GEOLOGICAL SURVEY CIRCULAR 132

August 1951

GEOLOGIC CONSTRUCTION-MATERIAL RESOURCES IN RAWLINS COUNTY, KANSAS

By

Henry V. Beck and Robert K. McCormack

PREPARED IN COOPERATION WITH THE
STATE HIGHWAY COMMISSION OF KANSAS

R. C. Keeling, State Highway Engineer
S. E. Horner, Chief Geologist
R. D. Finney, Engineer of Materials

Prepared as Part of a Program
of the Department of the Interior
for Development of the Missouri River Basin

CONTENTS

ILLUSTRATIONS

TABLE

GEOLOGIC CONSTRUCTION-MATERIALS RESOURCES IN RAWLINS COUNTY, KANSAS

By

Henry V. Beck and Robert K. McCormack

INTRODUCTION

Purpose of the investigation

The State Highway Commission of Kansas and the United States Geological Survey are cooperating in the compilation of a State-wide inventory of construction materials. A field party composed of personnel from the two cooperating agencies was sent into Rawlins County, Kans., in the summer of 1949 to investigate sources of engineering construction materials. This report of the Rawlins County investigation is a part of the general inventory, and a contribution to the geologic mapping and mineral resource investigation being made in connection with the studies of the Missouri River basin. (Congressional documents, 1944.)

The primary objective of the investigation was to accumulate all field and laboratory data pertaining to the geologic materials in Rawlins County that would be of use in the constructions 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. --Rawlins County is in the first tier of Kansas counties south of the Nebraska border and in the second tier east of the Colorado border. (See fig. 1.) It comprises 30 townships and covers an area of about 1,080 square miles. The county is bounded by Decatur County on the east, Thomas County on the south, Cheyenne County on the west, and Hitchcock County, Nebr., on the north.

Topography. --Rawlins County is near the center of the Great Plains physiographic province, and near the eastern boundary of the High Plains subdivision of that province. The southeastern part of the county has been considerably more dissected by streams than has the northwestern part. Dissection is most conspicuous in the drainage area of Beaver Creek. The interstream areas are generally flat and wide.

The average altitude of the county is about 3,000 feet. The lowest point, 2,650 feet, is on Beaver Creek at the eastern boundary of the county, and the highest point, 3;350 feet, is near the western border of the county in the vicinity of MacDonald.

Drainage. --The principal streams in Rawlins County are North Fork and South Fork Beaver Creek, which join at Atwood to form Beaver Creek, and North Sappa, Middle Sappa, and South Sappa Creeks. The northward-flowing tributaries of these streams are from 1 to 7 miles long and average 2 miles in length. The southward-flowing tributaries are less numerous; they are from 2 to 6 miles long and average 3 miles in length. (See pl. 1.)

Climate. --Rawlins County is in an area of continental-type climate in which the summers are relatively long and hot, and the winters short and cold. The mean annual temperature is 52°F.; the mean temperature ranges from a low of 28°F. in January to a high of 78°F. in July. There are, on the average, 50 cloudy days a year, 125 partly cloudy days, and 190 clear days. The ground is snow-covered 30 days of the year. The normal annual precipitation is 18.53 inches. The average date of the first killing frost in the fall is October 5, and that of the last killing frost in the spring is May 3. (Flora, 1948.)

Figure 2, a chart showing temperature ranges at Atwood, Kans., was compiled from Climatological Data (U.S. Weather Bureau, 1938-47) for the years 1937 to 1946, inclusive, to provide basic data on temperature in relation to engineering construction. The chart indicates, for the 10-year period, the number of days each month in which the maximum daily temperature fell within certain designated ranges arbitrarily based on temperatures important in various phases of engineering construction.

Days in which the maximum temperature does not exceed 32°F. occur only from November to April, inclusive, with the maximum incidence, 6.3 days, in January. July is the warmest month of the year, with an average of 23.9 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, 34°F., is in October; and the least difference, 26°F., is in February.

Inasmuch as precipitation also conditions the number of working days in engineering construction, figure 3, a chart showing precipitation ranges at Atwood, Kans., is presented to show the effect of this climatic factor. The ranges in precipitation were selected arbitrarily.

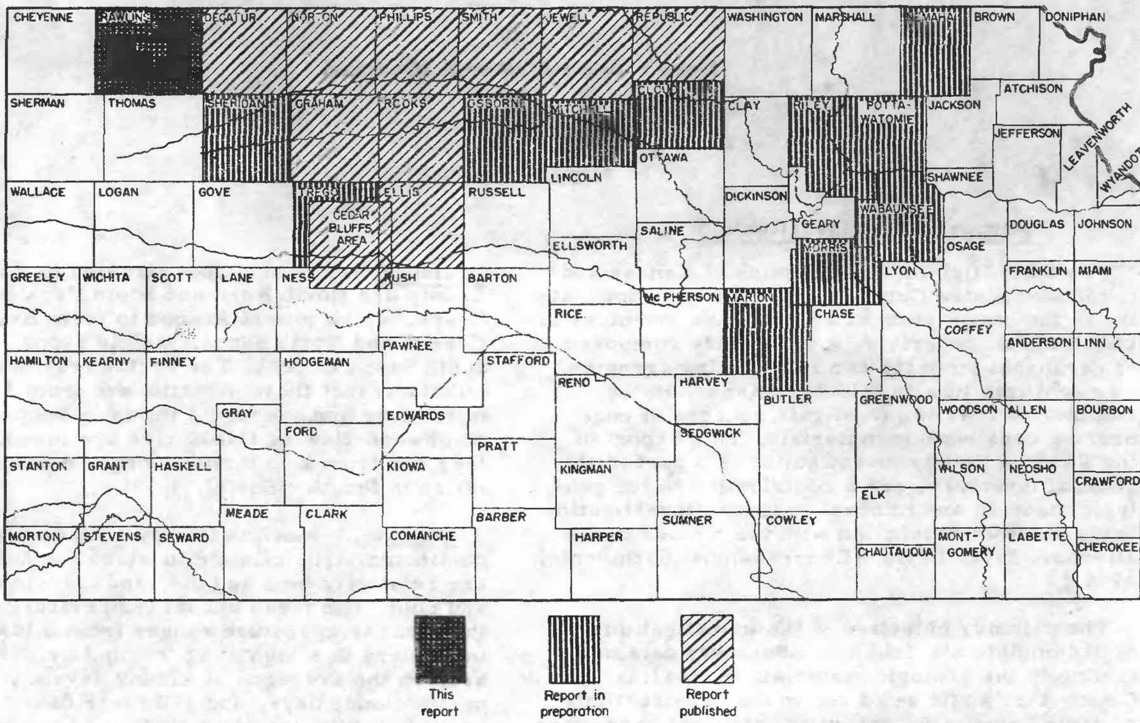


Figure 1.—Index map of Kansas showing areas covered by this report and by other construction materials investigations

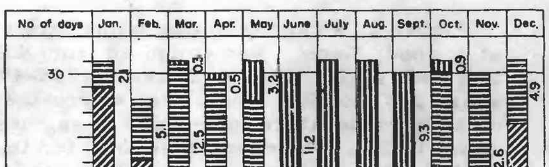


Figure 2.—Chart showing temperature ranges at Atwood, Kansas

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

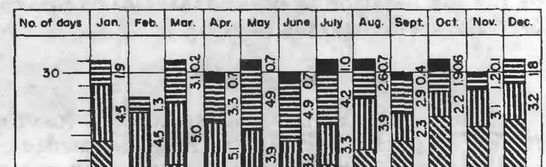


Figure 3.—Chart showing precipitation ranges at Atwood, Kansas

Based on a 10-year average (U.S. Weather Bur., 1938-47) there are 21.5 days in May, for example, in which no measurable precipitation fell; 3.9 days in which the precipitation ranged from a trace to 0.1 inch; 4.9 days in which 0.11 to 1 inch of rainfell; and 0.7 day 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.

Transportation routes.--Rawlins County is served by one railway, a branch line of the Chicago, Burlington, and Quincy; one transcontinental highway (U.S. Highway No. 36), and two Kansas highways (K 25 and K 117). State Route 117, and State Route 25 north of Atwood, are metaled, all-weather roads. Kansas Highway 25 south of Atwood and U.S. Highway No. 36 are of the black-top type of construction.

County and township roads, for the most part, follow section lines. Some of them are metaled with materials available locally, whereas others are maintained as earth roads.

The locations of roads and the railroad are shown on plate 1.

Investigation procedure

This report is based on field work of the reconnaissance type. The base map (scale: 1 mile to 1 inch), including drainage lines, was provided by the State Highway Commission of Kansas. The areal distribution of the stratigraphic units that outcrop in Rawlins County was then mapped in the field. The mapped stratigraphic units are those recognized by the U. S. Geological Survey (Wilmarth, 1938) and the Kansas Geological Survey (Moore and others, 1944). The principal emphasis of this report is on construction 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; these are presented in table 1, a summary of materials tests.

Acknowledgments

Appreciation is expressed to the following for their aid in contributing information found useful in the compilation of the geologic map and of construction-materials data included in this report: the State Highway Commission of Kansas at Topeka and Manhattan, Kans., S. E. Horner, chief geologist, R. D. Finney, engineer of materials, and W. E. Gibson, engineer of tests; the Rawlins County office of the Soil Conservation Service, United States Department of Agriculture; and Glenn W. Sloan. county engineer of Rawlins County.

This report, in manuscript form, was reviewed by various members of the U. S. Geological Survey.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

Introduction

This discussion of the outcropping stratigraphic units of Rawlins County emphasizes the areal distribution, general characteristics, thickness, and the construction materials in each formation. This part of the report presents the geological information required for the location and effective development of the construction materials.

A summary of the data for each geologic formation is presented in figure 4, and the relations of the stratigraphic units to one another are illustrated in figure 5, a geologic cross section of the valley of Middle Beaver Creek.

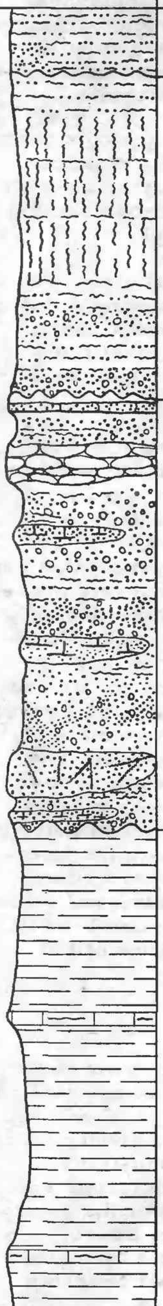
The areal distribution of the local stratigraphic units is shown on plate 1, a map showing construction materials and geology of Rawlins County, Kans. Each unit is indicated by an identifying symbol, and its outcrop areas are shown by a distinctive pattern.

The locations of pits and quarries also are shown on plate 1. The symbols indicate whether the pit or quarry is or has been operated or is a prospect, the type of construction material available at each site, and the quantity of the material (in units of 10,000 cubic yards) that can be removed under no more than moderate overburden (unconsolidated sediments less than 6 feet thick). Most of these sources are listed in table 1. Materials represented on the map by inclined letters have not been tested and are not listed in table 1. All materials sources listed in table 1 are numbered within each materials classification according to the following plan: The numbering starts in the northeasternmost township and continues along the same tier to the western boundary of the county; it is continued in the next tier south starting again with the township in the easternmost range and proceeding to the western boundary of the county, and so on. Within a township the sources are numbered in the same sequence as are the sections of the township.

Pierre shale

Areal distribution.--The Pierre shale is the only stratigraphic unit of Cretaceous age that crops out in Rawlins County. (See pl. 1 and fig. 4.) It probably underlies the entire county but is concealed by younger overlying formations except along stream courses. Its outcrops are most numerous in the eastern part of the county along the south wall of the valley of Beaver Creek. Three small outcrops of this formation are mapped in the northwesternmost township.

General description.--The Pierre shale, the only formation of marine origin cropping out in Rawlins County, is gray, blue black, or rust-colored. It is predominantly clayey and noncalcareous. The light-colored layers are thin-bedded, whereas the blue-black layers are very thin bedded (fissile). All exposures are characterized by flaky or nodular concretions of hydrous iron oxide (limonite). Thin lenses of



Section	Outcrop thickness (feet)	Stratigraphic units: System	Series	Formations	Generalized description	Construction materials
	0–30	Quaternary	Pleistocene and Recent	Terrace deposits	Gray, light-gray, or tan-gray silt with some clay; lenses of sand and gravel in basal part.	Aggregate Road metal Mineral filler
	0–150	Quaternary	Pleistocene and Recent	Sanborn formation	Predominantly tan-gray silt with some clay in the upper part and local lenses of sand and gravel in the basal part; buried soil present locally; lenses of volcanic ash in some places; tends to stand in vertical banks. Fossil snails common.	Mineral filler Aggregate Road metal Volcanic ash
	200	Tertiary	Pliocene	Ogallala formation	Interbedded lenses of sand, gravel, silt, and clay; tan, green, red-brown, and brown; thick red-black clay shale lenses occur locally; lenticular ledges of gray mortar bed, light-green quartzite, and white and yellow-gray opal; lenses of light-groy and white volcanic ash; bed of hard limestone ot or near top in some places.	Aggregate Road metal Riprap Structural stone Volcanic ash Calcareous binder
		Cretaceous	Upper Cretaceous	Pierre shale	Thin-bedded dark-gray, black, and rust-brown clay and silt shales; contains thin lenses of limestone concretions, thin beds of bentonite, and veins of crystalline gypsum (selenite).	

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

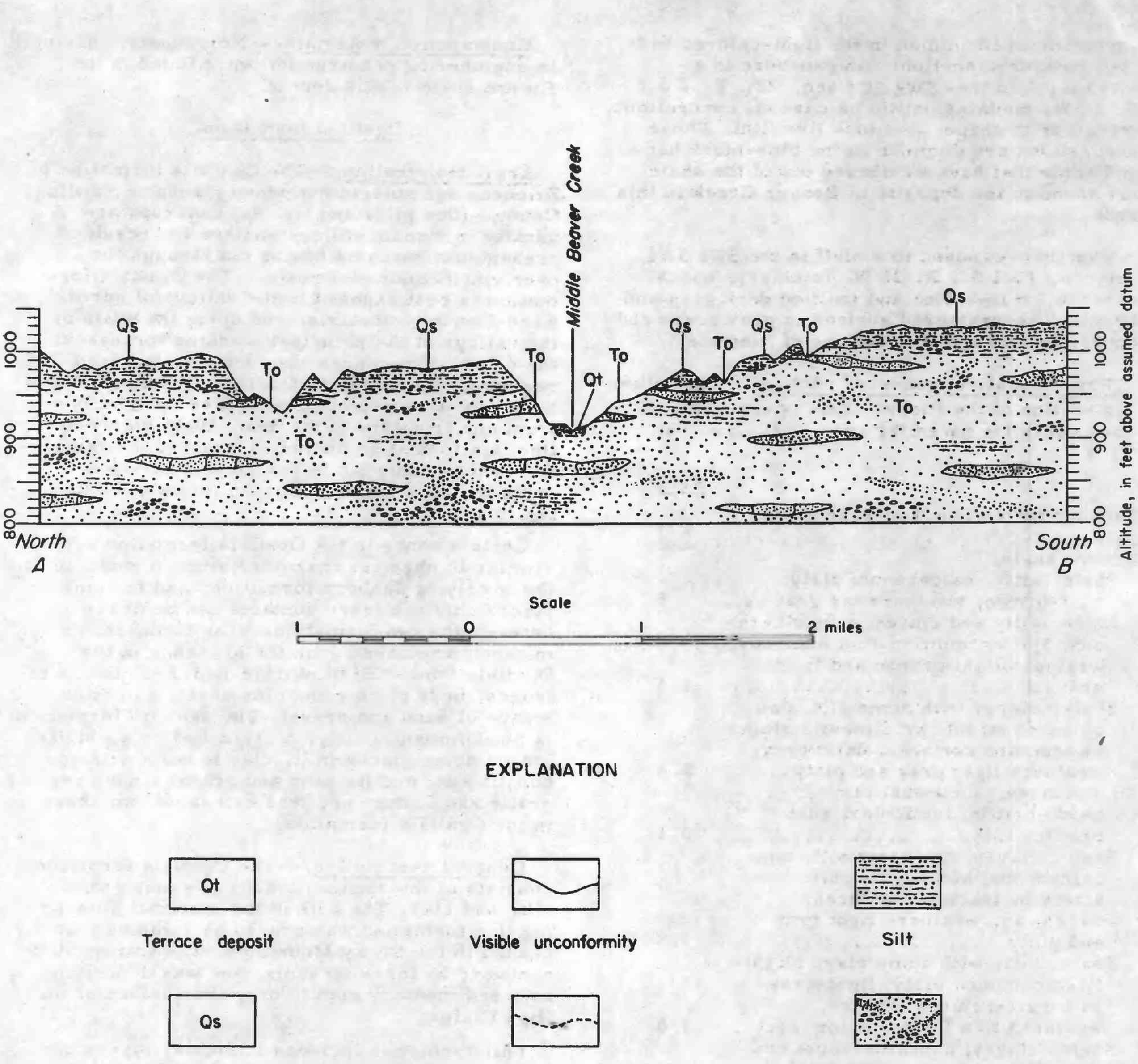


Figure 5.—Geologic cross section of the valley of Middle Beaver Creek along line *A—B* (along section line between secs. 10 and 11, T. 3 S., R. 35 W. and secs. 2 and 3, T. 4 S., R. 35 W.)

limestone are common in the light-colored beds (see measured section). An exposure in a stream cut in the SW¼ SE¼ sec. 22, T. 2 S., R. 32 W. contains brittle calcareous concretions, irregular in shape, that look like flint. These concretions are common in the blue-black beds, and some that have weathered out of the shale are found in the deposits of Beaver Creek in this area.

The shale exposed in a bluff in the SE¼ SW¼ sec. 10, T. 1 S., R. 36 W. is clayey, noncalcareous, thin-bedded and mottled dark gray and brown. The weathered surface is gray green and covered with flaky concretions of limonite.

Representative measured section.--The following section of the Pierre shale is exposed in a road cut in the SW¼ SW¼ sec. 1, T. 3 S., R. 33 W.:

	Feet
Sanborn formation: Tan-gray clayey silt	8.2
Pierre shale:	
Shale, silty, calcareous; platy; rust-brown, weathers tan gray	.5
Shale, silty and clayey, noncalcareous; blocky; mottled rust and gray, weathers light orange and light gray	1.3
Shale, clayey with some silt, noncalcareous; blocky; limonite stains on fracture surfaces; dark-gray, weathers light gray and platy	8.8
Limestone, somewhat clayey; hard, brittle; lenticular; rust brown	0.1
Shale, clayey with some silt, noncalcareous; blocky; limonite stains on fracture surfaces; dark gray, weathers light gray and platy	1.8
Shale, silty with some clay, slightly calcareous; platy; light-gray with rust-colored streaks, weathers to a lighter color	1.6
Shale, clayey; noncalcareous; contains flaky gypsum; thin-bedded; dark-blue-gray, weathers light blue gray	6.1
Limestone; lenticular; the upper half shows cone-in-cone structure; gray-brown, weathers rust-colored	.4
Shale, clayey, noncalcareous; blocky, limonite stains on fracture surfaces; olive-drab, weathers gray	6.0
Total thickness exposed (base covered)	26.6

Thickness.--Individual outcrops of the Pierre shale are between 5 and 35 feet thick. The thickest exposures are those along the south wall of the valley of Beaver Creek near the eastern border of the county. The total exposed thickness of the formation is estimated to be 300 feet, but about 1,000 feet of Pierre shale was encountered in a well drilled in the SE¼ SE¼ sec. 1, T. 2S., R. 31 W.

Construction materials.--No materials useful in engineering construction were found in the Pierre shale in this county.

Ogallala formation

Areal distribution.--The Ogallala formation of Pliocene age outcrops in many places in Rawlins County. (See pl. 1 and fig. 4.) Outcrops are usually in stream valleys and are the result of present-day streams having cut through the overlying Sanborn formation. The Ogallala formation is best exposed in the valleys of northward-flowing tributaries and along the walls of the valleys of the principal streams throughout the county. Exposures also occur in the head regions of the southward-flowing tributaries of the main streams, but usually are not continuous from one tributary to the next. Undoubtedly the Ogallala formation underlies much of the remainder of the county but is buried to a bariable depth by the overlying Sanborn formation. (See fig. 5.)

Certain zones in the Ogallala formation are similar in physical characteristics to zones in the overlying Sanborn formation, and in some places only arbitrary contacts can be drawn between the two formations. The contacts, as mapped, are based upon the presence in the Ogallala fromation of mortar-bed and quartizite ledges, beds of clay and clay shale, and thick lenses of sand and gravel. The sanborn formation is predominantly silty, mortar-bed or quartzite ledges do not occur in it, clay is not a principal constituent, and its sand and gravel lenses generally are thinner and less extensive than those in the Ogallala formation.

General description.--The Ogallala formation consists of interbedded lenses of sand, gravel, silt, and clay. The bulk of the material composing this formation was eroded by streams that headed in the Rocky Mountains, was transported eastward by these streams, and was deposited as a sedimentary mantle over the surface of the High Plains.

This formation includes lenticular layers of light-gray, massive, lime-cemented sand or sandy gravel. Such layers are termed mortar beds. A mortar bed is harder than most of the other materials in the formation so that differential erosion usually causes it to outcrop as a conspcuous hillside ledge. Some ledges are less than a foot thick, but many others are as much as 6 feet thick, such as those exposed on the hillside in the NW¼ NE¼ sec. 10, T. 3 S., , R. 33 W. Generally the mortar beds are composed of fine sand cemented by calcium carbonate. A mortar bed composed of coarse sand and gravel is exposed in a valley wall in the NE¼ NW¼ sec. 22, T. 1 S., R. 36W. This ledge is unusually well cemented and forms a prominent ledge along the east side of a large tributary. Outcrops of mortar bed are poorly developed on the west side of this stream. The coarse particles included in the mortar beds are fragments of granite, quartz, and fledspar. Crossbedding is a characteristic feature of the coarse-textured beds but is less well developed in the fine-texture ledges.

Ledges of quartzite occur in the Ogallala formation, but their outcrops are less numerous than those of mortar bed. The quartzite is a sand or gravelly sand that has been very firmly cemented through the deposition of opal, by percolating subsurface waters, in the original pore spaces of the material. The quartzite is typically light green and lenticular. A ledge exposed in the SW¼ SE¼ sec. 22, T. 2 S., R. 32 W. is composed of coarse sand- and gravel-size particles of quartz and feldspar, as well as some clay balls. The Pierre shale immediately underlies the quartzite in this exposure, as it does in all exposures. Most of the outcrops occur in the south valley wall of Beaver Creek near Herndon in the eastern part of the county.

A layer of chert in the Ogallala formation is exposed in the south wall of the valley of North Fork Beaver Creek. In an outcrop in the SE¼ SE¼ sec. 9, T. 4 S., R. 36 W. the chert is 95 percent opal with no indication of sand and gravel being present in the deposit as they are in mortar bed and quartzite. The upper 2 feet is nearly white and has a quartz-like appearance. This rock is brittle and tends to break in small, angular, sharp-edged pieces. In a road cut a mile west of this place an algallike limestone occurs about 10 feet above the chert. It has been used to define the top of the Ogallala formation in other parts of the State and it would thus appear that the chert occurs near the top of the formation.

Algal-like limestone is exposed in a road ditch in the NW¼ SW¼ sec. 4, T. 5 S., R. 35W. Scattered sand grains are present in this brittle, nodular, light-gray limestone. The nodules are composed of concentric bands of tan and brown calcium carbonate. The ledge is a foot thick.

Most of the Ogallala formation consists of lenses and beds of unconsolidated sand, gravel, silt, and clay. Sand, gravel. and silt are exposed in an abandoned pit in the NW¼ NE¼ sec. 24, T. 3 S., R. 35 W. The gravel is composed of particles of quartz and feldspar, and fragments of granite and other igneous rocks. Red-brown silt overlies the sand and gravel and is cut by intersecting stringers of calcium carbonate. Capping the pit is a 4-foot ledge of mortar bed.

Lenses of volcanic ash are present in the Ogallala formation. The ash is material discharged into the atmosphere during the explosive phase of a volcanic eruption and carried by the wind to be deposited in sheltered places on the land surface, as in stream valleys and lake basins. The ash consists of shards of glass-like material, and is white to light gray. The ash sometimes contains extraneous particles of sand, gravel, and silt washed in by streams or slope-wash during the period of ash fall. The beds of ash in the Ogallala formation average about 4 feet thick. A lens exposed in the NW¼ NW¼ sec. 33, T. 3 S., R. 34W. has been impregnated with calcium carbonate in its upper part. The ash is compact, shows bedding on fresh surfaces, and is light gray.

<u>Representative measured sections</u>. --1. The following section of the Ogallala formation is exposed in a stream cut in the NW¼ NE¼ sec. 6, T. 4 S., R. 35 W.:

	Feet
Soil: Silt with mortar-bed fragments; loose; tan-gray	0.6
Ogallala formation:	
Mortar bed; fine sand cemented by calcium carbonate; dense, hard; lenticular; light-gray, weathers tan gray and develops an uneven surface	1.8
Chert; dense, hard, brittle; lenticular; mottled clear and gray; resembles quartz	1.0
Silt; calcium carbonate in pore spaces and as stringers; partially compacted; red-brown, weathers red tan	1.7
Mortar bed; fine sand cemented by calcium carbonate; dense; lenticular; light-gray, weathers tan gray	2.1
Silt, noncalcareous; stands in vertical bank; white, platy; pipe-like concertions parallel and at right angles to the plane of bedding; reddish-brown, weathers pinkish tan	7.0
Mortar bed; fine sand loosely cemented by calcium carbonate; granular; forms a minor ledge; light-gray, weathers pink gray	1.8
Silt, with some fine sand, noncalcareous in upper part, calcareous in lower part; lenticular; white calcareous concretions throughout; gray-green, weathers gray	3.3
Silt, some fine sand, noncalcareous; contains concretions of silt and sand comented by calcium carbonate; reddish-tan	2.8
Total thickness exposed (base covered)	21.5

2. A hillside in the NW¼ NE¼ sec. 10, T. 3 S., R. 33 W. shows the following section of the Ogallala formation:

	Feet
Ogallala formation:	
Mortar bed; medium sand and fine gravel loosely cemented by calcium carbonate; lenticular; light-tan, weathers gray; forms massive ledge	5.7
Silt and fine sand, slightly calcareous; compact; contains calcareous concretions; light-brown, weathers tan	5.3
Mortar bed; fine sand and silt poorly cemented by calcium carbonate; lenticular; tan, weathers mottled gray and black	3.6
Silt and some fine sand, noncalcareous; partially compacted; light-tan	3.1

Ogallala formation.--Continued

	Feet
Sand, fine, with some silt, calcareous; locally lime-cemented; gray-green	2.5
Mortar bed; fine sand and scattered gravel particles well-cemented by calcium carbonate; lenticular; light-tan, weathers mottled gray and black; forms massive ledge	5.3
Mortar bed; fine sand, poorly cemented; massive, lenticular; light-tan, weathers mottled gray and black	6.3
Sand, fine, poorly cemented by calcium carbonate; tan, weathers tan gray	4.1
Mortar bed; fine sand with scattered gravel particles in upper part, well-cemented by calcium carbonate; tan, weathers gray; forms ledge	4.9
Sand, fine, and silt, poorly cemented by calcium carbonate; light-tan, weathers gray	3.0
Total thickness exposed (base covered)	43.0

Thickness.--The thickness of the Ogallala formation is variable throughout the county, and ranges from a feather edge to a maximum of 200 feet. Typical outcrops are 35 feet thick.

Construction materials.--In Rawlins County, the construction materials from the Ogallala formation are: volcanic ash, riprap, road metal, aggregate for concrete, and calcareous binder.

Sanborn formation

Areal distribution.--The Sanborn formation of Pleistocene and Recent age is the most widely distributed formation cropping out in Rawlins County. (See pl. 1 and fig. 4.) At one time the formation undoubtedly extended over the full area of the county, but it subsequently has been eroded from the courses of many of the streams. The formation caps the interstream areas where it conceals older stratigraphic units. (See fig. 5.)

General description.--The Sanborn formation is composed of materials deposited by streams, slopewash, wind, and by the action of gravity. Frye and Fent (1947) have divided the formation into members. It was not feasible to attempt the mapping of these 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 formation as an undivided unit seems adequate to serve the purpose of this construction-materials inventory.

The upper part of the formation is predominantly silt with particles of sand and gravel scattered throughout. The color is tan or tan gray, and there is a prominent soil profile developed at the top of the formation. The "A" horizon is characteristically thin, ranging from 0.4 to 1 foot in thickness, is usually dark gray, and has a granular texture. The thick "B" horizon is characterized by lighter color and secondary calcium carbonate deposited by down-percolating subsurface water. The calcium carbonate is disseminated throughout the horizon but may be concentrated locally in the form of nodules or pipelike concretionary masses. This zone characteristically stands in vertical banks and develops a crude columnar structure, the result of the intersection of irregular joint planes.

A buried ("fossil") soil is exposed in a road cut on U. S. Highway 36 in the SW¼ SW¼ sec. 2, T. 3 S., R. 33 W. In this exposure, the modern soil is about 0.8 foot thick and is separated from a buried soil zone by 3.2 feet of slightly clayey, calcareous, tan-gray silt. The buried soil is dark-gray silt with some clay, is slightly calcareous, and about 2.8 feet thick. Fossil snails are found above and below the buried soil zone.

Lenses of sand or sandy gravel are present in the basal part of the formation. They are 6 to 9 feet thick, pinch out laterally within short distances, and contain materials derived through the weathering and erosion of the Ogallala formation. Such lenses are deposits laid down by streams or slope-wash, and are usually markedly cross bedded. A pit in the SE¼ NW¼ sec. 7, T. 3 S., R. 34 W. exposes a lens of sandy gravel characteristic of this formation. There are thin lenses of silt and clay interbedded with it. The gravel particles consist of about 10 percent fragments of mortar bed; the remainder is composed of fragments of quartz, feldspar, and igneous rocks.

Several deposits of volcanic ash were found in the basal part of the Sanborn formation. The ash exposed in a pit in the SE¼ NW¼ sec. 14, T. 3 S., R. 35 W. is overlain by 5 feet of silt. The ash is in two layers which are separated by a lens of gravel 0.1 foot thick; the upper layer of ash is gray, the lower layer is white, and their aggregate thickness is about 12 feet. This deposit is typical of the ash found in the Sanborn formation.

The Sanborn formation occurs in two topographic positions: as a blanket of unconsolidated material covering the interstream areas and as a relatively thin veneer of material covering the lower part of the valley walls of the larger streams in the county. The deposits are mapped as a single stratigraphic unit because the contact between these two levels of Sanborn deposition has been obscured over much of the county through the action of slopewash.

Generally the Sanborn formation is eroded to form a gently undulating surface. The headward parts of some stream valleys that have been cut into the Sanborn formation exhibit a phenomenon known as "catstep erosion," which is probably the result of gravity sliding of water-saturated silt down toward the streams. The catsteps are bounded by scarps 1 to 10 feet high and can be traced horizontally for several hundred feet. In the northeastern part of the county the catsteps have developed to such an extent that the valleys appear to be U-shaped in their headward portions.

An unusual topography is exhibited by this formation in the northern half of T. 1 S., R. 36 W. A markedly uneven surface has been developed there by the small streams flowing northward through this area. The V-shaped valleys of the streams are deeply incised into the Sanborn formation and have produced a local relief of about 150 feet and a badland type of topography.

Representative measured section. --The following section is exposed in a road cut along U. S. Highway 36 in the SW¼ SW¼ sec. 2, T. 3 S., R. 33 W.:

	Feet
Sanborn formation:	
Silt, calcareous; friable; gray-brown, weathers tan gray	0.8
Silt, slightly clayey; calcium carbonate disseminated throughout; light-tan-gray, weathers light gray. Fossil snails common	3.2
Silt, clayey, calcareous; dark-gray.	2.8
Silt, clayey, very calcareous; granular; tan, weathers tan gray. Fossil snails common	26.5
Silt, some clay, very calcareous; granular; gray-brown, weathers reddish brown producing a prominent color band	3.0
Silt, some clay and fine sand, very calcareous; tan, weathers light gray	2.4
Total thickness present (underlain by the Ogallala formation)	38.7

Thickness. --The formation has been completely eroded from the valleys of many of the streams. Its greatest thickness, about 150 feet, is in the interstream areas in the northwestern quarter of the county. The average thickness is 50 feet.

Construction materials. --Construction materials from the Sanborn formation in Rawlins County are: mineral filler, volcanic ash, aggregate for concrete, and road metal.

Terrace deposits

Areal distribution. --Terrace deposits are characteristic of the valleys of the larger streams in the county, and narrow extensions of the terraces project into the valleys of their tributaries. (See pl. 1 and fig. 4.) The width of the terrace deposits changes rapidly within short distances. Those of Beaver Creek are about 0.6 mile wide in the eastern part of the county and narrow westward to about 0.2 mile. The deposits along the branches of Sappa Creek range from 0.4 mile wide in the eastern part of the county to 0.1 mile near the southern border. The position of the terrace deposits relative to other formations is illustrated in figure 5.

General description. --The terrace deposits are composed mostly of silt, but the upper part is somewhat clayey and the lower part is somewhat sandy. Lenses of cross-bedded sand and gravel are present but are not extensive. The silt is light gray, gray, or tan gray, and there is almost always a well-developed "A" soil zone present at the top of each outcrop. This horizon is usually dark gray. The underlying "B" horizon is typically tan gray and more clayey than the horizons above and below it.

The lenses of sand and gravel in the lower part of a terrace deposit are composed of granitic material (quartz, pink fledspar, and particles of granite), and fragments of local rock such as mortar bed, quartzite, and limestone. A wet pit in the SW¼ SW¼ sec. 14, T. 2 S., R. 32 W. exposes layers of well-sorted sand and gravel composed of both granitic and local material which has been used extensively as metal for the county roads in this vicinity. Some of the limestone pebbles have been silicified.

Representative measured sections. --1. The following section of a terrace deposit was obtained by drilling an auger hole in the valley of North Sappa Creek in the SW¼ NW¼ sec. 16, T. 4 S., R. 31 W.:

	Feet
Soil: Gray clayey silt	1.0
Terrace deposit:	
Silt, clacareous; friable; tan-gray.	4.6
Silt, clayey, calcareous; gray	1.4
Silt, very clayey, slightly calcareous; dark-gray; possible a buried soil	.5
Silt, clayey, impreganted with calcium carbonate; olive-drab	0.8
Silt, clayey, some sand, calcareous; limonite stained; tan-gray	4.7
Silt, fine sand, some clay, calcareous; tan gray	3.0
Total depth of hole	16.0

2. A road ditch in the SW¼ SE¼ sec. 9, T. 4 S., R. 36 W. shows the following section of the terrace deposit of North Fork Beaver Creek:

	Feet
Soil: Gray clayey silt	2.0
Terrace deposit:	
Silt, slightly clayey, calcareous; compact; scattered particles of sand an lower part	1.2
Silt, calcareous; granular; dark-gray	1.8
Silt, noncalcarous; granular; gray	2.0
Silt, clayey, noncalcarous; blocky; mottled gray and tan	6.0
Total thickness exposed (base covered)	11.0

Thickness. --The height of the terraces above the streams is variable but is greatest--about 10 feet--in the western part of the county. The full thickness of the terrace deposits is estimated to be 30 feet in the larger valleys in the eastern part of the county. The thickness of extensions of the terrace deposits into tributary valleys decreases away from the junctions with the larger streams.

Construction materials. --Construction materials from the terrace deposits in Rawlins County are: aggregate for concrete, mineral filler, and road metal.

INVENTORY OF CONSTRUCTION MATERIALS

General

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

Whenever available, laboratory test data have been introduced into the report to aid the reader in his evaluation of the materials. The information given in table 1 is based on the standard testing procedures of the State Highway Commission of Kansas (1945) and the American Association of State Highway Officials (1947). It is expected that prospects 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.

Al though numerous prsopect 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 Rawlins 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 nonproductive 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 classified as fine aggregate and mixed aggregate in table 1 and on plate 1. In this report, the distinction is an arbitrary one based on the percentage of material retained on a standard no. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. The material is classified as mixed aggregate if the coarse fraction is 5 percent or more by weight of the whole sample; as fine aggregate if the coarse fraction is less than 5 percent. Fine and mixed aggregate will be considered together because of the standard practice of bringing the grading to specifications by sweetening or screening.

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

Stratigraphic sources and performance characteristics. --The following stratigraphic units are actual or potential sources of aggregate for concrete: 1. Ogallala formation. Four samples of fine aggregate (fa 2 to fa 4, and fa 6) and 4 samples of mixed aggregate (ma 8, ma 13, ma 17, and ma 18) were obtained from the Ogallala formation. The principal difference between aggregates of this formation and those of the Sanborn formation is that the aggregate in the latter contains a higher percentage of fragments of mortar bed and quartzite.

2. Sanborn formation. One sample of fine aggregate (fa 1) and 14 samples of mixed aggregate (ma 1 to ma 7, ma 9 to ma 12, and ma 14 to ma 16) were obtained from the Sanborn formation. Sand and gravel of this formation are composed of particles of granite, quartz, feldspar, basic igneous rocks, mortar bed, and quartzite.

Additional supplies of sand and gravel are doubtedly present in the basal part of the formation. They can best be located by intensive search in the margins of the mapped area of outcrop (see pl. 1), especially on the north side of the major streams and on the east side of their larger southward-flowing tributaries, as well as places where streams have cut through the Sanborn formation into underlying stratigraphic units. However, the sand and gravel occur as lenses of limited extent, generally with only small quantities of material available in them.

3. Terrace deposits. One sample of the fine aggregate (fa 5) was taken from a terrace deposit; the sampled locality is mapped on plate 1 and the test characteristics of the sample are given in table 1. Sand and gravel of the terrace deposits are predominantly fragments of quartz, granite, and feldspar; they also contain minor amounts of basic igneous rocks, fragments of carbonate rocks, and chert.

The quantity of sand and gravel that can be obtained from terrace deposits is not large inasmuch as the lenses of sand and gravel are small and not numerous. Other deposits are probably present in the valleys of the larger streams in the eastern part of the county. The overburden is silt and may be removed easily.

Road Metal

Engineering and geologic characteristics. --Road metal, known also as surfacing 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 differ from one area to another. The following materials are abailable in Rawlins County for use as road metal:

1. Aggregate for concrete. (See above.)

2. Indurated rocks that are available for use as road metal are: (a) mortar bed, a compact,

massive layer of sand or gravelly sand firmly cemented by calcium carbonate; (b) quartzite, a massive layer of sand or sandy gravel firmly cemented by silica by percolating ground water; (c) chert, a compact and hard siliceous (opaline) rock.

The materials included here under crushed rock are listed in table 1, and mapped on plate 1 under the more specific designations of mortar bed, quartzite, and chert because, in addition to their use as road metal, they may be used as structural stone and riprap.

Stratigraphic sources and performance characteristics. --1. Sources of aggregate for concrete. The materials listed in the section on aggregate for concrete have been used in Rawlins County as road metal on light-traffic roads or as base-course material in roads of the black-top type of construction. Field observation indicates that they are adequate for these purposes. Their sources have been discussed under aggregate for concrete.

2. Crushed rock.

(a) Mortar bed of the Ogallala formation. Mortar beds are numerous throughout the county and are a potential source of crushed rock for road metal. The first mile of the county road from U. S. Highway No. 36 north to Beardslee has been surfaced with crushed mortar bed. This work was done recently and a good surfacing has resulted. The sand and gravel particles in the mortar bed are bound by the calcium carbonate cement to form a traffic-bound macadam. One sample (mb 1) is considered to be characteristic of this material, has been tested, and the location of its source is mapped on plate 1.

(b) Quartzite of the Ogallala formation. Ledges of quartzite in the eastern part of the county are a potential source of crushed rock for road metal, but this use of the quartzite was not observed in Rawlins County. Field observations in other counties indicate that the performance characteristics of this material are satisfactory if it is crushed to a size smaller than 0.5 inch. The performance is improved if a binder material is added to the crushed rock.

(c) Chert of the Ogallala formation. The ledges of chert in the western part of the county are potential sources of crushed rock. Objections to the use of the chert as road metal are the expense of crushing it and the sharp edges of the crushed fragments. One sample (ch 1) of the material has been tested (see table 1) and the location of its source is mapped on plate 1.

Mineral filler

Engineering and geologic characteristics. --Material composed predominantly of silt-size mineral particles (50 percent or more of the material passing the no. 200 sieve) is classified in this report as mineral filler. It has no more than a trace of sticks or other organic debris, but may contain minor amounts of fine sand or clay. W. E. Gibson of the Road Materials Laboratory of the State Highway Commission of Kansas states (personal communication) that material will qualify for mineral filler only if laboratory tests indicate a low coefficient of cementation.

Stratigraphic sources and performance characteristics. --The following stratigraphic units are actual or potential sources of mineral filler:
1. Sanborn formation. Two samples from the Sanborn fromation (mf 1 and mf 3) are classified as mineral filler. Field investiagtion indicates that the silt of the Sanborn formation is in general more friable than that of the terrace deposits, although the content of clay is sufficiently high, in the samples tested, that the cementation factor is probably excessive.

2. Terrace deposits. One sample (mf 2) of material classified as mineral filler was collected from a terrace deposit. The test data for this sample are given in table 1 and the locality is mapped on plate 1.

Volcanic ash

Engineering and geologic characteristics. --Volcanic ash is sometimes classified as mineral filler, but in this report it is distinguished as a special type of mineral filler because it is suitable for certain uses that the usual silty filler is not. Volcanic ash consists predominantly of the fine, glass-like shards ejected during the explosive phase of a volcanic eruption. The deposit may include silt-size particles of other origins and occasional thin seams of gravel and sand.

Stratigraphic sources and perfomance characteristics. --1. Ogallala formation. One deposit of volcanic ash of this formation was sampled and tested (see va 1). Other deposits of volcanic ash undoubtedly can be located within the mapped outcrop areas of the formation.

2. Sanborn formation. Two samples of volcanic ash of this formation were collected and tested (va 2 and va 3). Test characteristics of this material indicate that it is apparently suitable for use as mineral filler and it has been used in bituminous-mat construction in this part of the state.

Other small lenses of volcanic ash are undoubtedly present in the basal part of the Sanborn formation elsewhere in Rawlins County. Exploration for additional deposits should be undertaken in areas near the heads of tributary streams that have cut will down into the basal part of this formation.

Riprap

Engineering and geologic characteristics. --Riprap, as defined in this report, is any material suitable for protecting earther 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 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. Mortar bed of the Ogallala formation. One sample (mb 1) of mortar bed was tested and the test data are presented in table 1. The data indicate that mortar bed may not be acceptable for use as riprap, and the service history of this material used as riprap in other counties demonstrates that the material disintegrates seriously within a short time.

2. Quartzite of the Ogallala formation. Three outcrops of quartzite were sampled and tested and the data are presented in table 1 (qtz 1, qtz 2, and qtz 3). The test characteristics of this material indicate that it would be satisfactory for use as riprap. The dam impounding Lake Atwood was constructed over 20 years ago and was riprapped with this rock. There is no evidence of serious deterioration of the rock. Quartzite quarries out in large angular blocks which would be satisfactory insofar as size and shape are concerned. Outcrops of quartzite in this county are confined to the south wall of the valley of Beaver Creek in the eastern part of the county.

3. Chert of the Ogallala formation. One sample of chert (ch 1) was tested and the results are presented in table 1. The test characteristics indicate that this material would be adequate for use as riprap but, at best, the chert can be considered as a source of only small quantities of riprap in the western part of the county.

Structural stone

Engineering and geologic characteristics. --Structural stone, as defined in this report, is any hard, dense rock material that can be quarried and produced to desired size and shape. Materials fulfilling these requirements are in the Ogallala formation.

Stratigraphic sources and performance characteristics. --1. Mortar bed of the Ogallala formation. Use as structural stone of ledge-forming mortar beds of the Ogallala formation was observed in Rawlins County, although the use of the stone has been in the foundations for farm buildings. In such a use, the mortar bed shows signs of deterioration because of the moist ground in contact with it which causes disintegration by slaking during the wet season and freeze-and-thaw druing the winter months.

The test characteristics of mortar bed (see table 1) indicate that it is acceptable for use as structural stone but field observation reveals that the mortar bed ledges are not uniformly hard. The appearance of finished structures built of this material may be marred by differential weathering of some of the blocks.

2. Quartzite of the Ogallala formation. Quartzite of the Ogallala formation has been quarried extensively in Rawlins County for use as structural stone. The school building at Ludell, a number of small buildings, and several bridges were constructed of this material. However, the quartzite is so hard that producing it to required size and shape is difficult.

3. Chert of the Ogallala formation. The lenses of chert in the southwestern part of the county are a potential but minor source of structural stone for that area. The rock is very hard and would be difficult to cut to the desired size and shape. No structures were observed in which chert had been used.

Calcareous binder

Engineering and geologic characteristics. --To be classified as calcareous binder the material must be composed essentially of calcium carbonate and must be soft and easily pulverized. A variety of geologic materials is included in this classification. One local stratigraphic unit is a source or potential source of calcareous binder.

Stratigraphic source and performance characteristics. --Mortar bed of the Ogallala formation has been accepted as calcareous binder by the State Highway Commission of Kansas, and this rock in Rawlins County is thought to be suitable for this use. The more desirable ledges are those which contain only a small percentage of sand or gravel.

REFERENCE CITED

American Association State Highway Officials, 1947, Standard speicfications for highway materials and methods of sampling and testing, pt. 2, 5th ed. Contains: Absorption, pp. 251-252; Compressive strength, pp. 257-258; Deval abrasion, pp. 235-236; Liquid limit, pp. 198-201; Los Angeles abrasion, pp. 237-239; Plasticity index, pp. 202-204; Specific gravity, pp. 249-250; Toughness, pp. 240-241; Weight per cubic foot, pp. 253-254.

Congressional documents, 1944, Missouri River basin, conservation, control, and use of water resources: 78th Cong., 2d sess., S. Doc. 191.

Flora, S. D., 1948, The climate of Kansas: Kansas State Bd. Agri., vol. 67, No. 285, 320 pp.

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

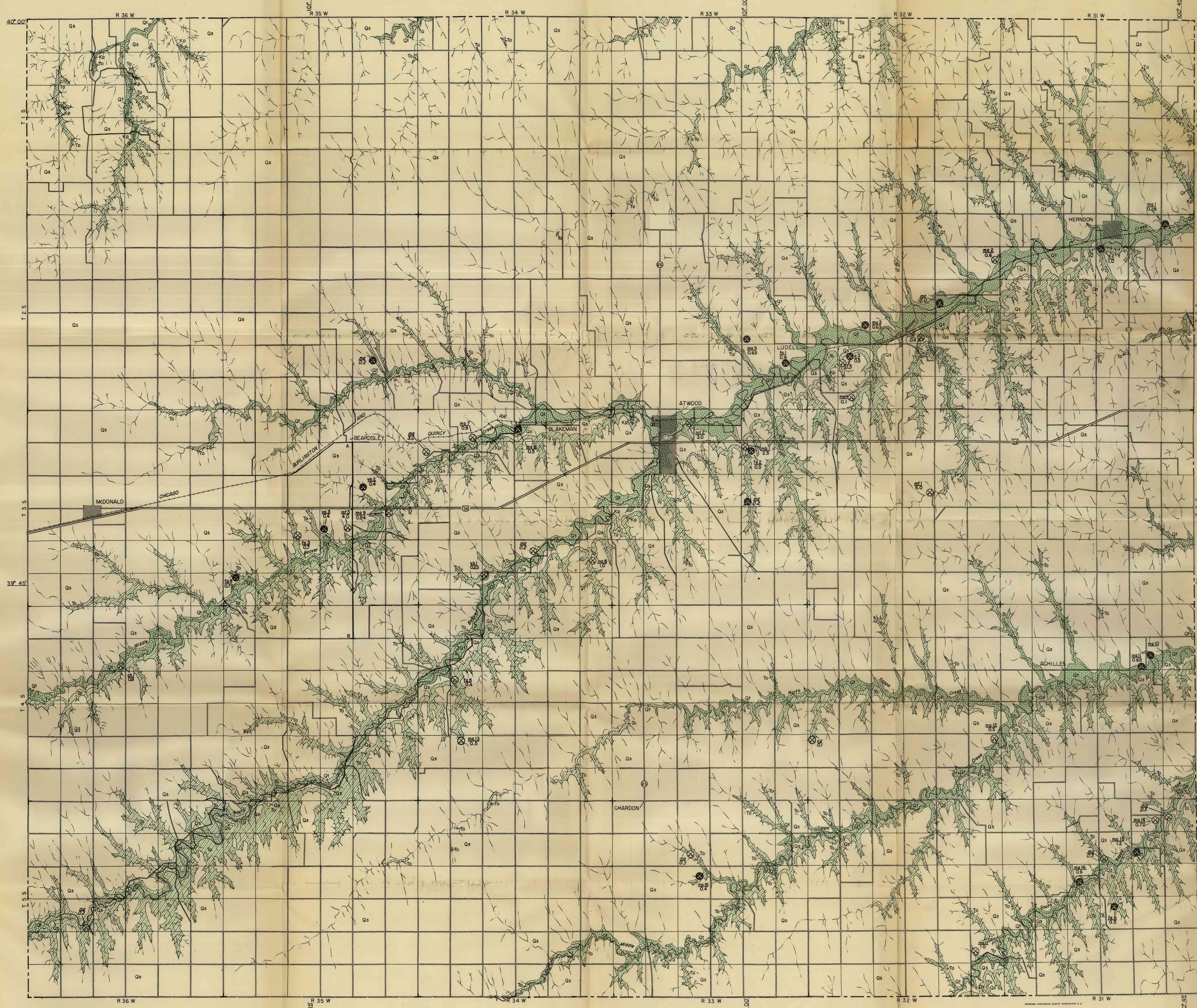
Kansas State Highway Commission, 1945, Standard specifications for State road and bridge construction. Contains: Gradation factor, p. 16; Sieve analysis, pp. 333-334; Soundness, pp. 335-336.

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

U. S. Weather Bureau, 1938-47, Climatological data, Kansas sec.: Dept. Agri., vols. 24-26; Dept. Comm., vols. 27-33.

Wilmarth, M. G., 1938, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pts. 1 and 2, 2,396 pp.

INT.-DUP. SEC., WASH., D.C.2523



MAP SHOWING CONSTRUCTION MATERIALS AND GEOLOGY OF RAWLINS COUNTY, KANSAS

Scale

0 1 2 3 4 miles

1951

Base map prepared by
State Highway Commission of Kansas
Drafted by V.L. Stallbaumer and H.M. Lay,
U. S. Geological Survey

Geology by H. V. Beck and Robert K. McCormack

MAP SHOWING CONSTRUCTION MATERIALS AND GEOLOGY OF RAWLINS COUNTY, KANSAS 1951

EXPLANATION

QUATERNARY — Pleistocene and Recent

Qt — Terrace deposit
Light-colored clayey silt; lenses of sand and gravel in basal part. Source or potential source of: aggregate, road metal, mineral filler.

Qs — Sanborn formation
Upper part tan-gray clayey silt; lower part silt with interbedded lenses of sand, gravel, and volcanic ash; tends to stand in vertical banks; fossil snails common. Source or potential source of: mineral filler, aggregate, road metal, volcanic ash.

TERTIARY — Pliocene

To — Ogallala formation
Interbedded lenses of sand, gravel, silt, and clay; varicolored some thick lenses of red-black clay shale; lenticular beds of mortar bed, quartzite, opal, hard limestone, and volcanic ash in some places. Source or potential source of: aggregate, road metal, riprap, structural stone, volcanic ash, calcareous binder.

CRETACEOUS — Cretaceous

Kp — Pierre shale
Thin-bedded dark-colored silt and clay shales; thin lenses of limestone and thin beds of bentonite; veins of crystalline gypsum.

Geologic contact

Operated pit or quarry

Prospect pit or quarry

fa
Fine aggregate

ma
Mixed aggregate

mf
Mineral filler

va
Volcanic ash

ch
Chert

q
Quartzite

mb
Mortar bed

ma
Inclined letters indicate materials not tested

ma l
Vertical letters indicate materials listed in table l and their sample numbers.

1.0
Quantity of materials available (in units of 10,000 cubic yards)

36
Federal (U S) highway

23
State highway

Other roads, all classes

Railroad

City

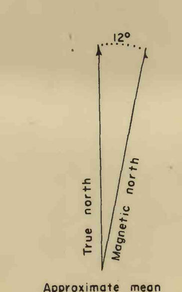
Section line

Township corners

Stream, permanent

Stream, intermittent

A B
Line of cross section, figure 5 (along line between secs. 10 and 11, T. 3S., R. 35W., and secs. 2 and 3, T. 4S., R. 35W.)



Approximate mean declination, 1951

Table 1. Summary of material tests

(Blank spaces indicate data not available)

Classification of the material	Number on plate 1	Location: 1/4 fraction	Location: 1/4 fraction	Location: Section	Location: Township (S)	Location: Range (W)	Estimated quantity of material (cubic yards)	Average thickness: Material (feet)	Average thickness: Overburden (feet)	Accessibility	Geologic formation	Authority for test data[1]	Date of test	Sieve analysis: Percent on 3/4 inch	Percent on 3/8 inch	Percent on No. 4	Percent on No. 16	Percent on No. 100	Percent passed No. 200 (wash)	Description of the material[2]: Fraction	Granite	Quartz	Feldspar	Acid igneous rock	Basic igneous rock	Quartzite	Chert, opal, and chalcedony	Sandstone	Mortar bed	Shale and clay	Laboratory test data: Weight per cubic foot (dry)	Specific Gravity (dry)	Gradation factor	Compressive strength ratio: 1 day	Compressive strength ratio: 3 days	Los Angeles percent loss	Soundness[3] (25 cycles)	Toughness	Cementation	Absorption	Color	Laboratory No.	Remarks
Fine aggregate	fa 1	NW	SE	25	2	33	9,000	9	3	Fair	Sanborn	SHCK	1946	0	0	1	15	92	5.8	C	55				15				30		108.4	2.58	2.29	1.09	1.10	31.5	0.91				Light Straw	509645	Acceptable under Secs. 105, 108, 109, 110, and 112, Kans. Highway Stand. Spec. (ed. 1945).
																				F	20	60	15					Tr	5														
	fa 2	C	NW	11	3	33	5,000	12	2	Fair	Ogallala	USGS	1949	0	0	2	39	94	1.90	C	90				5	5	Tr				114.4	2.60	2.79	1.37	1.36	30.0	0.94				Clear	64745	Overburden well compacted.
																				F	30	55	10		5	Tr	Tr																
	fa 3	SE	SW	21	3	35	7,000	9	6	Poor	Ogallala	SHCK	1946	0	1	2	16	83	10.0	C	85			5	5	5					110.8	2.56	2.09	1.06	0.97	31.3	0.97				Light Straw	50953	Acceptable under Secs. 105, 106, 108, 109, 110, and 112, Kans. Highway Stand. Spec. (ed. 1945).
																				F	15	70	10	5	Tr	Tr																	
	fa 4	NE	NW	31	3	35	7,500	15	5	Fair	Ogallala	SHCK	1942	0	1	2	29	92	4.5	C	80			2	10	5	2	1			112.0	2.62	2.81	1.26	1.02	29.1	1.00		15		Clear	44487	Acceptable under Secs. 65, 67, 69, 71, 73, and 75, Kans. Highway Stand. Spec. (ed. 1937).
																				F	30	40	20		5	5																	
	fa 5	SW	NW	17	4	34	4,000	6	1	Fair	Terrace deposit	SHCK	1942	0	1	3	39	96	3.2	C	70				5	5			20		108.0	2.60	3.15	1.19	1.05	28.1	0.90				Straw	44484	Acceptable under Secs. 65, 67, 69, 71, 73, and 75, Kans. Highway Stand. Spec. (ed. 1937).
																				F	25	45	10		Tr	Tr			20														
	fa 6	SE	NW	22	5	31	5,000	5	4	Fair	Ogallala	USGS	1949	0	1	4	31	97	0.83	C											110.5	2.61	2.88	1.30	1.22						Light Straw	64638	Overburden is poorly cemented silt and fine sand.
																				F																							
Mixed aggregate	ma 1	SW	NW	1	2	31	2,800	6	3	Good	Sanborn	SHCK	1946	0	2	10	52	95	4.2	C	70				5	10	5		10	Tr	115.8	2.56	3.54	1.41	1.38	33.0	0.90				Straw	51129	Acceptable under Secs. 105, 106, 109, 110, and 112, Kans. Highway Stand. Spec. (ed. 1945).
																				F	15	60	20			5			Tr	Tr													
	ma 2	NE	SE	12	2	32	6,000	6	3	Good	Sanborn	SHCK	1942	0	2	7	44	98	1.7	C	80					5			15		111.0	2.60	3.40	1.25	1.33	30.0	0.94				Light Straw	44481	Acceptable under Secs. 65, 67, 69, 71, 73, and 75, Kans. Highway Stand. Spec. (ed. 1937).
																				F	25	50	15		Tr.	5			5														
	ma 3	NE	SE	20	2	32	6,300	9	4	Good	Sanborn	SHCK	1937	1	5	21	70	100	0.5	C	70				5		3		20	2	112.0	2.62		1.22	1.16						Light Straw	36837	Acceptable under Sec. 57, Kans. Highway Stand. Spec. (ed. 1934) and Sec. 23 of Supplement.
																				F	15	50	25		Tr				10														
	ma 4	NW	SE	32	2	32	1,000	6	4	Fair	Sanborn	SHCK	1946	0	2	7	35	88	9.6	C	75			5	5	5	5		5		111.4	2.55	2.90	1.12	1.15	31.2	0.88				Light Straw	50952	Acceptable under Secs. 105, 108, 109, 110, and 112, Kans. Highway Stand. Spec. (ed. 1945).
																				F	30	40	20			Tr			10														
	ma 5	SW	SW	23	2	33	6,300	9	4	Good	Sanborn	USGS	1949	1	3	14	54	92	5.88	C	75		10			3			10	2	111.1	2.54	3.54	1.37	1.42	28.2	0.90				Clear	64746	
																				F	40	35	15			5			5														
	ma 6	NW	SW	3	3	34	5,000	6	2	Good	Sanborn	USGS	1949	2	8	15	38	97	2.63	C	50				5	10	Tr		35		107.0	2.56	3.37	1.31	1.30	26.6	0.93				Clear	64778	Compact overburden; some gravel in basal part.
																				F	20	60	10				Tr		10	Tr													
	ma 7	SW	SE	5	3	34	9,000	9	4	Fair	Sanborn	SHCK	1942	4	7	12	45	98		C	45		1			5	2	2	45		111.0	2.60	3.60	1.69	1.26	29.8	0.99					44486	Acceptable under Secs. 65, 67, 69, 71, 73, and 75, Kans. Highway Stand. Spec. (ed. 1937).
																				F	25	50	15			Tr			10														
	ma 8	NE	SW	25	3	34	10,000	9	6	Poor	Ogallala	SHCK	1942	0	4	8	38	89	9.2	C	55				5	Tr			40		106.0	2.60	3.03	0.91	0.83	29.6	0.88				Straw	44486	Acceptable under Secs. 69, 73, and 75, Kans. Highway Stand. Spec. (ed. 1937).
																				F	30	35	5		Tr	5			25														
	ma 9	NW	NW	24	3	35	5,000	9	5	Good	Sanborn	SHCK	1938						1.7	C	55	10		Tr	5	10	Tr		20		112.0	2.55		1.07	1.01						Straw	34768	Acceptable under Sec. 67, Kans. Highway Stand. Spec. (ed. 1937).
																				F	40	45	10	Tr	Tr	5	Tr	Tr	Tr														
	ma 10	NW	SE	11	4	31				Fair	Sanborn	SHCK	1942							C	45		3		2	5	Tr		35	10												44483	Overburden too thick for further production.
																				F	20	55	10						5	10													
	ma 11	SE	SW	11	4	31	6,500	9	5	Good	Sanborn	USGS	1949	0	2	6	26	96	2.61	C	40	10				Tr			20	30	106.3	2.60	2.78	1.33	1.34						Clear	64779	Overburden is silt with some sand and clay.
																				F	10	60	15			Tr			5	10													
	ma 12	NE	NE	25	4	32	5,000	6	1	Fair	Sanborn	USGS	1949	0	2	8	48	98	1.15	C	90				2	3			5		108.0	2.59	3.50	1.27	1.38	31.8	0.97				Clear	64640	Overburden is clayey silt with some sand in basal part.
																				F	10	70	15	Tr	5																		
	ma 13	SE	NW	29	4	34	5,000	6	3	Fair	Ogallala	USGS	1949	0	4	12	51	98	1.09	C	80				20	Tr					112.0	2.60	3.54	1.50	1.40	28.4	0.95				Clear	64727	Overburden is clayey silt with some sand in basal part.
																				F	30	50	15	Tr	5																		
	ma 14	NE	SE	2	5	31	7,200	9	2	Good	Sanborn	USGS	1949	5	9	16	49	95	3.75	C	90				Tr	5			5		110.5	2.58	3.62	1.00	1.09	28.0	0.95				Straw	64726	Overburden is silt which contains some mortar-bed fragments.
																				F	30	50	20		Tr																		
	ma 15	NW	SW	11	5	31	12,000	9	3	Good	Sanborn	USGS	1949	0	5	18	82	94	4.82	C	50			2	3	5	Tr		40		102.4	2.56	4.29	1.61	1.61	30.4	0.92				Clear	64637	Overburden is calcareous silt.
																				F	25	45	15	Tr	2	3			10														
	ma 16	SE	NW	16	5	31	6,000	6.	3	Good	Sanborn	USGS	1949							C	75		3	2	10	Tr			10														
																				F	40	45	10	2	Tr	3																	
	ma 17	NW	SW	25	5	32	10,000	9	1	Fair	Ogallala	USGS	1949	1	5	14	63	97	2.71	C	85				5	10					106.2	2.56	3.96	1.70	1.63	30.6	0.98				Clear	64639	Overburden is silt with some sand and gravel.
																				F	40	50	5			5																	
	ma 18	SW	NE	16	5	33	4,000	9	7	Poor	Ogallala	SHCK	1942	0	7	12	44	85	13.5	C	65		5	Tr	10	Tr			20		112.0	2.62	3.15			29.8	0.97				Light Straw		Acceptable under Secs. 65, 67, 69, 71, 73, and 75, Kans. Highway Stand. Spec. (ed. 1937).
																				F	35	45	10	Tr	10	Tr	Tr																
Mineral filler	mf 1	NE	SE	15	3	32	60,000	9		Good	Sanborn	USGS	1949				0	1	99												77								100+				Liquid limit = 32; plasticity index = 9.
	mf 2	SE	NW	4	3	33	30,000	6		Good	Terrace deposit	USGS	1949				0	3	94												82								100+				Liquid limit = 30; plasticity index = 8.
	mf 3	NE	SE	22	3	33	40,000	12		Good	Sanborn	USGS	1949					0	99												75								100+				Liquid limit = 36; plasticity index = 14.
Volcanic ash	va 1	NW	NW	33	3	34	2,500	6	3	Good	Ogallala	USGS	1949			0	4	29	52	Volcanic ash impregnated with some calcium carbonate in upper part.											60.5	2.46							3				Overburden is sand and gravel.
	va 2	SE	NW	14	3	35	4,000	12	5	Fair	Sanborn	SHCK	1941			0	1	6	81.3																				1				Overburden is silt and clay with some sand in basal part.
	va 3	NW	SW	22	3	35	4,000	9	5	Poor	Sanborn	SHCK	1946				0	3	82												62.61	2.38							1				Acceptable as mineral filler under Secs. 108 and 109, Kans. Highway Stand. Spec. (ed. 1945).
Chert	ch 1	SE	SE	9	4	36	8,000	4	3	Good	Ogallala	USGS	1949							Opal, tough and brittle; yellowish-gray and white.												2.05				34.8	0.83			3.76			
Quartzite	q 1	SW	SW	3	2	31	10,000	5	3	Good	Ogallala	SHCK	1946							Conglomerate, silica-cemented; light-green.											144.1	2.32				48.8	0.93	7		1.72			
	q 2	NW	NW	10	2	31	10,000	5	3	Good	Ogallala	SHCK	1938							Sandstone, silica-cemented; light-green.											147.88	2.37					OK	6		1.79			
	q 3	SE	NW	29	2	32	5,000	5	2	Fair	Ogallala	SHCK	1946							Conglomeratic sandstone, silica-cemented; light-green.											149.1	2.37				39.9	OK	10		1.49			
Mortar bed	mb 1	NW	NW	11	3	33	25,000	9	2	Good	Ogallala	USGS	1949							Siliceous particles cemented with calcium carbonate.												2.05				88.6	0.57			6.43			

1. SHCK, State Highway Commission of Kansas: sieve analysis and laboratory tests. USGS, U. S. Geological Survey: sample collection and description of material.
2. C, coarse fraction, retained on no. 4 sieve; F, fine fraction, passed through no. 4 sieve; Tr, trace.
3. Loss ratio.