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CONSTRUCTION MATERIALS IN GRAHAM 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 a State-wide inventory of construction materials. A field party composed of personnel from the two cooperating agencies investigated sources of engineering construction materials in Graham County, Kans., in the summer of 1947. This report of the Graham County investigation is a part of the general inventory and a contribution to the geologic-mapping and mineral-resource investigations being made in connection with the studies of the Missouri River Basin. 1/

The primary objective of the investigation was that of accumulating all field and laboratory data pertaining to the geologic materials in Graham County that would be of use in the construction of dams, irrigation canals, highways, 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.

Area covered by the investigation

Graham County is in the second tier of Kansas counties south of the Nebraska border and in the fourth tier east of Colorado. (See fig. 1.) It comprises 25 townships and covers an area of about 900 square miles. The county is bounded by parallels 39°08' and 39°34' north latitude and meridians 99°36'30" and 100°10' west longitude. It is bounded on the north by Norton County, on the east by Rooks County, on the south by Trego County, and on the west by Sheridan County.

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

Geography of the area

Topography.--Graham County is in the Plains Border section of the Great Plains physiographic province. 2/ The surface drainage is to the east, and for that reason the eastern part of the county is somewhat more dissected than the western part. The interstream areas are usually flat or gently rounded; they are sharp-crested only along the valleys of the major streams. The valleys of the principal streams and their larger tributaries are cut 175 feet below the general upland level. The upland surface is highest along the western border of the county, in places rising slightly more than 2,500 feet above sea level. The lowest point in the county, at an altitude of about 1,980 feet, is in the valley of the South Fork Solomon River at the eastern boundary of the county.

Drainage.--The principal streams in Graham County are the South Fork Solomon River, the North Fork Saline River, and Bow Creek. (See pl. 1.) The southward-flowing tributaries to these streams are more numerous but appreciably shorter than the northward-flowing tributaries.

Climate.--Graham 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 53.9° F., and the mean daily temperature ranges from a low of

[2] Frye, J. C., The High Plains surface in Kansas: Kansas Acad. Sci. Trans., vol. 49, no. 1, pp. 81-82, June 1946.

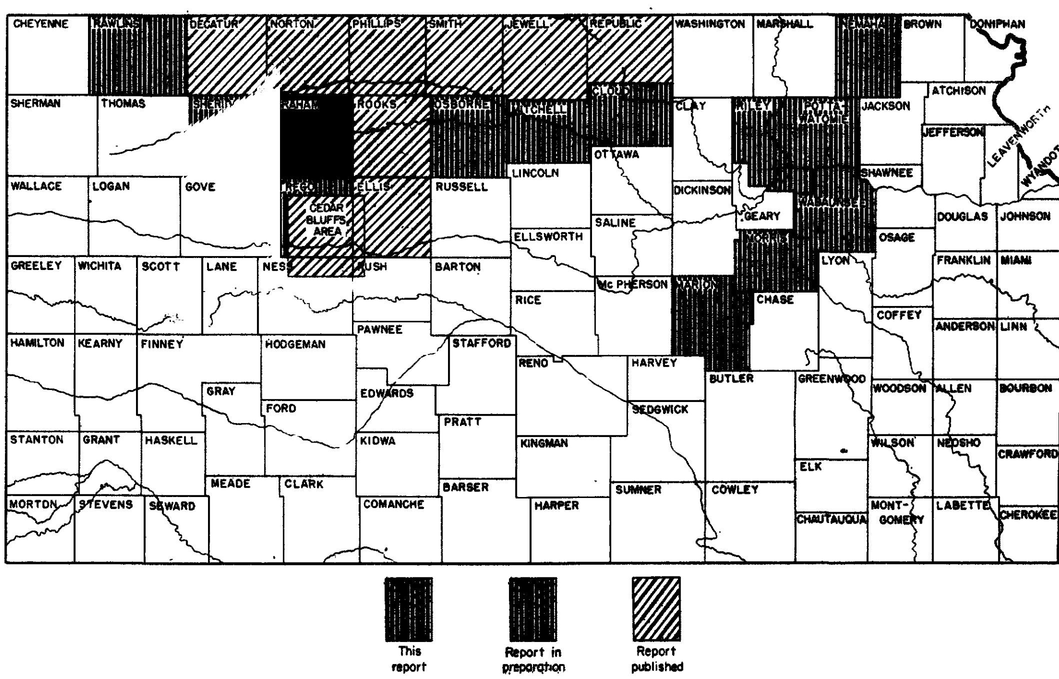


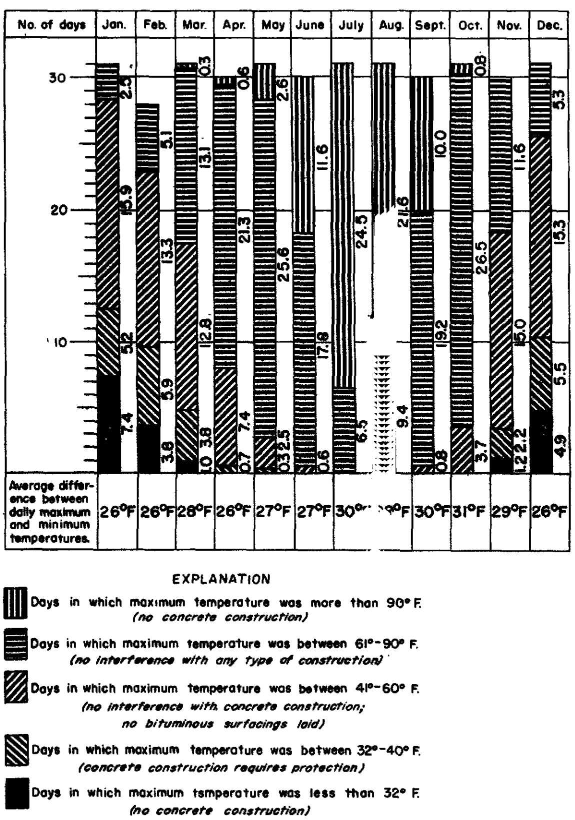
Figure 1.—Index map of Kansas showing areas covered by this report and by other construction materials investigations

28.5° F. in January to a high of 79° F. in July. There are 40 cloudy days a year, 100 partly cloudy days, and 225 clear days. The ground is snow-covered 31 days of the year. The normal annual precipitation is 20.55 inches. The average date of the first killing frost in the fall is October 12, and that of the last killing frost in the spring is April 30. 3/

Figure 2, a chart showing temperature ranges at Hill City, Kans., was compiled from Climatological Data 4/ 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 March, inclusive, with the maximum incidence of 7.4 days in January. July is the warmest month of the year, with an average of 24.5 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, 31.11° F., is in October; and the least difference, 25.61° 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 Hill City, Kans., is presented to show the effect of this climatic factor. The ranges in precipitation were selected arbitrarily.



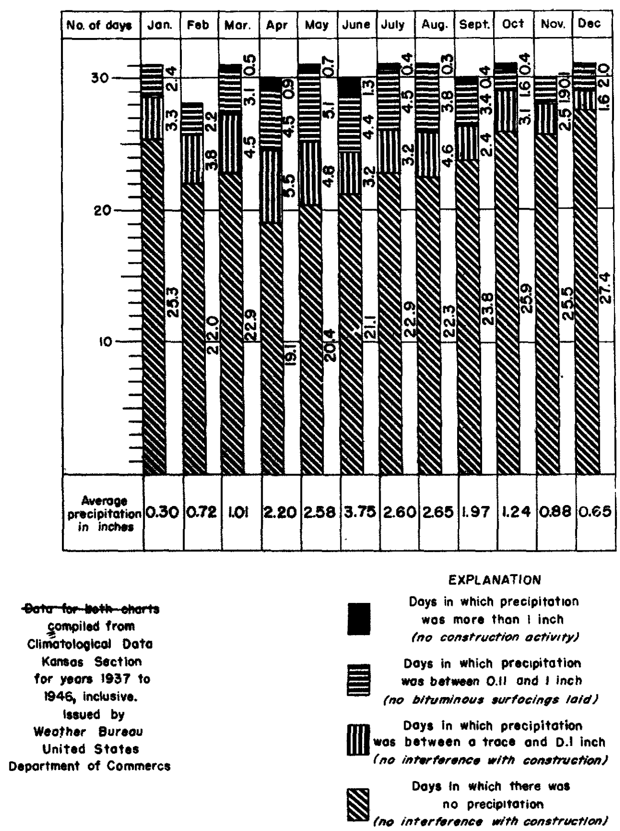


Figure 2.—Chart showing temperature ranges at Hill City, Kansas. Figure 3.—Chart showing precipitation ranges at Hill City, Kansas.

3 Flora, S. D., The climate of Kansas: Kansas State Board of Agriculture, Rept., vol. 67, no. 285, 320 pp., 1948.
4 U. S. Dept. Commerce, Weather Bur. Climatological Data (Kansas section)

As based on a 10-year average, 5/ there are 21.1 days in June, for example, in which no measurable precipitation fell; 3.2 days in which the precipitation ranged from a trace to 0.1 inch; 4.4 days in which 0.11 to 1 inch of rain fell; and 1.3 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.

Transportation routes.--Graham County is served by one railroad, a branch line of the Union Pacific; two transcontinental highways (U. S. 24 and U. S. 283); and one highway (18). The Federal highways are of the black-top type of construction, and the State highway is a metaled, all-weather road. 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 the roads and the railroad are shown on plate 1.

Investigation procedure

This report is based on field work of the reconnaissance type. The original base map was compiled at a scale of 1 inch equals 2 miles by the Soil Conservation Service of the United States Department of Agriculture from large-scale aerial photographs. This base map was enlarged photographically to a scale of 1 inch equals 1 mile. The areal distribution of the stratigraphic units that crop out in Graham County was then mapped in the field on the enlarged base map. The mapped units are those recognized by the United States Geological Survey 6/ and the Kansas Geological Survey. 7/ 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 material tests.

Acknowledgments

Generous assistance in the compilation of construction-materials data by the following is appreciated: R. D. Finney, engineer of materials, and his associates in the State Highway Commission at Topeka and Manhattan Kans.; and the district office of the Corps of Engineers, United States Army, at Kansas City, Mo. The State Geological Survey at Lawrence, Kans., J. C. Frye, executive director, made available its information on quartzites in Graham and surrounding counties.

This report, in manuscript form, was reviewed critically by S. E. Horner, chief geologist of the State Highway Commission and the United States Geological Survey.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

General

This discussion of the geologic formations that crop out in Graham County emphasizes the areal distribution, the general characteristics, and the thickness of each stratigraphic unit. This part of the report presents the geological information required for the location and the effective development of the construction materials.

A summary of the data for each mapped unit is presented in figure 4, and the relations of the stratigraphic units to one another are illustrated on figure 5, a geologic cross section of the South Fork Solomon River Valley.

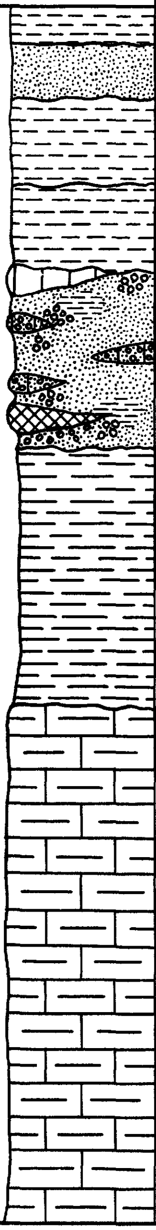
The areal distribution of the local stratigraphic units is shown on plate 1, a map showing construction materials and geology of Graham County, Kans. Each unit is indicated by an identifying symbol, and its outcrop areas are shown by a distinctive pattern.

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 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 northeastermost 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 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.

[5] Idem.

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

[7] 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.



Section	Outcrop thickness (feet)	Stratigraphic units: System	Series	Formations and members	Generalized description	Construction materials
	0-20	Quaternary	Pleistocene and Recent	Alluvium	Lenses of silt, sand, and gravel; silt predominant in upper part only.	Aggregate Road metal
	0-30	Quaternary	Pleistocene and Recent	Dune sand	Brownish-tan, cross-bedded fine sand; local extent only.	Aggregate Road metal
	0-50	Quaternary	Pleistocene and Recent	Terrace deposits	Predominantly reddish-brown silts; lenses of sand and gravel in basal part; tends to stand in vertical banks; often buried soil in upper part.	Aggregate Road metal Mineral filler
	0-50	Quaternary	Pleistocene and Recent	Sanborn formation	Upper part, gray and yellow-brown silt locally with a prominent buried soil zone; tends to stand in vertical banks; fossil gastropods common. Lenses of sand and gravel in lower part.	Aggregate Road metal Mineral filler Volcanic ash
	0-100	Tertiary	Pliocene	Ogallala formation	Lenses of vari-colored silt, clay, and cross-bedded sands and gravels; numerous lenticular beds of hard, green or chocolate-brown quartzite; lenses of soft or hard gray mortar bed; local lenses of hard, dense limestone in upper part.	Aggregate Road metal Riprap Structural stone Calcareous binder
	0-150	Cretaceous	Upper Cretaceous	Pierre shale	Blue-gray clay shales interbedded with thin beds of bentonite; small selenite crystals occur locally.	
	0-300	Cretaceous	Upper Cretaceous	Niobrara formation: Smoky Hill chalk member	Thick beds of gray, orange-gray, and yellow shales interbedded with thin beds of chalky limestone and very thin beds of bentonite or bentonitic shale. Silicified zones in upper part. Abundant fossil shells of clams and oysters.	Road metal Riprap Structural stone Calcareous binder

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

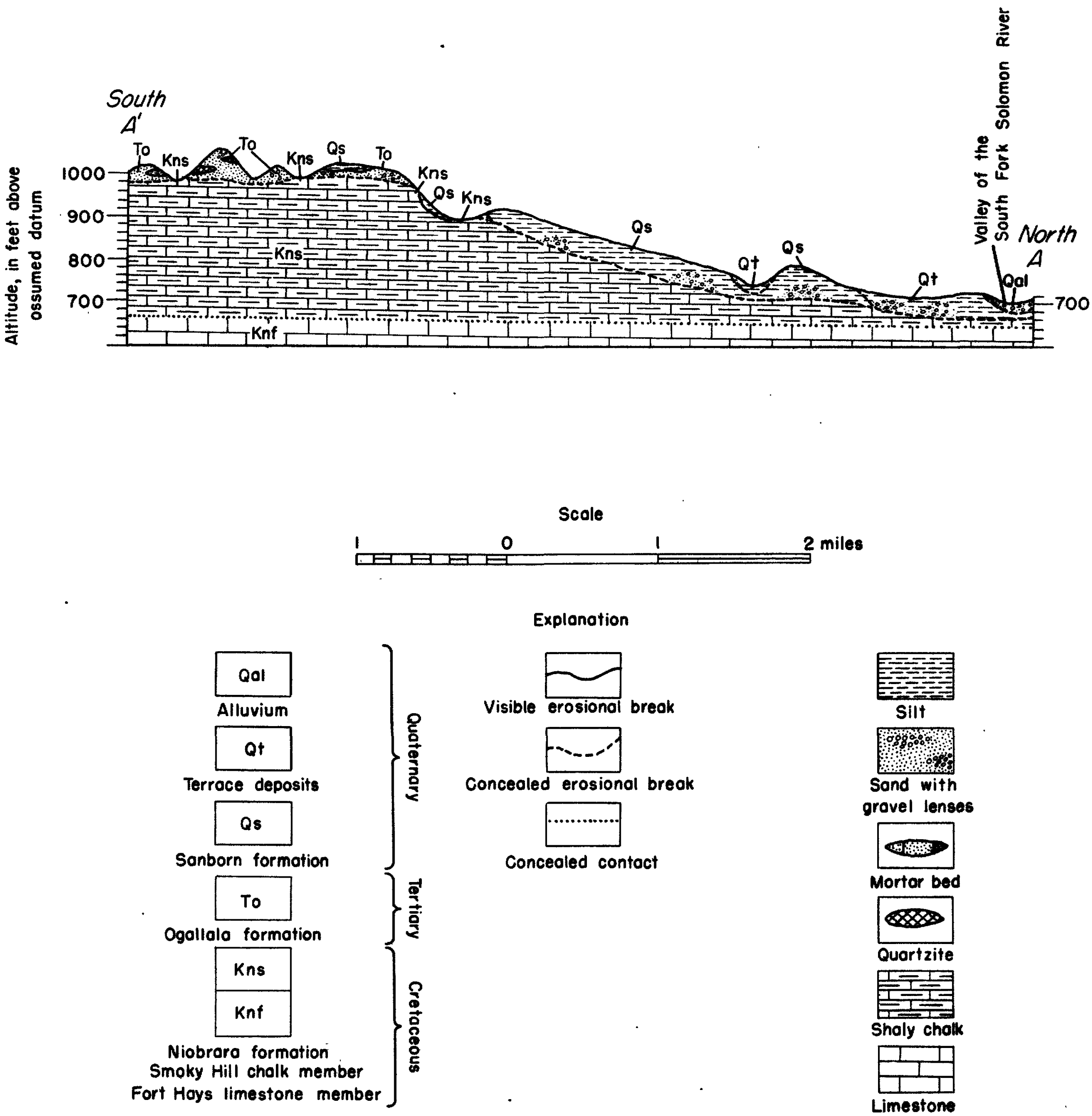


Figure 5.—Geologic cross section of the South Fork Solomon River along the line from intersection of secs. 23 and 24, T. 8 S., R. 23 W., to intersection of secs. 13 and 14 T. 9 S., R. 23 W.

Smoky Hill chalk member of the Niobrara formation

Areal distribution. --The Smoky Hill chalk member of the Niobrara formation of Upper Cretaceous age is the oldest stratigraphic unit cropping out in Graham County. (See pl. 1 and fig. 4.) The lower member of the Niobrara formation, the Fort Hays limestone, underlies the Smoky Hill chalk member throughout the area of the county but is not exposed at the surface. The Smoky Hill chalk crops out principally along the valley walls of the South Fork Solomon River, the North Fork Saline River, and their tributaries. The member is covered by younger stratigraphic units in the divide areas of the county. No outcrops of the Smoky Hill chalk were found in the northwest part of the county, although it probably is present in the valley of Bow Creek beneath a thin cover of Quaternary terrace deposits. The chalk is overlain by the Pierre shale but is separated from all younger stratigraphic units by a pronounced intervening erosional break (an unconformity). (See fig. 5.)

General description. -- The Smoky Hill chalk member of the Niobrara formation consists of thick beds of chalky shale interbedded with relatively thin beds of chalky limestone and very thin layers of bentonite. The member is blue gray and light gray in the eastern part of the county but is orange gray in the western part. Along the western border of the county it is bright yellow.

The thin layers of bentonite, which average only 0.1 foot in thickness, appear to be persistent over considerable distances. The bentonites are white on unweathered surfaces but weather to yellow brown.

The beds of chalky limestone interbedded with the chalky shales are of the same color as the shale zones in which they occur. The limestones are soft, massive, and generally less than a foot thick.

In the vicinity both of Penokee and of Morland the uppermost chalk beds in the Smoky Hill member have been silicified through the action of percolating subsurface waters. The silicified beds are olive green and are composed of dense, hard, brittle opaline material. A typical exposure of the silicified chalk occurs in a road ditch along U. S. 24 in the NE¼NE¼ sec. 15, T. 8.S., R. 24 W. The quartzite beds in the Ogallala formation are quite numerous in this this area (see pp. 7 and 8), and ground waters heavily charged with dissolved silica probably replaced the calcium carbonate of the Smoky Hill chalk with silica. Frye and Swineford 8/ suggest that the silica may have been dissolved in a stratigraphically higher beds of volcanic ash.

Fossil shells of invertebrates and fragments of the fossilized skeletons of vertebrates have been reported from the Smoky Hill chalk. The numerous fossil shells are those of clams and oysters.

[8] Frye, J. C., and Swineford, Ada, Silicified rock in the Ogallala formation: Kansas Geol. Survey Bull. 64, pt. 2, p. 57, 1946.

The Smoky Hill chalk member of the Niobrara and the overlying Pierre shale dip generally at a low angle toward the northwest, and the older Cretaceous formations in the subsurface of Graham County probably dip in the same direction. Local, minor variations in the secondary structure of the Smoky Hill chalk were noted but are not mapped on plate 1 because they do not affect the availability of construction materials. There is a high-angle reverse fault exposed in the west valley wall of a small stream in the SE¼SE¼ sec. 29, T. 8 S., R. 25 W. The fault plane dips toward the south at an angle of about 75° from the horizontal, and the south block is upthrown about 10 feet.

Beds of the Smoky Hill chalk member in the SW¼SE¼ sec. 11, T. 8 S., R. 25 W., dip about 20° E., whereas a mile east, in the SW¼SE¼ sec. 12, T. 8 S., R. 25 W., the dip is about 15° W., an angle appreciably greater than the regional dip. A small fault was noted in the cut bank in which the representative measured section of the Smoky Hill chalk is displayed.

Representative measured section. --The following section of the Smoky Hill chalk member of the Niobrara formation was measured in the NW¼SW¼ sec. 15, T. 10 S., R. 22 W., in a cut bank of a tributary to the North Fork Saline River:

	Feet
Smoky Hill chalk member of the Niobrara formation:	
Chalk; light gray, weathers buff. Fossiliferous	0.2
Shale, chalky; light gray, weathers buff; limonite-stained. Fossiliferous	2.4
Chalk, soft, massive; bluish gray, weathers light gray. Fossiliferous	1.0
Shale, chalky; stains and stringers of limonite; light gray, weathers buff. Fossiliferous	1.1
Chalk, soft; bluish gray, weathers light gray	.1
Shale, chalky; dark brown, weathers blue gray. Fossiliferous	1.0
Chalk, soft; bluish gray, weathers light gray	.2
Shale, chalky, limonite-stained; bluish gray, weathers light gray. Fossiliferous	3.0
Chalk; bluish gray, weathers light gray	.1
Shale, chalky; 0.5- to 5-inch bentonitic concretions scattered throughout; bluish gray, weathers light gray. Fossiliferous	32.0
Base covered	41.1

Thickness. --Individual outcrops of the Smoky Hill chalk member are relatively thin, the probable maximum thickness being about 50 feet and the average thickness about 15 feet. Outcrops generally are appreciably thicker in the eastern part of the county than they are in the western part. Estimates based on the width of outcrop and the regional dip of this member toward the west and northwest place its total thickness in Graham County at about 300 feet.

Construction materials. --

Road metal.
Structural stone.
Riprap.
Calcareous binder.

Pierre shale

Areal distribution. --Four outcrops of the Pierre shale of Upper Cretaceous age were found by the field party in Graham County. (See pl. 1 and fig. 4.) The largest of these is in secs. 28, 29, and 32, T. 8 S., R. 25 W., where the formation is exposed in the valley wall of a northward-flowing tributary of the South Fork Solomon River. A second outcrop was examined in the NE¼SE¼ sec. 15, T. 8 S., R. 25 W., in a cut bank along the Solomon River. There is a small outcrop of the Pierre shale in the SE¼SW¼ sec. 18, T. 9 S., R. 23 W., in the valley of a small northward-flowing tributary of the South Fork Solomon River. The fourth outcrop was found in the SE¼NW¼ sec. 9, T. 8 S., R. 25 W., in a cut bank just above the water level of Antelope Lake.

The Pierre shale is the youngest sedimentary rock of marine origin in Graham County. It overlies the Smoky Hill chalk member of the Niobrara formation but is separated from all younger stratigraphic units by a pronounced erosional break. Undoubtedly the Pierre shale is extensive in the interstream areas of Graham County but is concealed by the younger Ogallala and Sanborn formations.

General description. --Only the basal part of the Pierre shale crops out in the county. The shale generally is very thin bedded, is composed predominantly of clay-size particles, is noncalcareous, and has a soapy feel. Most of the shale zones are blue gray or blue black, but thin beds of white or brown bentonite are interbedded with the clay shales. The bentonitic zones increase in thickness in the upper part of the Pierre shale in Graham County, the maximum thickness observed being about 6 feet (in the SE¼SW¼ sec. 18, T. 9 S., R. 23 W.). The bentonite is white on fresh surfaces but weathers brown. Small crystals of a variety of gypsum (selenite) occur locally in some zones of the clay shales. Limonite also is present in the shale zones.

Representative measured sections. --

(1) The following section of the Pierre shale is exposed in a cut bank of a tributary to the South Fork Solomon River in the SW¼NE¼ sec. 32, T. 8 S., R. 25 W.:

	Feet
Sanborn formation: Silt and sand	5.9
Pierre shale:	
Shale, bentonitic; buff with irregular gray stringers throughout; weathers yellow	7.0
Bentonite, white	.1
Shale, bentonitic, yellow brown	.3
Bentonite, white	.2
Shale, bentonitic, fairly compact; buff, weathers yellow	3.5
Bentonite; buff with white stringers in upper and lower parts	.2
Shale, bentonitic, quite compact; buff, weathers yellow	1.5
Bentonite, brown	.3
Shale, clay, noncalcareous; black, weathers light blue gray	4.0
Base covered.	17.1

(2) Another exposure of the Pierre shale was measured in a cut bank in the NE¼SW¼ sec. 15, T. 8 S., R. 25 W., as follows:

	Feet
Terrace deposits: Silt, sand, and gravel	30.0±
Pierre shale:	
Shale, very thin bedded; dark brown, weathers light brown	.5
Shale; some sandy zones and small selenite crystals; very thin bedded; black, weathers dark gray	3.0
Bentonite; yellow brown, weathers grayish white	.1
Shale, noncalcareous, very thin bedded; weathers light gray	6.0
Shale, very thin bedded; black, weathers light gray; limonite-stained	3.5
Shale, very thin bedded; black, weathers light gray	5.0
Base covered.	18.1

Thickness. --The total thickness of the Pierre shale in Graham County may be more than 150 feet, but the greatest thickness of any of the outcrops observed is about 18 feet. The formation undoubtedly is thickest in the interstream areas, especially those along the western border of the county.

Construction materials. --No materials of general use in engineering construction are found in the part of the Pierre shale that crops out in Graham County. The bentonitic beds in the formation might be used in sealing earthen structures against water percolation, but tests made by the State Geological Survey of Kansas 9/ indicate that the bentonites of Kansas do not swell as much when water-saturated (3 times the original volume) as do bentonites from Wyoming (15 times the original volume).

Ogallala formation

Areal distribution. --The Ogallala formation of Pliocene age crops out in all parts of Graham County. (See pl. 1 and fig. 4.) The outcrops generally are restricted to the valleys of tributary streams and the valley walls of the major streams. (See fig. 5.) In some places the Sanborn formation, which overlies and thus conceals the Ogallala, has been eroded completely and the Ogallala formation has been uncovered extensively, as in the outcrop area a short distance south of Hill City.

General description. --The Ogallala formation includes interbedded lenses of silt, clay, and cross-bedded sands and gravels that indicate the stream-deposited origin of much of the formation. The lenses vary in both thickness and areal extent. The bulk of the material composing the Ogallala was eroded in the Rocky Mountain area by streams that transported the material toward the east and deposited it as a sedimentary layer over the High Plains. The Ogallala sediments constitute an enormously extensive piedmont alluvial plain formed on the east flank of the Rocky Mountains during the Tertiary period. Probably some lake-deposited (lacustrine) beds are included in the formation.

The sand and gravel lenses are composed principally of fragments of quartz, granite, and feldspar and often contain clay balls 3 or 4 inches in diameter. The coarsest gravel particles are about 1.5 inches in average diameter. The sand and gravel particles are subrounded to rounded in shape, many of them coated with a film of calcium carbonate. The silt and clay particles are subangular to angular in shape and are predominantly quartz and kaolinite.

Lenticular beds of quartzite are quite numerous in the central part of Graham County and usually occur in the lower part of the Ogallala formation. Some of them were traced over distances of more than a mile, but most of them are quite local, the average extent being about 0.25 mile in any one direction. The average thickness of the quartzite is 3 to 4 feet, but some of it is as much as 12 feet thick. The ledges are far harder than the other materials composing the Ogallala formation and are exposed at the surface as very conspicuous hillside ledges. The quartzite usually is green, but some beds are tan and a few are chocolate brown. The beds consist of cross-bedded sand or gravelly sand in which the constituent particles are usually very firmly cemented by silica deposited in the original pore spaces by percolating subsurface waters.

Mortar beds constitute another rock material characteristic of the Ogallala formation. A mortar bed is a lens of lime-cemented sand or gravel, or both, and is generally less hard than the silica-cemented quartzites, although mortar beds usually form conspicuous hillside ledges. The ledges generally are light gray and weather to irregular surfaces. Their thickness ranges from 1 foot to about 5 feet.

Local beds of hard, dense, gray limestone occur near the top of the Ogallala formation in the northwestern part of Graham County. The beds are as much as 4 or 5 feet thick in some places. The limestone probably was deposited as a surface or near-surface caliche by subsurface waters heavily charged with calcium carbonate. One prospect is mapped on plate 1 in the NW¼NE¼ sec. 4, T. 6 S., R. 25 W.

Representative measured sections. --

(1) A road cut in the NE¼NE¼ sec. 32, T. 7 S., R. 24 W., shows the following section of the Ogallala formation:

	Feet
Ogallala formation:	
Mortar bed, fine, sandy, fairly hard, gray	5.0
Silt, clayey, lenticular, light green-gray	.9
Silt; some fine sand; soft; brown, weathers light tan	.8
Sand, silty; brown, weathers light brown	.6
Sand, fine, partly cemented; green gray, weathers gray	0.1
Sand; occasional small gravel particles not cemented; brown, weathers light gray	.5
Silt, sandy, somewhat cemented; dark brown, weathers light brown	.1
Sand, fine, somewhat cemented; brown, weathers light brown	.3
Sand; scattered gravel particles; somewhat cemented; green gray, weathers gray	1.0
Base covered.	9.3

(2) The following section of the Ogallala formation was measured in a road cut in the SW¼NW¼ sec. 6, T. 9 S., R. 21 W.:

	Feet
Ogallala formation:	
Quartzite, fine-grained, very hard; green, weathers gray	3.1
Silt, brown; scattered sand and gravel particles	.5
Quartzite, fine-grained, very hard; green, weathers gray	1.6
Silt, calcareous; occasional sand and gravel particles; brown	5.5
Base covered.	9.9

Thickness. --The Ogallala formation is thickest along the western boundary of Graham County, where it may reach an estimated maximum thickness of about 100 feet. It thins somewhat toward the east, and along the eastern boundary its maximum thickness is probably less than 50 feet. The formation is thickest in the center of the interstream areas and tapers to a feather edge along the stream valleys.

[9] Jewett, J. M., and Schoewe, W. H., Kansas mineral resources for wartime industries: Kansas Geol. Survey Bull. 41, pt. 3, p. 124 1942.

Construction materials. --

Riprap.
Structural stone.
Road metal.
Aggregate for concrete.
Calcareous binder.

Sanborn formation

Areal distribution. --The Sanborn formation of Pleistocene and Recent (?) age is the most widely distributed stratigraphic unit cropping out in Graham County. (See pl. 1 and fig. 4.) It occurs as an extensive blanket of silt of variable thickness capping the interstream areas and as a discontinuous deposit of silt part way up the valley walls of the major streams and their larger tributaries. This discontinuous deposit is well developed along the south side of the South Fork Solomon River Valley just south of Hill City. The two phases of the Sanborn are mapped as a single stratigraphic unit because their lithologic characteristics are similar.

The Sanborn formation is separated from all older stratigraphic units by a well-marked erosional break. It overlies the Ogallala formation in the interstream areas and the Smoky Hill chalk member of the Niobrara formation and the Pierre shale along the stream courses. (See fig. 5.)

General description. --The Sanborn formation is composed of materials deposited by streams, slope wash, and wind and through the action of gravity. No attempt was made to subdivide the formation into members as was done by Frye and Fent 10/ in Norton County. 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 inventory of construction materials.

Silt-size particles predominate in the upper part of the formation. Occasional particles of sand and gravel, however, are scattered throughout the silt and locally may be concentrated in thin lenses. The color varies from medium gray in the northwestern part of the county to yellow brown in the southeastern part.

There is a well-developed soil zone at the top of the formation, and a buried soil zone is reported by Hibbard, Frye, and Leonard. 11/ Its presence in Graham County was confirmed by the field party. The "A" zone of the profile averages about a foot in thickness and is underlain by a prominent "B" zone several times as thick. The "B" zone is characterized by secondary deposits of calcium carbonate in the form of pipelike concretionary masses, stringers, nodules, and impregnations. The "C" zone of the soil profile does not contain unusual concentrations of secondary calcium carbonate.

Silts of the Sanborn formation exhibit a marked tendency to stand in vertical cut banks and often show a crude columnar structure. The columnar structure is the result of the intersection of irregular joint planes.

The basal part of the formation includes numerous local lenses of tan-gray sand or gravel, or both. The gravel lenses consist of fragments of local limestone, mortar bed, quartzite, quartz, feldspar, chert, and calcite. The sands are predominantly particles of quartz and feldspar. The lenses are channel deposits and generally pinch out within relatively short distances. Their average thickness is about 4 feet, although in one location there is a sand and gravel lens 24 feet thick. (See representative measured section.) This phase is well displayed, also, in a road cut along U. S. 24 in the SE¼NE¼ sec. 8, T. 8 S., R. 22 W., and in numerous road cuts and cut banks in the south-central and southeastern parts of the county.

Landes 12/ reports a deposit of volcanic ash about 1.5 miles north of Morland. This probably is a deposit in the NE¼SW¼ sec. 11, T. 8 S., R. 25 W., that consists of thin lenses of light-gray volcanic ash interbedded with thin lenses of sand and fine gravel, all of which are embedded in a light-brown mixture of ash and silt. The upper part of the deposit contains channel fillings of gravel apparently reworked from the Ogallala formation. The gravel particles include numerous fragments of mortar bed and quartzite. The Ogallala formation crops out in the same vicinity, but the contact between the ash and the Ogallala is buried. The age of the ash is uncertain, therefore, but the deposit is assigned tentatively to the basal part of the Sanborn formation on the basis of the reworked Ogallala rocks in the channel fills.

A deposit of ash and interbedded silty ash was found by the field party in the NW¼NE¼ sec. 30, T. 10 S., R. 21 W. The layers of ash are relatively free from adulterants, but the quantity available here is not more than several hundred cubic yards. The deposit is assigned to the basal part of the Sanborn formation. Another small deposit of the same age was noted in the NW¼NE¼ sec. 1, T. 8 S., R. 24 W., but the ash is adulterated by an extensive mixture of silt.

The fossil shells of snails (gastropods) are fairly abundant in the Sanborn formation.

Erosion of the Sanborn formation generally produces a smoothly undulating surface. Along the walls of valleys that have been cut into underlying stratigraphic units the Sanborn may develop "catstep" erosion. The catsteps appear to be caused by the sliding of water-saturated silt under the influence of gravity down the gentle valley walls toward the stream. The catsteps are bounded by scarps a foot or more high and are slump blocks from several feet to about 20 feet wide. Two or more series of catsteps may develop along the valley slopes.

Representative measured section. --The following section of the Sanborn formation was measured in a cut bank of a tributary to the Saline River in the NE¼SW¼ sec. 26, T. 10 S., R. 21 W.:

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

[11]Hibbard, C. W., Frye, J. C., and Leonard, A. B., Reconnaissance of Pleistocene deposits in northcentral Kansas: Kansas Geol. Survey Bull. 52, pt. 1, p. 13, 1944.

[12]Landes, K. K., Mineral resources of Kansas counties: Kansas Geol. Survey Bull. 38, No. 11, p. 37, 1937.

	Feet
Soil, silty, calcareous, brown	1.5
Sanborn formation:	
Silt; calcareous concretions scattered throughout; yellowish brown, weathers light brown	2.0
Sand, silty; some scattered gravel particles up to 1 inch in diameter; dark brown, weathers light brown; fossil gastropod shells	1.2
Sand; some gravel-size particles, including local limestones; gray brown, weathers gray	1.5
Sand, very fine, silty, calcareous; gray, weathers light gray; numerous fossil gastropod shells	.9
Sand; small scattered gravel particles; light brown, weathers gray	.3
Silt, clayey; dark gray, weathers light gray; shows columnar structure; fossil gastropod shells	1.5
Silt; light brown, weathers light gray; shows columnar structure; fossil gastropod shells	2.8
Silt, sandy; gray brown, weathers gray; columnar structure; fossil gastropod shells	1.5
Sand, silty; occasional small gravel particles; yellow brown, weathers gray brown; columnar structure; fossil gastropod shells	1.4
Silt, clayey; small amount of fine gravel; mottled brown and yellow; fossil gastropod shells	1.1
Silt, sandy; yellow brown, weathers light gray	1.0
Sand and coarse gravel, latter with many local limestone particles; light gray to brown, weathers light gray	24.0
	39.2

Underlain by Smoky Hill chalk member of Niobrara formation.

Thickness. --The thickness of the Sanborn formation in Graham County varies from a feather edge along the valleys to a maximum thickness of about 50 feet in the high interstream areas of the northwestern part of the county. Its average thickness is probably between 15 and 25 feet.

Construction materials. --

Aggregate for concrete.
Mineral filler.
Road metal.
Volcanic ash.

Terrace deposits

Areal distribution. --Terrace deposits are developed extensively in the valley of the South Fork Solomon River. (See pl. 1 and fig. 4.) The width of these terraces varies from 1.5 to 2 miles. Bow Creek, in the northern part of the county, has a much smaller terrace, its width ranging from 0.2 mile in the western part of the county to 0.5 mile in the eastern part. Fingerlike extensions of the terrace deposits, some of them as much as 12 miles long, project into the valleys of streams tributary to these major drainage lines. Two or more terrace levels are recognized in Graham County but are mapped as a single stratigraphic unit inasmuch as the sediments composing them are similar. The terrace deposits are separated by erosional breaks from both older and younger stratigraphic units. (See fig. 5.)

General description. --The terrace sediments are composed predominantly of reddish-brown silt-size particles, but occasional lenses of sand or gravelly sand occur in the basal part of the formation. The gravel-size fraction consists for the most part of soft local limestone particles. Only the terraces of the South Fork Solomon River Valley contain sand-gravel lenses; those of Bow Creek Valley are composed entirely of silt. The physical characteristics of the silty part of the terrace deposits essentially duplicate those of the silty phase of the Sanborn formation.

Representative measured section. --The lithology of the terrace deposits is so similar to that of the Sanborn formation that it was not thought necessary to measure a representative section.

Thickness. --The estimated maximum thickness of the South Fork Solomon River terrace deposits is 50 feet. The terrace deposits of Bow Creek Valley probably are no more than 15 or 20 feet thick, and those of the larger tributary valleys are even thinner.

Construction materials. --

Aggregate for concrete.
Road metal.
Mineral filler.

Dune sand

Areal distribution. --Several deposits of dune sand in the east-central part of Graham County are mapped. (See pl. 1 and fig. 4.) The dunes usually cover areas of only a few hundred square yards, but one deposit about 4 miles north of Bogue extends over more than a square mile.

General description. --The sand of which the dunes are composed was deposited by wind within recent geologic time and is being deposited even now. The material is a fine, brownish-tan, cross-bedded sand. The South Fork Solomon River is the source of the sand that forms the dunes located in the valley between the stream channel and the north valley wall. The sand was carried to its present position by dry-season winds blowing prevailingly from the south and southwest.

The extensive area of dune sand north of Bogue is on a fairly high interstream area. The dunes are composed of sand-size, subangular to subrounded, somewhat frosted grains of quartz and, to a lesser extent, of feldspar. The characteristic hummocky topography is subdued, and the "A" soil zone is silty, indicating that the dunes are fairly old. Cultivation of some of the land within very recent times has broken the sod anchor and allowed the wind to blow the sand again. The sand probably was derived originally from the Ogallala formation, which crops out in the area adjacent on the west and north. Several small, low buttes capped by mortar-bed ledges of

Ogallala age are surrounded by sand now being reworked by the wind.

Representative measured section. --The dune sand is so homogeneous throughout that it was not thought necessary to measure a section of it.

Thickness. --The average thickness of the dune sand is about 10 feet, but the crests of the higher dunes in the valley of the South Fork Solomon River rise as high as 20 feet above the base of the deposit and some of the dunes in the area north of Bogue are at least 30 feet high.

Construction materials. --

Aggregate for concrete.
Road metal.

Alluvium

Areal distribution. --The deposits formed by streams in their present gradational cycles are mapped as alluvium. (See pl. 1 and fig. 4.) They and the dune sands constitute the most recent stratigraphic units in Graham County. Alluvium is defined in this report as the material which underlies the present flood plain of a stream. The flood plain is the area adjacent to the stream channel that is covered by water during normal flood stage.

Alluvium is mapped along the South Fork Solomon River only. Alluvial deposits are also present in some of the larger tributary valleys and along Bow Creek but could not be shown because of the map scale. The alluvial deposits of the South Fork Solomon River average about 0.3 mile in width.

General description. --The alluvium of the South Fork Solomon River is quite sandy, and numerous lenses of rounded gravel are interbedded with the sand. The gravel particles are rock fragments weathered and eroded from local stratigraphic units. Silt is characteristic of the upper part of the formation only.

Representative measured section. --The relief of the alluvium is so low that a representative section could not be measured.

Thickness. --The exact thickness of the alluvium could have been determined only by test drilling. It is estimated that the maximum thickness is no more than 20 feet and probably is somewhat less than that.

Construction materials. --

Aggregate for concrete.
Road metal.

INVENTORY OF CONSTRUCTION MATERIALS

General

The objectives of this inventory of construction materials in Graham County are to define the construction materials as as they are classified 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 American Association of State Highway Officials 13/ and the State Highway Commission of Kansas. 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.

Although numerous prospect pits and quarries were located in the field, no attempt was made to complete an exhaustive survey of all possible sources. If the construction materials that are available in Graham 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 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 a mixed aggregate if the coarse fraction is 5 percent or more by weight of the whole sample and as a 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 unconsolidated overburden sufficiently thin that they may be economically developed. Because of the added expense in the removal of the overburden, deposits of sand and gravel overlain by thick or consolidated beds usually are not included, nor are relatively inaccessible deposits; exceptions to this practice are noted in the "Remarks" column of table 1.

[13] American Association of State Highway Officials, Standard specifications for highway materials and methods of sampling and testing; pt. 2, 5th ed., 361 pp., 1947.
Absorption, pp. 251-252.
Compressive strength, pp. 257-258.
Deval abrasion, pp. 235-236.
Liquid limit, pp. 198-201.
Los Angeles abrasion, pp. 237-239.
Plasticity index, pp. 202-204.
Specific gravity, pp. 249-250.
Toughness, pp. 240-241.
Weight per cubic foot, pp. 253-254.
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.

Stratigraphic sources and performance characteristics

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

(1) Ogallala formation. Only one of the aggregate samples listed in table 1 (fa 1) was taken from the Ogallala formation, but in other counties of western Kansas the Ogallala is known to be an important source of both fine and mixed aggregates. The one sample analyzed is composed predominantly of fragments of quartz, feldspar, and basic igneous rocks. A small amount of chalk and a moderate percentage of limonite nodules are present in the coarse fraction. The coarse fraction, however, accounts for only 3 percent of the weight of the sample, so that these materials probably are not present in deleterious quantities. The test characteristics of the sample indicate that it may be acceptable for use as fine aggregate for concrete.

The field party in Graham County encountered numerous other occurrences of sands or gravelly sands in the Ogallala formation. In these, however, the presence of hard ledges of mortar bed or quartzite constitutes such an overburden problem that the deposits cannot be developed economically by present-day methods. Intensive exploration of the mapped outcrop areas of the Ogallala formation probably will result in the location of sand and gravel deposits under no more than unconsolidated overburden.

(2) Sanborn formation. The Sanborn formation is the source of four samples of fine aggregate (fa 3, fa 4, fa 6, and fa 7) and three of mixed aggregate (ma 1, ma 6, and ma 7). These are mapped on plate 1, and their test data are given in table 1. The mineralogical analyses indicate that the fine fraction of aggregates from the Sanborn formation is composed predominantly of quartz and feldspar particles. There are significant percentages of mortar-bed fragments in the coarse fraction of three samples analyzed (fa 6, fa 7, and ma 1), but the mortar-bed particles are fairly hard and probably are not deleterious. Fifteen percent quartzite fragments is included in the coarse fraction of sample fa 9, but that fraction constitutes only 2 percent of the total sample weight, and the quartzite probably is not present in a deleterious quantity.

The test characteristics of all the Sanborn formation samples indicate that the material may be acceptable as aggregate for concrete. Sand and gravel lenses in the base of the Sanborn formation are wide spread over Graham County but generally are limited in size. Undoubtedly, additional prospects can be located in the basal part of this formation, and exploration will be most profitable if the marginal areas of the mapped outcrops of the Sanborn are explored. Present-day streams have cut deepest into the Sanborn in such areas and are most likely to have exposed the basal sand and gravel lenses.

(3) Terrace deposits. No samples of sand and gravel were obtained from the terrace deposits, but the material is composed predominantly of quartz particles. It contains a subordinate amount of feldspar particles, and minor quantities of fragments of basic igneous rocks and local limestones also are present.

The sand and gravel lenses occur in the basal part of the terrace deposits, and because the deposits are channel fills, the quantity of material in any one deposit probably will be limited. Such sand and gravel deposits may be located by intensive exploration of the terrace deposits in the valleys of the South Fork Solomon River and its larger tributaries, as well as in the valleys of tributaries to the Saline River in the southern border area of Graham County. Field examination revealed that the terrace deposits of Bow Creek Valley are predominantly silt and that sands and gravels can be present only at some depth below the surface.

(4) Dune sand. One sample of dune sand (fa 2) was tested and is classified as fine aggregate. (See table 1 and pl. 1.) The material is a very fine sand composed predominantly of quartz particles but with minor amounts of feldspar, acid igneous rock, and basic igneous rock particles also present. Additional sources of similar materials are mapped as dune sand on plate 1.

(5) Alluvium. One sample of fine aggregate (fa 5) and four of mixed aggregate (ma 2, ma 3, ma 4, and ma 5) from the alluvium are listed in table 1, and the sample locations are mapped on plate 1. Alluvial deposits are now the most active sources of aggregate in Graham County. No samples were collected for mineral analysis, but on the basis of the generalized sample descriptions, the alluvial sands and gravels appear to be composed predominantly of fragments of quartz and igneous rocks with perhaps fairly heavy mixtures of calcareous particles in the coarse fraction. These particles probably are relatively soft local limestone and somewhat harder Ogallala mortar-bed fragments. The test characteristics indicate that alluvial sands and gravels may be acceptable for use in concrete. Additional aggregate materials are present in the alluvial deposits of the South Fork Solomon River in Graham County.

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. The geologic materials classed as road metal differ from one area to another. The following materials are available in Graham County for use as road metal:

(1) Sources of aggregate for concrete.

(2) Crushed rock. Indurated rocks available in Graham County for use as crushed stone in road construction, filter bed for earthen dams, or railway ballast are (a) limestone, a compact, massive layer of calcareous material, variable in its hardness; (b) silicified chalk, a compact, massive, originally calcareous rock that has been more or less completely replaced by silica (the known deposits of silicified chalk in Graham County are not mapped on plate 1 but are discussed under the Smoky Hill chalk member of the Niobrara formation); (c) quartzite, a massive, compact rock of variable hardness composed of sand or gravel particles (or both), usually firmly cemented by interstitial silica; (d) mortar bed, a massive, compact rock of

variable hardness composed of sand or gravel particles (or both), more or less firmly cemented by interstitial calcium carbonate.

Three of these materials are mapped on plate 1 and listed more specifically in table 1 as limestone, quartzite, and mortar bed, because, in addition to their use as road metal, some of them 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 the construction of bituminous-mat and water-bound macadam roads and as surfacing material on many light-traffic roads within the county. Field observation indicates that they are adequate for these purposes.

(2) Crushed rock.

(a) Smoky Hill chalk member of the Niobrara formation. Silicified chalk from the Smoky Hill chalk member has been uses as surfacing material on some roads in Graham County, and the county engineer reports that it is satisfactory if a thick application of material is laid down.

The beds of chalky limestones and shales in this member are used in the construction of light-traffic roads of the water-bound macadam type. This use also has been observed in other Kansas counties.

(b) Ogallala formation. Crushed quartzite has been used on several roads in Graham County as surfacing material. Field observation indicates that it is advisable to crush the quartzite to particle sizes less than 0.5 inch in diameter because particles larger than this tend to kick out from the road.

Crushed quartzite is reported by W. E. Gibson, engineer of tests, State Highway Commission of Kansas, to have been used in the construction of concrete pavement in Hill City. The pavement shows no evidence of failure due to reaction between the quartzite and the portland cement. It is to be noted, however, that the pavement is not in a water-saturated environment.

The more important operated or prospect quarries are mapped on plate 1, and the chemical compositions and test characteristics of some of the quartzites are listed in table 1. The amount of quartzite available in Graham County is almost unlimited, and a quarry could be opened in this material at almost any convenient site in the central part of the county.

Mortar-bed material from the Ogallala formation has been used in the construction of a county road south of Penokee, apparently with satisfactory results. Fairly soft mortar beds can be crushed and worked into a water-bound macadam type of construction. The calcium carbonate cement resets under this treatment to bind the sand and gravel particles of the mortar bed and thus form a firm surface course for light-traffic roads.

Some light-traffic roads in north-central Kansas have been metaled with crushed rock quarried from the hard limestone bed near the top of the Ogallala formation. Field observation indicates that the material performs satisfactorily when so used.

Mineral filler

Engineering and geologic characteristics

Material composed predominantly of silt-size mineral particles (50 percent or more of which pass 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. S. E. Horner, of the State Highway Commission of Kansas, states in a letter dated January 4, 1947, that material will qualify for mineral filler if laboratory tests indicate a low coefficient of cementation.

Stratigraphic sources and performance characteristics

(1) Sanborn formation. Two samples of mineral filler were obtained from the Sanborn formation (mf 1 and mf 2); the sample locations are mapped on plate 1, and the test characteristics are given in table 1. Test data indicate that the material probably is satisfactory for use as mineral filler but that the cementation factor might be excessive. It is probable that the samples were taken from the "B" zone of the soil profile, because the high-cementation factors undoubtedly are the result of impregnation of the silt with calcium carbonate deposited by percolating subsurface waters. Silt in the Sanborn formation taken from below the "B" zone should have a cementation factor within acceptable limits. This stratigraphic unit is the principal source of mineral filler in Graham County, and because of the widespread availability of the silt, it was not thought necessary to map any more than these two prospects. Pits can be opened in the formation wherever it is desired to use the silt in engineering construction. It is recommended that the material be laboratory-tested and its cementation factor determined prior to the development of a site.

(2) Terrace deposits. Two samples of silt from terrace deposits along the South Fork Solomon River (mf 3 and mf 4) were tested. The data are given in table 1, and the locations are mapped on plate 1. The test characteristics of these samples are similar to those of the mineral-filler samples from the Sanborn formation that were tested.

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 to which the usual silty filler is not adapted. Volcanic ash consists predominantly of the fine, glasslike shards ejected during the explosive phase of a volcanic eruption. The ash may include clay- or silt-size particles of other origins and occasional thin seams of gravel and sand.

Stratigraphic sources and performance characteristics

Two deposits of impure volcanic ash were observed by the Graham County field party. One of these, in the NE¼SW¼ sec. 11, T. 8 S., R. 25 W., is tentatively classified as belonging to the Sanborn formation; the other, in the NE¼SW¼ sec. 15, T. 8 S., R. 25 W., is in the basal part of a high-level terrace deposit. Deposits of volcanic ash of both Ogallala and Sanborn age occur with some frequency in western Kansas, but volcanic ash is less common in terrace deposits than elsewhere.

It is entirely likely that ash deposits of commercial quality and quantity might be found in Graham County if an intensive program of field exploration were undertaken. The position of the volcanic ash within the Ogallala formation is variable, but in the Sanborn formation the ash generally is found in the basal part. Prospecting probably will be most profitable in the marginal parts of the mapped outcrop areas of the Sanborn where the base of the formation has been exposed.

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 abrasion, 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) Smoky Hill chalk member of the Niobrara formation. The silicified chalk in this stratigraphic unit appears acceptable as riprap for earthen structures. Similar uses of the silicified chalk have been observed in other Kansas counties, and its performance is satisfactory. The presently known occurrences in Graham County are in the Penokee and Morland areas.

(2) Ogallala formation. The quartzites of the Ogallala formation are acceptable as riprap on the basis of test characteristics (table 1) and field observation. The material is sound, its specific gravity is adequate, and its abrasion loss is relatively low. The upstream face of the Antelope Lake dam in the NE¼ sec. 9, T. 8 S., R. 25 W., was riprapped with quartzite blocks about 1937. The riprap was inspected in 1948 and showed no indication of deterioration, either at the water line or on the freeboard of the dam. Quarries could be opened in quartzite ledges of the Ogallala in many parts of Graham County.

Mortar-bed ledges in the Ogallala formation vary in hardness; some are cemented firmly enough that they are satisfactory as riprap. One of the mortar-bed samples tested (mb 2) has been accepted for this use by the State Highway Commission of Kansas. A small earthen dam constructed in 1935 in the SW¼SW¼ sec. 28, T. 10 S., R. 22 W., was riprapped with mortar-bed blocks measuring about a foot on a side and, when examined in 1947, showed no marked evidences of deterioration of the riprap blocks. Mortar-bed ledges vary greatly in hardness within short distances, and a constant check of hardness will be necessary to assure acceptable rock.

The dense, hard limestone layer found near the top of the Ogallala formation in the northwestern part of Graham County appears adequate for use as riprap, although no such use was observed in this 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 the desired size and shape. Materials fulfilling these requirements occur in the Smoky Hill chalk member of the Niobrara formation and in the Ogallala formation.

Stratigraphic sources and performance characteristics

(1) Smoky Hill chalk member of the Niobrara formation. Test characteristics and field observations of the more massive beds of chalky limestone in the Smoky Hill member indicate that the limestone is acceptable for use as structural stone. No such use was observed in Graham County, but farm buildings observed elsewhere in Kansas indicate that the stone is satisfactory if it is not used in a place where it will be subjected to water saturation. The chalky limestone deteriorates rapidly in the presence of water, either by slaking or freeze-and-thaw.

The silicified chalks locally present in the Smoky Hill chalk member are potentially useful as structural stone. The material is unusually hard, however, and producing it to the desired size and shape may be an excessive cost factor. In addition, its brittleness may cause it to shatter too much during the quarrying operation. The chemical properties of the silicified chalk are probably similar to those of quartzite.

(2) Ogallala formation. Quartzites of the Ogallala formation were used in the construction of the city hall and the buildings in the city park of Hill City and in Antelope Lake Park. Field observations of these structures in 1947 and 1948 disclosed no evidences of surface deterioration or excessive reaction with the mortar, but it is possible, according to Mansfield Merriman, Bureau of Reclamation, United States Department of the Interior, that failure through mortar reaction may occur in structures or parts of structures immersed in water. Because of the hardness of the quartzite, the process of producing it to the desired size and shape may be costly.

Hard mortar-bed ledges in the Ogallala have been used as structural stone in other counties in western Kansas, as in the grade-school building at Traer, Norton County. Field observation indicates that the harder mortar-bed ledges perform satisfactorily when so used. It is recommended that a constant check be made of the quality of this stone because of rapid lateral variations in mortar beds.

Stone quarried from the hard local limestone bed near the top of the Ogallala formation was used in the construction of the church in New Almelo, Norton County, Kans. The stone is not too pleasing in appearance but has stood up very well for nearly 50 years.

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.

Stratigraphic sources and performance characteristics

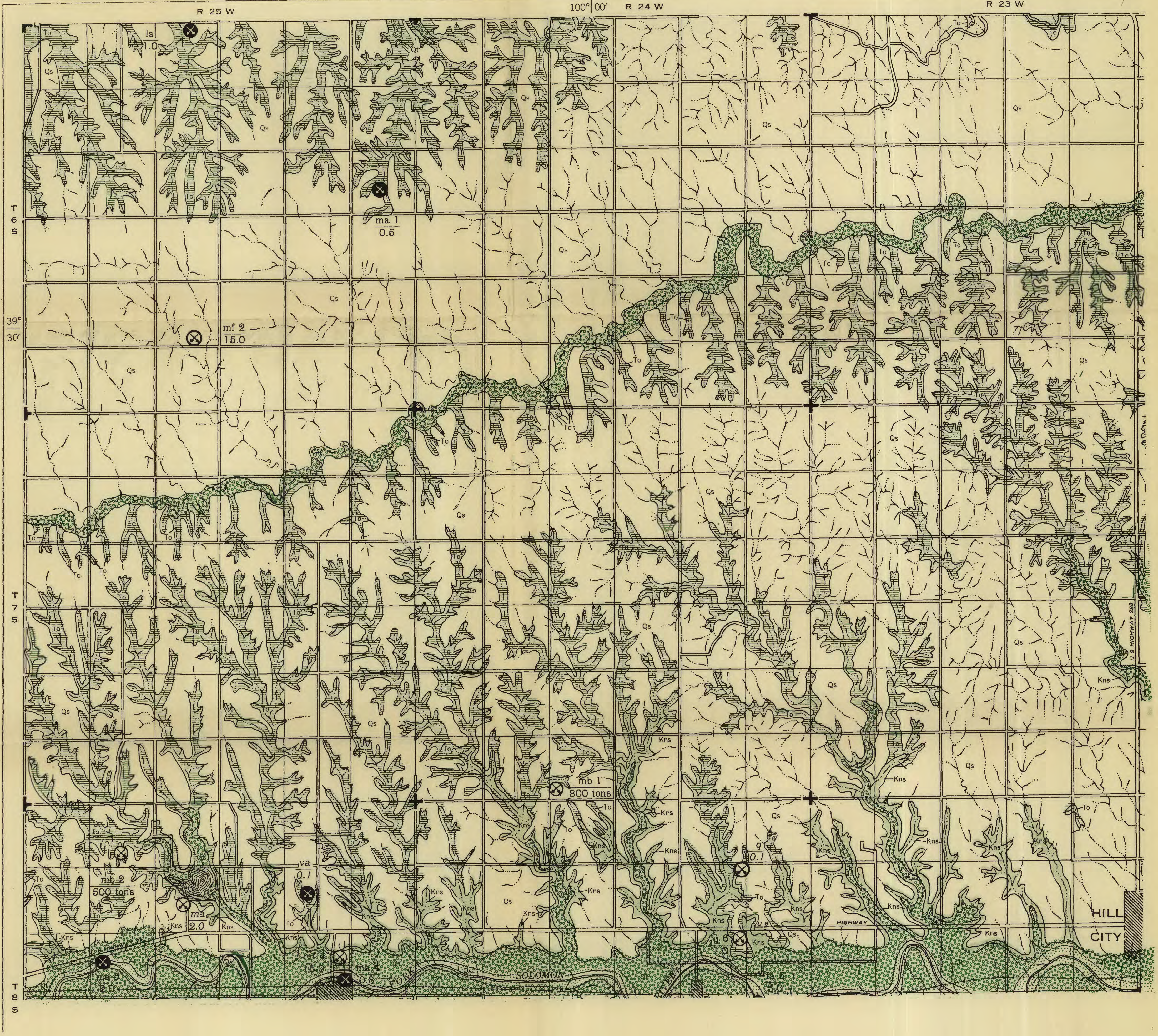
(1) Smoky Hill chalk member of the Niobrara formation. The chalk beds in the Smoky Hill chalk member have been accepted by the State Highway Commission of Kansas as calcareous binder. Although no one of them in Graham County was tested for this use, the chalk appears to be acceptable because it is soft and easily pulverized. The fact that the chalky limestones are relatively thin probably is not a serious objection inasmuch as the shales interbedded with the limestones also contain a high percentage of calcium carbonate.

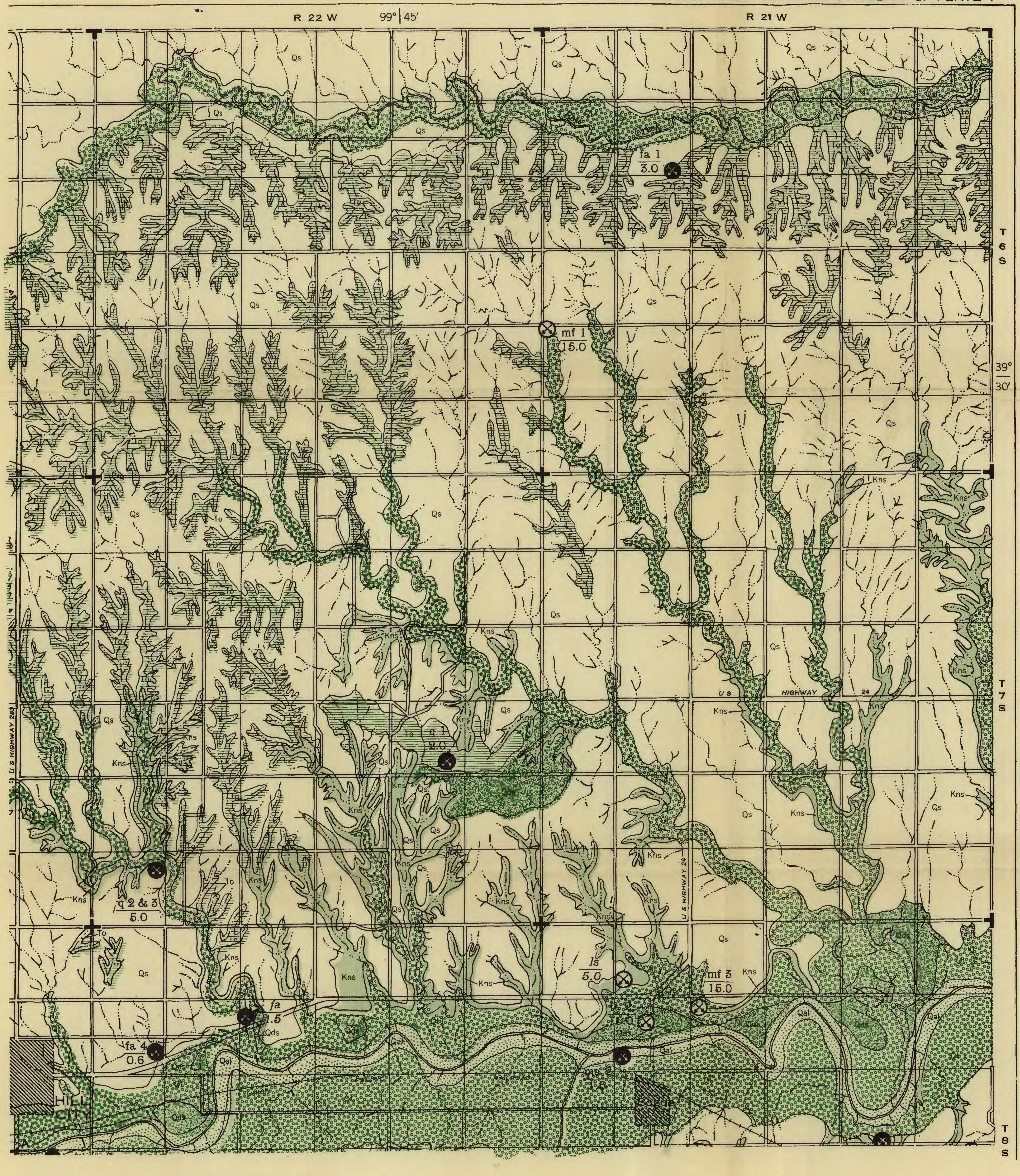
(2) Ogalla formation. Relatively soft ledges of mortar bed in the Ogallala formation at sites in other Kansas counties have been tested by the State Highway Commission and accepted as calcareous binder. Field observation indicates that similar beds in Graham County probably are acceptable for this use. The mortar beds contain a very high percentage of calcium carbonate, and some of them are sufficiently soft that they can be pulverized easily. The material is widely distributed throughout the mapped outcrop area of the Ogallala formation.

Interior—Duplicating Section, Washington, D. C. 68546

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NORTHWEST QUARTER CIRCULAR 51 PLATE I





EXPLANATION

QUATERNARY — *Pleistocene and Recent*

Qal

Alluvium

Lenses of silt, sand, and gravel; silt predominant in upper part only. Source or potential source of aggregate and road metal.

Qds

Dune sand

Brownish-tan, cross-bedded fine sand; local extent only. Source or potential source of aggregate and road metal.

Qt

Terrace deposits

Predominantly reddish-brown silts; lenses of sand and gravel in basal part; tends to stand in vertical banks; often buried soil in upper part. Source or potential source of aggregate, road metal, and mineral filler.

Qs

Sanborn formation

Upper part, gray and yellow-brown silt locally with a prominent buried soil zone; tends to stand in vertical banks; fossil gastropods common. Lenses of sand and gravel in lower part. Source or potential source of aggregate, road metal, mineral filler, and volcanic ash.

TERTIARY — *Pliocene*

To

Ogallala formation

Interbedded lenses of silt, clay, and cross-bedded sands and gravels; numerous lenticular beds of hard, green or chocolate-brown quartzite; lenses of soft or hard gray mortar bed; local lenses of hard, dense limestone in upper part. Source or potential source of aggregate, road metal, riprap, structural stone, and calcareous binder.

CRETACEOUS — *Upper Cretaceous*

Kp

Pierre Shale

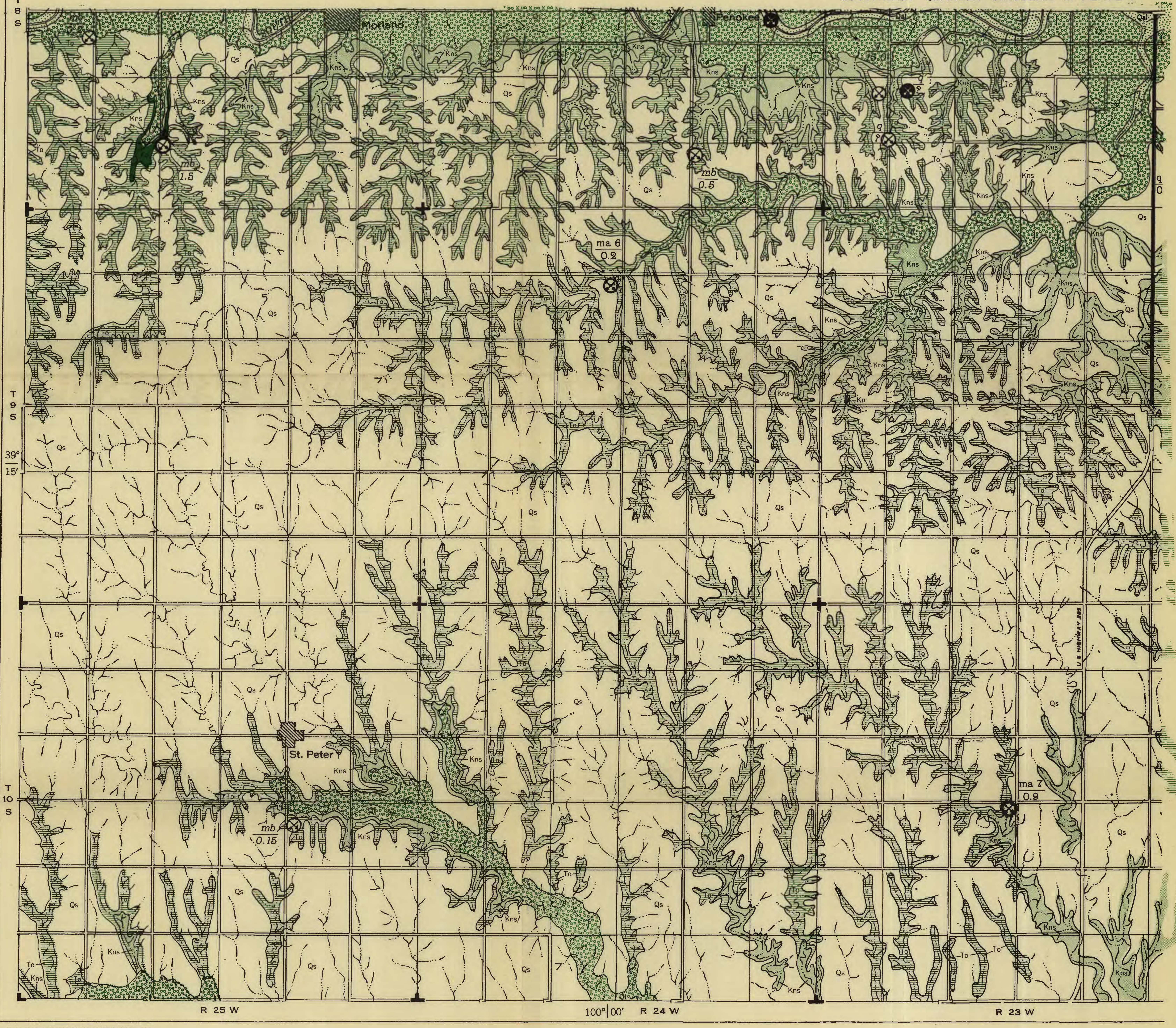
Blue-gray clay shales interbedded with thin beds of bentonite; small selenite crystals occur locally.

Kns

Niobrara formation

Smoky Hill chalk member

Thick beds of gray, orange-gray, and yellow shales interbedded with thin beds of chalky limestone and very thin beds of bentonite or bentonitic shale. Silicified zones in upper part. Abundant fossil shells of clams and oysters. Source or potential source of road metal, riprap, structural stone, and calcareous binder.



Base map enlarged photostatically from map compiled by the Soil Conservation Service, U. S. Department of Agriculture.

SOUTHEAST QUARTER CIRCULAR 51 PLATE I

Geologic contact

Operated pit or quarry

Prospect pit or quarry

ls
Limestone

q
Quartzite

mb
Mortar bed

fa
Fine aggregate

ma
Mixed aggregate

mf
Mineral filler

va
Volcanic ash

ma
Inclined letters indicate materials not tested

ma 4
Vertical letters indicate materials listed in table 1, and their sample number

15.0
Quantity of material available (in units of 10,000 cubic yards)

Federal U. S. Highway

State highway

Railway

City

Section line

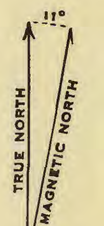
Township corner

Permanent stream

Intermittent stream

Artificial lake

Line of cross section (on north-south road between sections 23 and 24, T. 8 S., R. 23 W., and sections 13 and 14, T. 9 S., R. 23 W.)



APPROXIMATE MEAN DECLINATION, 1947

Geology mapped by V. B. Coombs and C. W. Matthews in 1947.

MAP SHOWING CONSTRUCTION MATERIALS AND GEOLOGY OF GRAHAM COUNTY, KANSAS

Scale
1 0 1 2 3 4 Miles

1951

Table 1.—Summary of materials tests

[Blank spaces indicate data not available]

Classification of the material	Number on plate 1	Location: 1/4 fraction	Location: 1/4 section	Location: Section	Location: Township (S)	Location: Range (W)	Estimated quantity of material (in cubic yards)	Average thickness: Material (in feet)	Average thickness: Overburden (in 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 passing No. 200 (wash)	Description of the material[2]: Fraction	Quartz	Feldspar	Acid rocks	Basic rocks	Mortar bed	Carbonate minerals	Chalk	Silicified chalk	Quartzite	Chert and/or chalcedony	Limonite nodules	Laboratory test data: Weight per cubic foot (dry)	Specific gravity (saturated)	Gradation factor	Compressive strength ratio: 1 day	Compressive strength ratio: 3 days	Los Angeles loss percent	Soundness[3] (25 cycles)	Toughness	Cementation	Absorption	Color[4]	Remarks
Fine aggregate	fa1	SW	SE	8	6	21	30,000	30	2-10	Good	Ogallala	SHCK USGS	9-47	0	1	3	27	94	5.3	C	33	15		33			4				15	108.7	2.56	2.78	1.00	0.99		0.94				cl	Overburden is silt and thin mortar bed; fairly high percentage of limonite nodules.
																				F	87	7		3							3												
	fa2	SE	NW	8	8	21	150,000	20	0	do	Dune sand	do	7-47				0	95	0.64	C												102.8	2.61	1.89	0.92	0.92						cl	Gradation factor and compressive-strength ratios low.
																				F	90	5	2	3		Tr																	
	fa3	SW	SE	14	8	21	5,000	10	1	do	Sanborn	do	do	2	2	2	40	97	2.61	C	80	15		2		3	Tr					105.9	2.60	3.19	1.42	1.38						lt st	Overburden is silt.
																				F	91	7		1		1																	
	fa4	NE	SE	7	8	22	6,000	8	1.5	do	do	SHCK	2-46	0	1	2	27	96	3.0													106.0	2.58	2.85	1.34	1.16							Average of 11 auger samples. Overburden is silt.
	fa5		NW	24	8	24	30,000	12	0	do	Alluvium	do	do	0	1	3	17	93	5.4														2.58	2.24	1.06	1.12	30.8	0.65					Average of 11 auger samples.
	fa6	SW	NW	12	10	22	6,500	5	0-5	do	Sanborn	SHCK USGS	7-47		0	2	29	91	4.74	C	34	24	2		15				15		2	107.1	2.60	2.68	1.30	1.31						cl	Overburden is silt of the Sanborn formation; 8% brown siltstone and fairly high percentages of mortar bed and quartzite fragments in coarse fraction.
																				F	85	8	1	4	Tr						1												
	fa7	NW	NE	25	10	22	7,500	8-10	1-3	do	do	do	do		0	1	6	96	3.29	C	65	20		Tr	11	2					2	101.3	2.60	2.16	1.02	0.98						lt st	Overburden is silt of the Sanborn formation.
																				F	92	5		1		2																	
Mixed aggregate	ma1	NE	SW	13	6	25	5,000	8-12	5-8	Fair	do	do	8-47	0	2	10	52	93	5.72	C	50	25		Tr	25							116.5	2.59	3.35	1.65	1.81						cl	Overburden is silt of the Sanborn formation; high percentage of mortar-bed fragments in coarse fraction.
																				F	80	15		5	Tr																		
	ma2		SW	8	8	21	15,000	12	0	Good	Alluvium	SHCK	4-42	8	9	13	34	97		Siliceous and calcareous particles.												109.0	2.62	3.39	1.24	1.15	30.0	0.85					
	ma3		N1/2	24	8	23	15,000	14	0	Fair	do	do	2-46	1	3	9	43	98	1.5													107	2.60		1.09	1.11	29.6	0.86				cl	Average of 4 auger samples.
	ma4	E1/2	SE	14	8	25	8,000	11	0	Good	do	do	do	0	3	8	45	96	2.5													109	2.62		1.08	1.10	30.2	0.87				lt st	Average of 5 auger samples.
	ma5		NW	17	8	25	20,000	15	0	do	do	do	4-42	1	2	6	39	99		Siliceous and calcareous particles.												110.0	2.61	3.31	1.16	1.21	29.8	0.92					
	ma6		NE	9	9	24	2,000				Sanborn	do	8-46	1	5	17	59	100	0.26	Siliceous and calcareous particles.												112.3	2.62	4.02	1.55	1.40		0.99					Accepted for use under sections 105, 106, 100 to 110, and 112, SHCK specifications. Probably Sanborn; location not certain.
	ma7		NE	21	10	23	9,000			Poor	do	do	5-46	2	3	5	38	93	5.20	Siliceous and calcareous particles.												112.1	2.56	3.05	1.47	1.39		0.95					Probably Sanborn; location not certain.
Mineral filler	mf1	NW	NW	30	6	21	150,000	25	0	Good	do	SHCK USGS	8-47				0	5	93.8	Yellowish-gray silty clay.												73.9	2.58							100+			Cemetation factor high.
	mf2	SW	SE	28	6	25	150,000	15+	2	do	do	do	do				0	4	93.6	Yellow silty clay.												72.6	2.57							100+			Overburden is "A" zone of soil profile; cementation factor high.
	mf3	NW	NW	9	8	21	150,000	10	2	do	Terrace deposit	do	do			0	6	61	35.6	Yellowish-gray silty clay; some fine sand.												96.4	2.61							96			Overburden is "A" zone of soil profile; cementation factor high.
	mf4	S1/2	NE	14	8	25	150,000	15	2	do	do	do	do				0	14	84.8	Dark brownish-gray silty clay.												83.4	2.59							100+			Overburden is "A" zone of soil profile; cementation factor high.
Mortar bed	mb1		SW	33	7	24	800 tons	6	0	Fair	Ogallala	SHCK	8-32							Soft white limestone with streaks and specks.													2.35					OK	3		4.8		Deval abrasion loss, 12.4%; material not acceptable for bituminous-mat surface.
	mb2		S1/2	5	8	25	500 tons	6	0	do	do	do	10-37							White limestone.													2.24					OK	5		7.2		Deval abrasion loss, 8.8%; satisfactory for riprap under sec. 78, SHCK specifications.
	mb3	NE	NW	19	10	22	5,000	6-8	0-8	Good	do	SHCK USGS	8-47																				2.32				72.4	0.61			7.1		Overburden is silt.
Quartzite	q1	S1/2	SE	23	7	22	20,000	4	0-5	Fair	do	SHCK	5-46							Light-green sandstone with some coarse grains.													2.33				46.4	0.87	6		3.07		Acceptable under sec. 108, SHCK specifications.
	q2		NE	31	7	22	50,000	6	1	Good	do	do	1-42							Fine-grained green sandstone.													2.34				44.0	OK	6		1.8		Acceptable under secs. 68 to 71, 73, and 76, SHCK specifications.
	q3		NE	31	7	22	50,000	5	0-10	do	do	CE	1-46	Chemical composition (%): SiO_2, 88.09; Al_2O_3, 3.5; Fe_2O_3, 1.35; CaO, 0.69; MgO, 1.08; Na_2O, 1.01; K_2O, 1.47; undetermined, 0.4; HCl soluble, 4.9.																			2.33					OK			2.0		Deval abrasion loss, 6.81%; classified as an opaline sandstone; sample locality probably same as q2 above.
	q4	SW	SE	34	8	22	3,000	10	0-3	do	do	do	10-45	Chemical composition (%): SiO_2, 97.1; Al_2O_3, 1.26; Fe_2O_3, 0.08; MgO, 0.1; undetermined, 0.02; HCl soluble, 3.62.																			2.38					OK			1.05		Deval abrasion loss, 2.81%.
	q5	NE	SW	36	8	23	4,000	5		do	do	SHCK	5-46							Greenish-gray coarse-grained sandstone.													2.41				38.8	0.88	9		1.52		Acceptable under secs. 108 to 112 and 114, SHCK specifications.
	q6	NE	NE	14	8	24	10,000	4	1	do	do	do	do							Green coarse-grained sandstone.													2.42				37.9	0.89	7		1.58		Acceptable under secs. 108 to 112 and 114, SHCK specifications.

1. SHCK, State Highway Commission of Kansas. SHCK and USGS, sieve analysis and laboratory tests by State Highway Commission of Kansas; sample collection and description of material by U. S. Geological Survey. CE, Corps of Engineers, U. S. Army.
2. C, coarse fraction, retained on No. 4 sieve; F, fine fraction, passed through No. 4 sieve; Tr, trace; in terms of percent composition.
3. Loss ratio.
4. Cl, clear; lt st, light straw.