregate

14/ Rhoades, R. and Mielenz, R. Z., Petrographic and mineralogic characteristics of aggregates: American Society for Testing Materials, Special Technical Publication No. 83, pp. 44 and 45, 1948.

from the Kansas River had been used, is the result of an injurious reaction between the mortar matrix and these two deleterious mineral substances.

The quantity of mixed aggregate which can be obtained from the alluvium of the Kansas and Blue Rivers is almost unlimited. (See pl. 1.) The alluvium of other streams in the county, however, appears to contain too high a percentage of silt to be acceptable in this classification.

(2) Dune sand and glacio-fluvial deposits. Three samples of material are reported as fine aggregates in table 1. Two of these, fa 1 and 3, are samples of dune sand from the valley of the Kansas River; and fa 2 is a sample collected from glacio-fluvial sediments at the southeast corner of the Fort Riley Military Reservation. (See pl. 1.) The samples of dune sand do not contain detectable quantities of deleterious mineral or rock substances. The sample of glacio-fluvial sediments (fa 2), however, shows 5 percent of chert or chalcedony and may thus be reactive if used with standard portland cement.

The gradation factor (fineness modulus) of the glacio-fluvial material is appreciably higher than that of dune sand and, at a depth too great for economic production, they contain a higher percentage of gravel-size particles. These fine aggregates may have some use as an additive to decrease the gradation factor of a mixed or coarse aggregate to required specifications. Very likely, however, their principal use in highway and airport construction would be in a bituminous-mat type of surfacing; probably the material represented by fa 2 would be more desirable for this use. A large quantity of dune sand is available in the places mapped on plate 1. Glacio-fluvial sand-gravels occur under unconsolidated overburden about 25 feet thick in the vicinity of Manhattan.

(3) Limestones of the Permian and Pennsylvanian systems. Numerous limestones outcropping in Riley County have been accepted by the State Highway Commission of Kansas as sources of crushed rock for use as coarse aggregate in concrete. The test properties and geologic characteristics of these limestones will be discussed in detail in another section of this report. Controlled tests made by W. E. Gibson, engineer of tests, State Highway Commission of Kansas, 14/ indicate that that an additive of

14/ Gibson, W. E., Use of sand-gravel aggregate in concrete: Kansas State College Bull. 51, pp. 83-95, 1946.

crushed limestone, in the grading of a coarse aggregate, to a reactive aggregate will diminish the deterioration due to the reaction of the deleterious mineral substances with the portland cement. However, no less than 25 to 40 percent by weight of the crushed limestone must be added to the mix in order that the deterioration be brought within reasonable limits. The Cottonwood limestone member of the Beattie limestone is said to be very satisfactory as a reaction-reducing additive.

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) Terrace deposits. Deposits of chert gravel are fairly numerous in the lower portions of the terraces which have been formed in the valleys of tributaries to the Kansas and Blue Rivers. One sample of chert gravel (cg 6) was taken from a terrace deposit and its sieve analysis indicates that it is unusually coarse. The abrasion loss in the Los Angeles test is rather low. Undoubtedly material similar to this would be satisfactory as road metal and might prove acceptable as coarse aggregate for concrete if washed to remove some of the fines.

(2) Sanborn formation. One sample of chert gravel (cg 3) was collected from the Sanborn formation. Tests indicate that the chert particles are sound, and that the sieve analysis qualifies this material for acceptance as road metal. Similar chert gravels occur in the basal part of the formation, especially where it is fairly low on a valley wall.

(3) Glacio-fluvial deposits. Five samples of chert gravel were collected from glacio-fluvial deposits (cg 1, 2, 4, 5, and 7). Lenses of chert gravel in glacio-fluvial sediments are rather numerous in the valleys of tributaries to the Kansas and Blue Rivers, and are most abundant in the valley of Wildcat Creek where some of them occur high on the valley walls. The test results of chert gravels from glacio-fluvial deposits indicate that the material is acceptable for use as road metal.

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. 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. Deficiencies of the tested samples in this characteristic are noted under Remarks on table 1. Failure of the material to pulverize easily, which is related to the degree of cementation, increases the difficulty of obtaining its uniform distribution throughout the total aggregate mixture. The coefficient of cementation is too high if the material contains a large percentage of calcium carbonate or clay-size particles and develops a cementation factor in excess of 85.

Stratigraphic sources and performance characteristics.--No materials completely acceptable as mineral filler were found in Riley County by the authors of this report. The characteristics of three of a number of samples collected (mf 1 to 3, pl. 1) are cited in table 1. The samples represent material from the Sanborn formation, a terrace deposit and a glacio-fluvial deposit. Grading of samples mf 1 and 2 is acceptable but that of sample mf 3 is somewhat too coarse. The specific gravity of each sample is above the minimum required limit (2.52). In all three samples tested, however, the cementation factor is in excess of 100 and the materials are not considered acceptable for use as mineral filler.

A more exhaustive search of the Sanborn formation, terrace deposits, and glacio-fluvial deposits might reveal sources of mineral filler. In most places in Riley County, however, the sediment composing these three formations apparently has too high a percentage of clay-size particles and thus cannot be pulverized readily enough.

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) Cretaceous system. The test characteristics of one sample of igneous rock of Cretaceous (?) age (se 1) are given in table 1 and the source of the material is mapped on plate 1. The specific gravity and abrasion loss of this rock are within acceptable limits, but its soundness ratio (0.80) is too low. The rock has been somewhat altered, and is cut by many close-spaced intersecting fractures. These are the factors which probably contribute to its low soundness ratio. Sample se 1 represents rock from the Bala occurrence; rock from the Stockdale and Leonardville occurrences has not been tested but may prove satisfactory.

(2) Permian system. Many limestones in the Permian system appear to be acceptable as sources of rock for riprap. The ones thought to be the most promising sources of riprap, both because of their test characteristics and of the quantity of material available under limited overburden, are the massive rimrock ledge in the Fort Riley limestone member of the Barneston limestone (ls 2); the massive lower part of the Cresswell limestone member of the Winfield limestone (ls 3); the Towanda limestone member of the Doyle shale (ls 2 and 8 to 10); the Aspinwall limestone (ls 12), although this material occurs in a ledge only 2 feet thick; the Five Point limestone (ls 13); the Cottonwood limestone member of the Beattie limestone (ls 15 and 16); the Neva limestone member of the Grenola limestone (ls 18); the Howe limestone member of the Red Eagle limestone (ls 14); the Eiss limestone member of the Bader limestone (ls 19); the Crouse limestone (ls 20); and the Funston limestone (ls 21).

It is to be noted, however, that one of the three ledges sampled from the Fort Riley limestone (ls 2, table 1) probably is not acceptable as riprap inasmuch as its specific gravity is quite low, its soundness ratio is below minimum requirements (0.80), and its Los Angeles abrasion loss is above the maximum allowable (50 percent). Further, although one sample of the Cresswell limestone (ls 3) is probably acceptable as riprap, two other samples of the same unit (ls 4 and 7) are below standard in one test characteristic or another. Because the quality of the stone changes rapidly from the bottom to the top of the bed, it is recommended that each ledge in a thick limestone be sampled and tested exhaustively before the site is accepted as the source of stone for riprap or any other engineering construction use.

Data are available for only one sample of rock from the Herington limestone member of the Nolans limestone (ls 1) and those data indicate that the rock undergoes excessive abrasion loss; this unit in other places may prove acceptable as a source of riprap. The Threemile and the Schroyer limestone members of the Wreford formation and the Florence limestone member of the Barneston limestone were eliminated by field inspection from consideration as sources of stone for use as riprap. They contain excessive amounts of chert and undoubtedly are unsound. Other limestones of the Permian system, such as the Stovall limestone member of the Winfield limestone and the Kinney limestone member of the Matfield shale apparently are too thin, where they occur in Riley County, to be sources of commercial quantities of stone.

(3) Pennsylvanian system. Of the limestones in the Pennsylvanian system outcropping in Riley County (see fig. 4G), only the Tarkio is considered an adequate source of stone for engineering construction. Other limestones in the Pennsylvanian system are acceptable insofar as their test characteristics are concerned, but field inspection indicates that they are too thin or occur under too heavy an overburden to permit economic production. The test characteristics of the Tarkio limestone (ls 11) given in table 1 show that stone similar to that sampled for this test has sufficiently high specific gravity and soundness ratio and sufficiently low abrasion loss to be acceptable as stone for riprap.

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.

Stratigraphic sources and performance characteristics.--Many limestones outcropping in Riley County have been used as structural stone. The igneous rock outcropping near Bala has been considered for such use but has been rejected because it is so extensively fractured. Although the test characteristics of many of the local limestones indicate that they are acceptable as structural stone, field observation indicates that only the following have been so used.

(1) Cresswell limestone member of the Winfield limestone. This rock is rather widely used as a structural stone in the northern and western parts of the county. (See Cr in fig. 6.) Its test characteristics and performance record show that it is acceptable for this use. Buildings constructed of the Cresswell limestone were observed in the city of Riley.

(2) Towanda limestone member of the Doyle shale. Stone from this stratigraphic unit is used in the construction of farm buildings in the western part of the county. (See T in fig. 6.) Its performance record is good. In past years, the Towanda and Fort Riley limestones were quarried, crushed, and used as ballast along the Chicago, Rock Island and

Pacific Railroad. The use of crushed limestone as ballast has largely been discontinued, however.

(3) Fort Riley limestone member of the Barneston limestone. The Fort Riley limestone is widely used in Riley County as structural stone. (See FR in fig. 6.) Field observation indicates that it serves excellently in that use as well as when used as riprap or as crushed-stone road metal.

(4) Threemile limestone member of the Wreford limestone. In the vicinity of Stockdale, the upper, noncherty part of the Threemile limestone has been quarried and cut for use as structural stone. This is the only such use observed in Riley County, although this part of the member outcrops extensively. Observation of buildings and piers in nearby counties in which the noncherty limestone outcrops indicates that it is not a desirable structural stone. The lower part of the Threemile limestone contains too many nodules and bands of chert, to warrant consideration as structural stone.

(5) Cottonwood limestone member of the Beattie limestone. The Cottonwood limestone is probably the most productive source of structural stone in this area. Observations of its use in buildings, piers, retaining walls, and as riprap have yet to reveal evidence of a failure of the stone. The areas in which the Cottonwood limestone can be produced economically are shown in fig. 6.

(6) Neva limestone member of the Grenola limestone. Use of the Neva limestone as a dimension stone is widespread in this area, particularly in the vicinity of Manhattan. (See N in fig. 6.) The buildings of Kansas State College, for example, are constructed of both the Cottonwood and Neva limestones. The stone in some of the older buildings, after 50 years or more, shows little or no deterioration.

(7) Aspinwall limestone. Only one use of the Aspinwall limestone as structural stone was observed in Riley County. The Christian Church in Zeandale utilizes the Aspinwall in its foundation and as trim stone. Field observation indicates that, as a foundation material, the Aspinwall limestone lacks adequate bearing strength; as a trim stone, however, the Aspinwall develops a good color contrast and its weathered texture is pleasing.

(8) Tarkio limestone. No use of the Tarkio limestone as structural stone was observed in Riley County although its test characteristics indicate that it can be so used. It outcrops extensively (see Ta in fig. 6), but its rather dark brown color may be considered objectionable.

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 of Quaternary age has been used extensively in Riley County in the construction of sand-gravel roads. Field observation indicates that the material is acceptable for this use. The alluvium is also the source of aggregate used in the construction of the base course for bituminous-mat roads and as aggregate in the construction of portland cement concrete pavement. As noted previously, the alluvial deposits in the valley of the Kansas River probably are too reactive for satisfactory performance in concrete roads. Although this use was encountered in the field, the material reported in table 1 as sample fa 2 probably would be acceptable for use in the construction of a bituminous-mat surface course.

(2) Chert gravel. Chert gravel of the Sanborn formation and the terrace and glacio-fluvial deposits is used extensively in Riley County in the surfacing of light-traffic roads. The performance record of the chert gravel in this use is generally good. Field observation indicates that a very effective road metal is produced by the admixture of chert and mixed aggregate. Commercial quantities of chert gravel occur in terrace deposits in the valleys of most of the streams tributary to the Kansas and Blue Rivers, and other deposits of chert gravel occur in the channels in many of the present-day streams. This material is known locally as "creek gravel" and is also used as road metal on light-traffic roads.

(3) Crushed rock.

(a) Igneous rock. No use of the igneous rock as a source of crushed rock for road metal has been observed. However, test characteristics of the rock near Bala indicate that it may be acceptable. A great quantity of rock is available under little or no overburden at this locality. The exposures of igneous rock near Stockdale and Leonardville are limited in their areal extent.

(b) Limestones of the Permian and Pennsylvanian systems. The limestones of the Permian and Pennsylvanian systems discussed previously in the sections on riprap and structural stone are generally acceptable as sources of crushed stone for road metal. The use of these limestones has been observed on many of the light-traffic roads in the county; the test characteristics of the limestones listed in table 1 indicate that almost all of them are acceptable.

(c) Paddock shale member of the Nolans limestone. Several quarries have been opened in the Paddock shale near the northwestern corner of the county to provide material for the construction of a self-bonding type of macadam road. (See sheet 1 of pl. 1.) Observation of the roads so constructed indicates that this material of the Paddock shale, and presumably of other similar shales of the Permian and Pennsylvanian systems, is acceptable as road metal.

(d) Sandstones of the Cretaceous and Permian systems. The Dakota sandstone of Cretaceous age is used as metal for roads in several counties in northcentral Kansas and might so be used in Riley County. The quantity of material, however, is limited (see sheet 1 of pl. 1) and production might not prove economical. Some zones of the Indian Cave sandstone member of the Towle shale (see sheet 3 of pl. 1) might be sufficiently friable so that the sand could be used to stabilize a clay road; however, the quantity of material probably is limited by excessive overburden.

Subgrade and embankment material

Engineering and geologic characteristics.--This definition of subgrade and embankment material is adapted from the specifications compiled from the A. A. S. H. O. 15/ Suitable geologic materials for this kind of

15/ Amer. Assoc. State Highway Officials, Highway materials, pt. 1, Specifications; pp. 37-38; 1947.

construction 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 of the particles 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 Riley 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, terrace deposits, and glacio-fluvial deposits contain almost unlimited quantities of clayey silt. Generally the percentage of clay is sufficiently low that the bearing strength of the silt is not markedly lowered. In fact, the clay content appears to be a desirable feature of these materials in that it increases plasticity somewhat and facilitates compaction of the fill.

(2) Coarse-granular sediments. The alluvium in the valleys of the Kansas and Blue Rivers and of their larger tributaries is a sand-gravel, for the most part, and is generally well-suited for the construction

of a subgrade or as an additive to fine material used in the construction of an embankment. This material is only a short-haul distance from most places in the eastern and southern parts of the county. Although there is a considerable amount of sand-gravel in the lower zone of the glaciofluvial deposits in the vicinity of Manhattan, it is covered to such a depth by fine sand or silt that it probably cannot be produced economically.

The chert and limestone gravels which occur as lenses in the Sanborn formation and terrace deposits and as bars in the channels of many of the smaller streams might be acceptable, after washing, for use as an additive to increase the grading of fine-grain subgrade material.

(3) Broken or c shed rock. Most limestones of the Pennsylvanian and Permian systems and the sandstone and serpentine of the Cretaceous system, when broken in excavation, are acceptable as material for fill. They are durable and generally resist crumbling and solution. In addition, these rocks can be quarried and crushed to specifications for use in subgrade construction.

The shales of the Pennsylvanian and Permian systems vary in their acceptability for use in the construction of embankments. The clay shales have appreciably lower bearing strengths when water saturated than do the silt shales. When used as material for embankments, stability of the clay shale can be achieved only when the shoulder slopes are held to low angles. The following shales, because of their high content of clay, are particularly suspect:

- Permian system
  - Chase group
    - Matfield shale
    - Havensville shale member of Wreford limestone
  - Council Grove group
    - Florena shale member of Beattie limestone (upper part)
    - Bennett shale member of Red Eagle limestone
    - Hamlin shale (basal part)
  - Admire group
    - West Branch shale
    - Hawxby shale
    - Towle shale
- Pennsylvanian system
  - Wabaunsee group
    - French Creek shale
    - Friedrich shale
    - Dry shale (upper part)
    - Willard shale
    - Harveyville shale

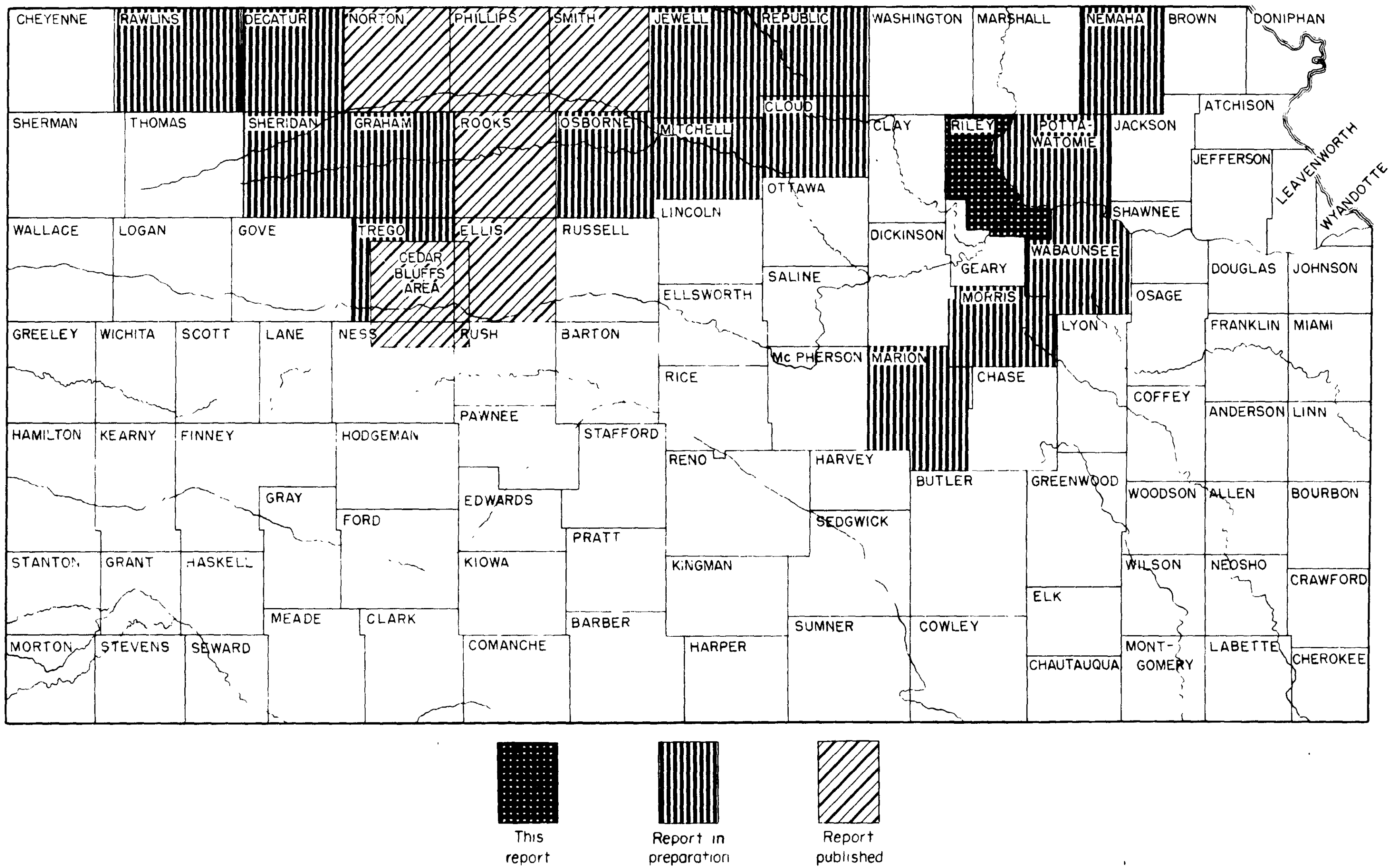

Figure 1.—Index map of Kansas showing areas covered by this report and by other construction materials investigations

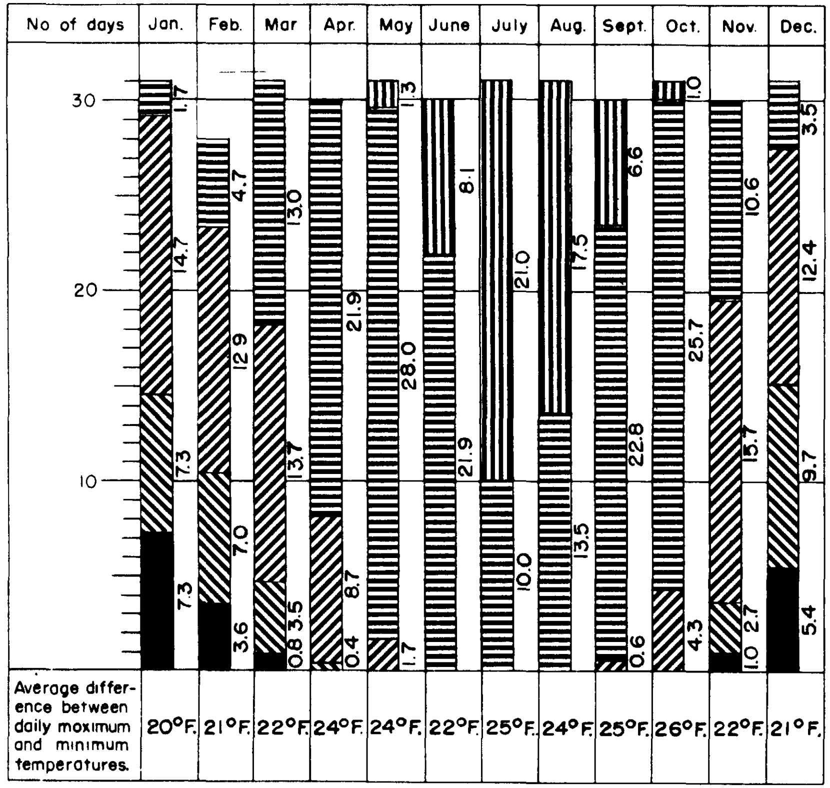

Figure 2.—Chart showing temperature ranges at Manhattan, Kansas.

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

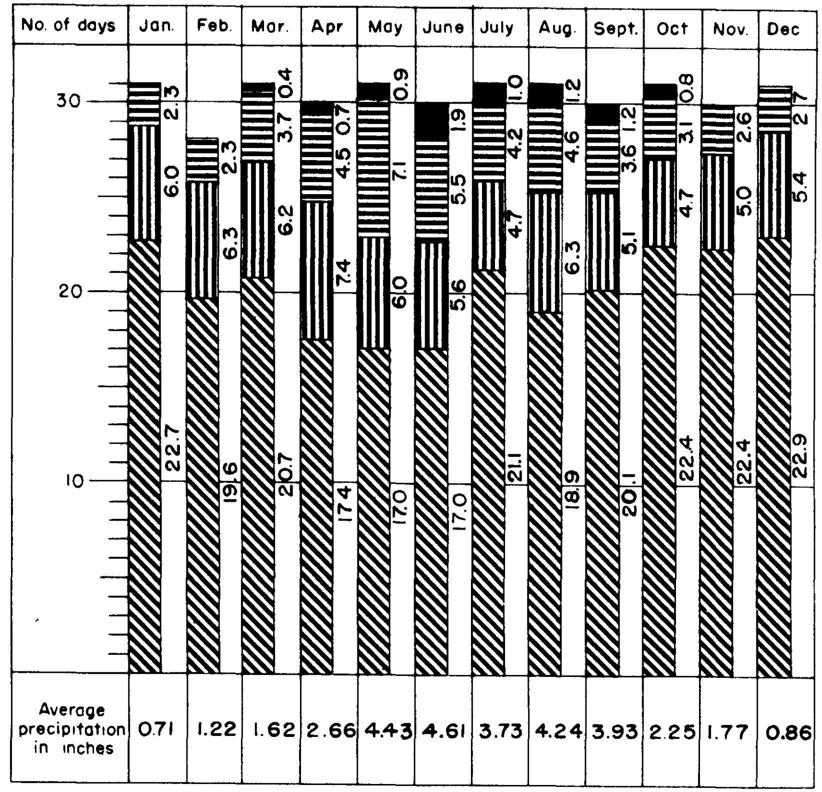

Figure 3.—Chart showing precipitation ranges at Manhattan, Kansas

System	Series	Group	Geologic formation or member		Location of representative section
Quaternary			Alluvium		In the valley of the Kansas River
			Dune sand		
			Terrace deposit		
			Sanborn formation		(S) SW NW 23, 8, 4
			Glacial till		(R) NE 8, 6, 7
			Glacial boulders		(H) C 27, 10, 9
			Glacio-fluvial deposits		(H) SE NW 6, 10, 8
Cret	U. Cret.		Igneous rocks		(H) NW NW 6, 9, 5
			Dakota sandstone		(R) NW NW 1, 6, 4
Permian (continued)	Leonard	Sumner	Wellington shale		
			Nolans limestone	Herington ls	(R) NE NE 14, 6, 4
				Paddock sh	(R) SW SW 36, 6, 4
				Krider ls	
	Wolfcamp (continued)	Chase	Odell shale		
			Winfield limestone	Cresswell ls	(R) NW NW 33, 8, 6; (R) NE SE 19, 7, 5
				Grant sh	(R) NE SE 14, 6, 6
				Stovall ls	
			Doyle shale	Gage sh	
				Towanda ls	(R) NW NW 6, 7, 6
				Holmesville sh	
			Barneston limestone	Fort Riley ls	(R) NE SW 29, 8, 7
				Oketo sh	
				Florence ls	
			Matfield shale	Blue Springs sh	
				Kinney ls	(S) SE NE 15, 7, 6
				Wymore sh	
			Wreford limestone	Schroyer ls	
				Havensville sh	(R) SW NW 33, 10, 8
				Threemile ls	(R) SW SE 28, 10, 8
		Council Grove (continued)	Speiser shale		
			Funston limestone		
			Blue Rapids shale		
			Crouse limestone		
			Easly Creek shale		(R) SE 29, 8, 8
			Bader limestone	Middleburg ls	
				Hooser sh	NW 9, 11, 7
				Eiss ls	10, 9
			Stearns shale		
			Beattie limestone	Morrill ls	
				Florena sh	10, 7
				Cottonwood ls	

(Continued from top of next column)

System	Series	Group	Geologic formation or member		Location of representative section
Permian	Wolfcamp	Council Grove	Eskridge shale		(R) SE NE 34; (R) SE; (R) NW NW 26
			Grenola limestone	Neva ls	
				Salem point sh	
				Burr ls	(RR) SW NE 24, 10, 7; (R) SW SE 7, 10, 8
			Roca shale		
			Red Eagle limestone	Howe ls	
				Bennett sh	(R, RR) SE SE 7, 10, 8
				Glenrock ls	
			Johnson shale		
			Foraker limestone	Long Creek ls	
				Hughes Creek sh	
				Americus ls	
		Admire	Hamlin shale		(H) C SW 30, 10, 9
			Five Point limestone		
			West Branch shale		(R) NE SE 7, 11, 9
			Falls City limestone		
			Hawxby shale		
			Aspinwall limestone		(S) NW NE 9, 11, 9; (S) NW NW 31, 10, 9
			Towle shale	Unnamed sh	
				Indian cave ss	(R) NE SW 30, 10, 9
Pennsylvanian	Virgil	Wabaunsee	Brownville limestone		
			Pony Creek shale		
			Caneyville limestone		
			French Creek shale		
			Jim Creek limestone		
			Friedrich shale		(S) SW SE 28, 10, 9
			Grandhaven limestone		(R) SE 5, 11, 9
			Dry shale		(S) C SW 32, 10, 9
			Dover limestone		(R) NW NW 27, 10, 9
			Langdon shale		
			Maple Hill limestone		
			Wamego shale		
			Tarkio limestone		(S) NE NW 5, 11, 9
			Willard shale		
			Elmont limestone		(R) C NW 2, 10, 9
			Harveyville shale		
			Reading limestone		
			Auburn shale		

Notes

Kind of outcrop: (R), road cut; (RR), railroad cut, (S), stream bank; (H), hillside.
Location example: NW NW 27, 10, 9 equals NW 1/4 NW 1/4 sec. 27, T. 10 S., R. 9 E.

Figure 5.—Location of representative sections of outcropping stratigraphic units in Riley County, Kans.

System	Series	Group	Geologic formation or member		Location of representative section
Quaternary			Alluvium		In the valley of the Kansas River
			Dune sand		
			Terrace deposit		
			Sanborn formation		(S) SW NW 23, 8, 4
			Glacial till		(R) NE 8, 6, 7
			Glacial boulders		(H) C 27, 10, 9
			Glacio-fluvial deposits		(H) SE NW 6, 10, 8
Cret	U. Cret.		Igneous rocks		(H) NW NW 6, 9, 5
			Dakota sandstone		(R) NW NW 1, 6, 4
Permian (continued)	Leonard	Sumner	Wellington shale		
			Nolans limestone	Herington ls	(R) NE NE 14, 6, 4
				Paddock sh	(R) SW SW 36, 6, 4
				Krider ls	
	Wolfcamp (continued)	Chase	Odell shale		
			Winfield limestone	Cresswell ls	(R) NW NW 33, 8, 6; (R) NE SE 19, 7, 5
				Grant sh	(R) NE SE 14, 6, 6
				Stovall ls	
			Doyle shale	Gage sh	
				Towanda ls	(R) NW NW 6, 7, 6
				Holmesville sh	
			Barneston limestone	Fort Riley ls	(R) NE SW 29, 8, 7
				Oketo sh	
				Florence ls	
			Matfield shale	Blue Springs sh	
				Kinney ls	(S) SE NE 15, 7, 6
				Wymore sh	
			Wreford limestone	Schroyer ls	
				Havensville sh	(R) SW NW 33, 10, 8
				Threemile ls	(R) SW SE 28, 10, 8
		Council Grove (continued)	Speiser shale		
			Funston limestone		
			Blue Rapids shale		
			Crouse limestone		
			Easly Creek shale		(R) SE 29, 8, 8
			Bader limestone	Middleburg ls	
				Hooser sh	NW 9, 11, 7
				Eiss ls	10, 9
			Stearns shale		
			Beattie limestone	Morrill ls	
				Florena sh	10, 7
				Cottonwood ls	

(Continued from top of next column)

System	Series	Group	Geologic formation or member		Location of representative section
Permian	Wolfcamp	Council Grove	Eskridge shale		(R) SE NE 34; (R) SE; (R) NW NW 26
			Grenola limestone	Neva ls	
				Salem point sh	
				Burr ls	(RR) SW NE 24, 10, 7; (R) SW SE 7, 10, 8
			Roca shale		
			Red Eagle limestone	Howe ls	
				Bennett sh	(R,RR) SE 7, 10, 8
				Glenrock ls	
			Johnson shale		
			Foraker limestone	Long Creek ls	
				Hughes Creek sh	
				Americus ls	
		Admire	Hamlin shale		(H) C SW 30, 10, 9
			Five Point limestone		
			West Branch shale		(R) NE SE 7, 11, 9
			Falls City limestone		
			Hawxby shale		
			Aspinwall limestone		(S) NW NE 9, 11, 9; (S) NW NW 31, 10, 9
			Towle shale	Unnamed sh	
				Indian cave ss	(R) NE SW 30, 10, 9
Pennsylvanian	Virgil	Wabaunsee	Brownville limestone		
			Pony Creek shale		
			Caneyville limestone		
			French Creek shale		
			Jim Creek limestone		
			Friedrich shale		(S) SW SE 28, 10, 9
			Grandhaven limestone		(R) SE 5, 11, 9
			Dry shale		(S) C SW 32, 10, 9
			Dover limestone		(R) NW NW 27, 10, 9
			Langdon shale		
			Maple Hill limestone		
			Wamego shale		
			Tarkio limestone		(S) NE NW 5, 11, 9
			Willard shale		
			Elmont limestone		(R) C NW 2, 10, 9
			Harveyville shale		
			Reading limestone		
			Auburn shale		

Notes

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Figure 5.—Location of representative sections of outcropping stratigraphic units in Riley County, Kans.

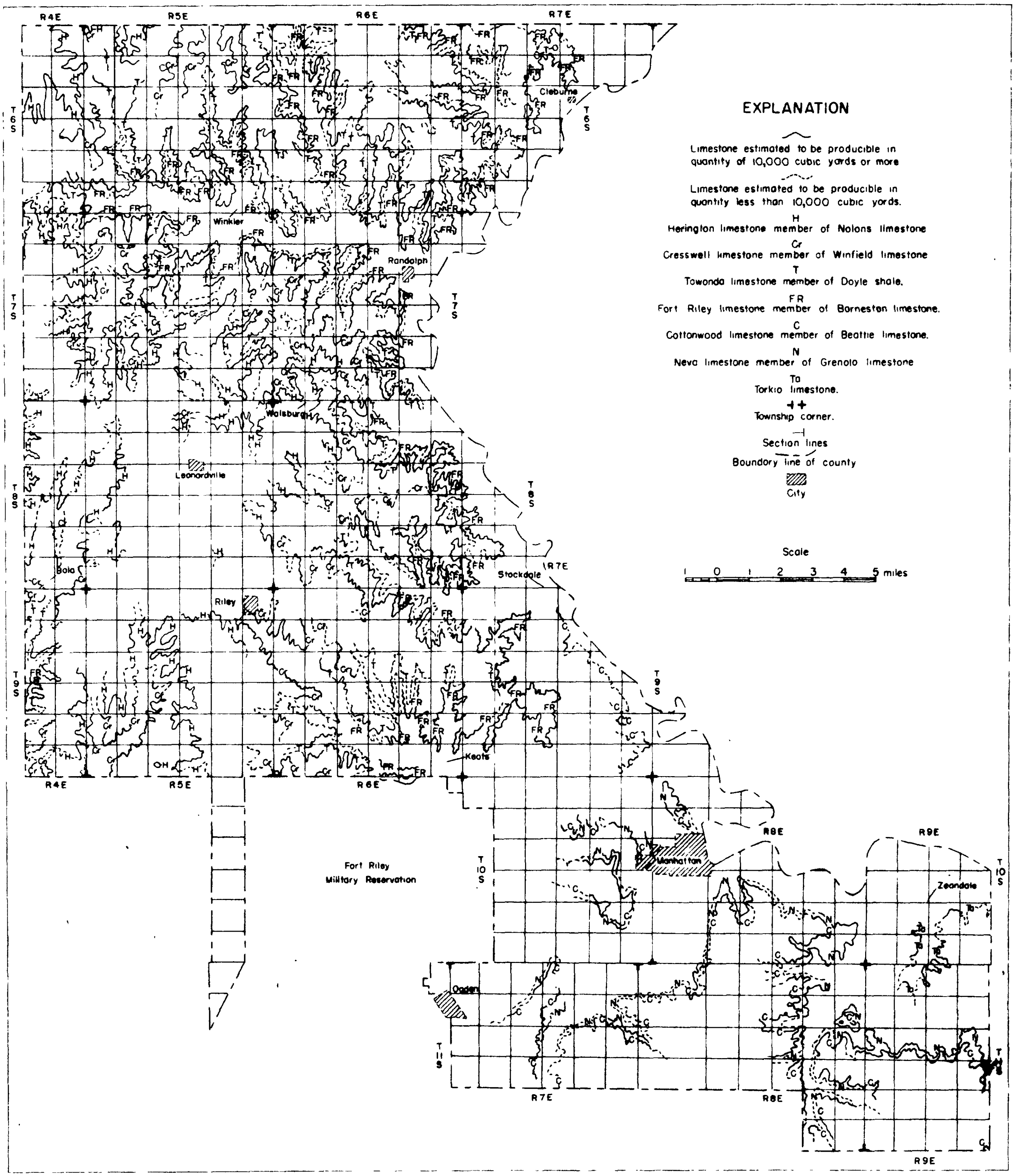

Figure 6.—Map showing limestone outcrops in Riley County, Kans, useful in engineering construction.