



UNITED STATES DEPARTMENT OF THE
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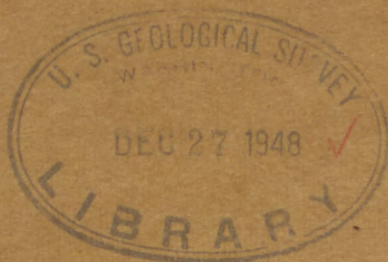
LAR 25

November 1948

CONSTRUCTION MATERIALS
IN
SMITH COUNTY, KANSAS

By

Frank E. Byrne, Max S. Houston, and Melville R. Mudge



WASHINGTON, D. C.

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INTRODUCTION

Purpose of the investigation

The State Highway Commission of Kansas and the United States Geological Survey are cooperating in the compilation of a State-wide inventory of construction materials. A field party composed of personnel from the two cooperating agencies was sent into Smith County, Kans., in the summer of 1947, to investigate sources of engineering construction materials. This report of the Smith County investigation is a part of the general inventory and a contribution to the geologic mapping and investigation of mineral resources being made in connection with 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 Smith County that would be of use in the construction of dams, irrigation canals, highways, airports, or 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 prospects to meet future engineering needs.

Area covered by the investigation

Smith County is in the first tier of Kansas counties south of the Nebraska border and in the sixth 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°34' and 40°00' north latitude and meridians 98°30' and 99°04' west longitude. It is bordered on the east by Jewell County, on the west by Phillips County, on the south by Osborne County, all in Kansas, and on the north by Franklin and Webster Counties, Nebr.

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

Geography of the area

Smith County is in the border region of the Great Plains physiographic province. It has been dissected into moderate relief by streams cutting headward from the lower level of the Central Lowlands province to the east. The principal streams have cut their valleys about 100 feet below the rolling upland surface. The lowest altitude is about 1,500 feet along Oak Creek in the southeast corner of the county. The highest altitudes are on the divides in the northwest corner of the county, some of which are more than 2,100 feet above sea level.

The North Fork of the Solomon River is the largest stream in Smith County. This stream enters from the west, about 6 miles north of the southern county line, and flows toward the east as far as the city of Gaylord, where it turns and flows southeast. It leaves the county at about the middle of the southern boundary. The stream rises in Thomas County, Kans., about 120 miles to the west. The southward-flowing tributaries of the North Fork Solomon River are markedly longer streams than the northward-flowing ones. The principal tributaries entering from the north are, in order from west to east, Cedar Creek, Beaver Creek, Spring Creek, and Oak Creek. The only important tributary entering from the south is Madison Creek in the southwest corner of the county.

Two railways serve Smith County. One of the main lines of the Chicago, Rock Island, and Pacific Railroad enters near the midpoint of the eastern boundary and crosses the county Smith Center, the county seat and largest city. Lebanon, Kensington, and Athol are located along this railroad. A branch line of the Missouri Pacific Railroad parallels the North Fork of the Solomon River and serves Gaylord, Cedar, Harlan, and Claudell.

Two Federal highways, both of the all-weather type of construction, principally black-top, cross the county. U. S. 36, a major east-west transcontinental route, extends through the center of the county. U. S. 281 enters the county from the south, runs north to Smith Center, turns east along

U. S. 36, which it follows to a point 1.5 miles south of Lebanon, then turns north again and leaves the county at its northeast corner. Kansas Highway 9 parallels the Missouri Pacific Railroad and from Gaylord southeast coincides with U. S. 281. Kansas Highway 181 enters the county 2 miles west of the southeast corner and extends north to its intersection near Lebanon with U. S. 281, which it follows to the northern border of the county. Kansas Highway 8 branches from U. S. 36 a mile west of Athol and extends north to the Nebraska border. The county and township roads generally follow section lines. The more important ones are metalled, and most of the others are maintained by grading.

Investigation procedure

This report is based on field work of the reconnaissance type. The base map (Highway Planning Map, scale 1 inch equals 1 mile) was provided by the State Highway Commission of Kansas. Drainage lines were added to the base map for greater ground control in mapping; these were taken from aerial photographs (scale 1 inch equals 1,000 feet) made available for that purpose by the Soil Conservation Service of the United States Department of Agriculture. The areal distribution of the stratigraphic units that crop out in Smith County was then mapped in the field. The mapped stratigraphic units are those recognized as of 1947 by the U. S. Geological Survey and the Kansas Geological Survey. Because the principal emphasis of the project is on construction materials, geologic problems not critically related to the presentation of information on construction materials are considered to be of secondary importance and are ignored insofar as the validity of the information presented is not affected.

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

Acknowledgments

Generous assistance in the compilation of the areal map and of construction-materials data by the following is appreciated: State Highway Commission of Kansas at Topeka and Manhattan, Kans., S. E. Horner, chief geologist, R. D. Finney, engineer of materials, and associates; State Geological Survey of Kansas, J. C. Frye, executive director; and the Smith County office of the Soil Conservation Service, U. S. Department of Agriculture.

This report, in manuscript form, was reviewed by S. E. Horner and by various

members of the U. S. Geological Survey. Illustrations were prepared by Ruth M. Soelter and others of the State Highway Commission of Kansas. The petrographic determinations included in table 1 were made by J. R. Chelikowsky of the State Highway Commission.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

General

This part of the report discusses the characteristics of each geologic formation or member cropping out in Smith County. The discussions emphasize the areal distribution, the general characteristics, and the thickness of each stratigraphic unit. A representative measured section is given for each formation or member. The measured sections are not necessarily intended to be complete but were selected to show typical outcrops of the unit in this county. The construction materials in each stratigraphic unit are listed. The principal purpose of this part of the report is that of presenting the geologic information required for the location and the effective development of the construction materials contained in each stratigraphic unit.

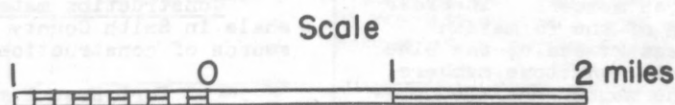
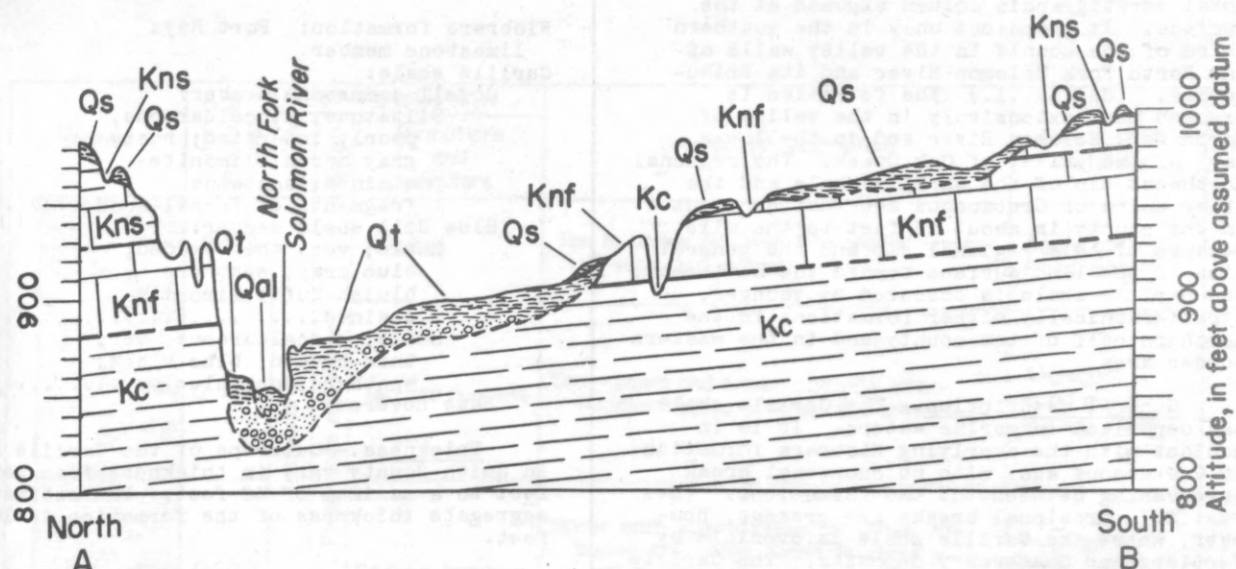
The relations of the stratigraphic units to one another are illustrated in figure 2, Geologic cross section of the Solomon River Valley, and a summary of the data for each unit is presented in figure 3, outcropping stratigraphic units in Smith County, Kans., and their construction materials.

The areal distribution of the local stratigraphic units is shown on plate 1, map showing construction materials and geology of Smith County, Kans. Each stratigraphic unit is indicated by an identifying symbol, and its outcrop areas are shown by a distinctive pattern. Railroads, roads, and streams are shown to provide a basis for evaluating the accessibility of sources of construction materials.

The locations of quarries and pits 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 sources represented on the map by inclined letters have not been tested and are not listed in table 1. All 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.

Carlile shale

Areal distribution.--The Carlile shale, of Upper Cretaceous age (see fig. 3), is the oldest formation cropping out in Smith County and is, therefore, the lowest unit in the



EXPLANATION

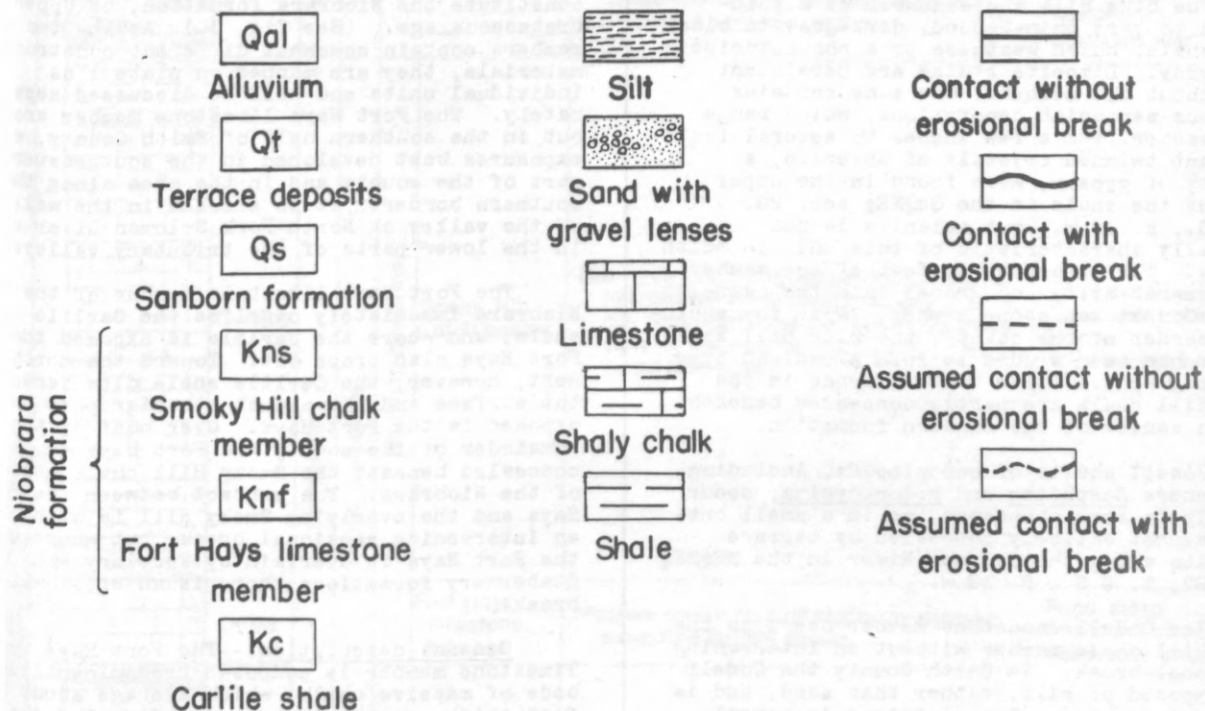


Figure 2.—Geologic cross section of the valley of North Fork Solomon River along the line between secs. 25 and 26, T. 4 S., R. 15 W., and secs. 25 and 26, T. 5 S., R. 15 W.

local stratigraphic column exposed at the surface. It crops out only in the southern third of the county in the valley walls of the North Fork Solomon River and its tributaries. (See pl. 1.) The formation is exposed most extensively in the valley of North Fork Solomon River and in the lower part of the valley of Oak Creek. The regional northwest dip of the Carlile shale and the other units of Cretaceous age that crop out in the county is about 13 feet to the mile. Because of this regional dip and the general rise of the land surface toward the northwest, the Carlile shale is obscured by younger, stratigraphically higher formations in the northern half of the county and in the western border area.

General description.--The Carlile shale was deposited in marine waters. It is in contact with the overlying Niobrara formation of Cretaceous age, with no erosional break intervening between the two formations. (See fig. 2.) Erosional breaks are present, however, where the Carlile shale is overlain by Tertiary and Quaternary deposits. The Carlile shale is composed of three members. In order from the base to the top of the formation these are the Fairport chalky shale, the Blue Hill shale, and the Codell sandstone members. Only the Codell sandstone member and the upper part of the Blue Hill shale member crop out in Smith County, and these are not differentiated on plate 1 or in figure 3.

The Blue Hill shale member is a thin-bedded to very thin-bedded, dark-gray to black clay shale, which weathers to a characteristic blue gray. Limonite stains are persistent throughout the member. One zone contains numerous septarian concretions, which range in diameter from a few inches to several feet. Abundant twinned crystals of selenite, a variety of gypsum, were found in the upper part of the shale in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 5 S., R. 12 W., but selenite is not generally characteristic of this unit in Smith County. The uppermost 10 feet of the member is somewhat silty and grades into the overlying Codell sandstone member. Near the southeast corner of the county, the Blue Hill shale member has been eroded to form a badland type of topography. Other badland areas in the Blue Hill shale are partly concealed beneath a thin veneer of the Sanborn formation.

Fossil shells of cephalopods, including the genera Scaphites and Prionocyclus, occur locally in some abundance, as in a small outcrop almost entirely concealed by terrace deposits along the Solomon River in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 27, T. 5 S., R. 13 W.

The Codell sandstone member overlies the Blue Hill shale member without an intervening erosional break. In Smith County the Codell is composed of silt, rather than sand, and is poorly indurated. The siltstone is noncalcareous, and its color ranges from tan in the lower part to rust brown in the upper part. It is reported to contain fossil teeth of sharks.

Representative measured section.--A cut bank along a small tributary of Spring Creek in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 4 S., R. 13 W. shows the following section:

	Feet
Niobrara formation: Fort Hays limestone member.	
Carlile shale:	
Codell sandstone member:	
Siltstone, noncalcareous, poorly indurated; rusty gray brown; limonite-stained; contains fragments of fossil wood.....	0.4
Blue Hill shale member:	
Shale, very thin-bedded; blue gray, weathers bluish buff; limonite-stained.....	.9
Shale, noncalcareous, very thin-bedded; blue black, weathers dark blue.....	6.0
Base covered	7.3

Thickness.--Outcrops of the Carlile shale in Smith County vary in thickness from several feet to a maximum of 30 feet. The estimated aggregate thickness of the formation is 100 feet.

Construction materials.--The Carlile shale in Smith County is not exploited as a source of construction materials.

Fort Hays limestone member of Niobrara formation

Areal distribution.--The Fort Hays limestone member and the Smoky Hill chalk member constitute the Niobrara formation, of Upper Cretaceous age. (See fig. 3.) As the two members contain somewhat different construction materials, they are mapped on plate 1 as individual units and will be discussed separately. The Fort Hays limestone member crops out in the southern half of Smith County, with exposures best developed in the southeastern part of the county and in the area along the southern border. It is exposed in the walls of the valley of North Fork Solomon River and in the lower parts of the tributary valleys.

The Fort Hays limestone member of the Niobrara immediately overlies the Carlile shale, and where the Carlile is exposed the Fort Hays also crops out. Toward the northwest, however, the Carlile shale dips beneath the surface and the oldest stratigraphic unit exposed is the Fort Hays. Over most of the remainder of the county the Fort Hays is concealed beneath the Smoky Hill chalk member of the Niobrara. The contact between the Fort Hays and the overlying Smoky Hill is without an intervening erosional break, but wherever the Fort Hays is overlain by Tertiary and Quaternary formations there is an erosional break.

General description.--The Fort Hays limestone member is composed predominantly of beds of massive chalk, which average about 3 feet thick, separated by beds of chalky shale usually about 0.1 foot thick. The chalk is quite soft, is buff on fresh surfaces, and weathers to white or tan gray. The interbedded chalky shales are buff or tan gray. This member contains numerous specimens of a fossil clam (Inoceramus) and of a fossil oyster (Ostrea). It is reported to contain fossil vertebrates.

Although the Fort Hays limestone is a relatively soft material, it erodes to form bluffs that are particularly conspicuous

Section	Outcrop thickness (feet)	Stratigraphic units			Generalized description	Construction materials
		System	Series	Formations and members		
	0-60	Quaternary	Pleistocene and Recent	Alluvium	Tan to brown silt with interbedded lenses of sand and gravel.	Aggregate Road metal
	0-100			Terrace deposits	Gray-brown and brown silt with interbedded lenses of sand and gravel.	Aggregate Road metal Mineral filler
	0-100			Sanborn formation	Upper part, gray to brown silt often with buried soil zones, tends to stand in vertical banks; lower part, brown silt with interbedded lenses of sand, gravel, limestone gravel, and volcanic ash.	Aggregate Road metal Mineral filler Volcanic ash
	0-100	Tertiary	Pliocene	Ogallala formation	Gray, tan, and brown lenses of sand, gravel, silt, and clay; ledges of light-gray mortar bed and green quartzite; dense gray limestone locally at top; occasional lenses of volcanic ash.	Calcareous binder Aggregate Road metal Volcanic ash Riprap Structural stone
	0-450	Cretaceous	Upper Cretaceous	Smoky Hill chalk member	Blue-gray and orange-gray chalky shales, interbedded shaly chinks; locally a hard, compact, light-green or brown silicified zone at the top; thin bentonitic zones; forms badlands.	Road metal Calcareous binder Riprap Structural stone
	0-45			Fort Hays limestone member	Massive cream to buff chalky limestones separated by thin shales.	Road metal Structural stone Calcareous binder
	100			Carlile shale	Thin rust-brown siltstone underlain by blue-black thin-bedded shales; zone of septarian concretions; forms badlands.	

Figure 3.—Outcropping stratigraphic units in Smith County, Kans., and their construction materials

along the southeastern border of its outcrop area. The valleys of streams cutting into the limestone are deeply incised. Weathering of the upper part of an outcrop of the limestone tends to produce a shattered zone, where the massive limestone breaks into irregular flattish fragments 1 or 2 inches thick and 4 or 5 inches long.

The regional dip of the Fort Hays limestone member of the Niobrara is the same as that of the Carlile shale, about 13 feet to the mile toward the northwest. Minor fractures and flexures were observed in this member but are not mapped because they do not affect the construction materials characteristics of the unit. A small normal fault was observed in the Fort Hays limestone overlying the section of the Carlile shale measured in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20, T. 4 S., R. 13 W. A small depressed block of rock (graben), the result of downfaulting, was noted in a road cut in the NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 16, T. 5 S., R. 12 W. Polished or striated surfaces (slickensides) had been developed on the rock along the fracture planes.

Representative measured section.--The face of a quarry in the SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 4 S., R. 15 W. revealed the following section:

	Feet
Fort Hays limestone member of Niobrara formation:	
Limestone, shattered zone.....	3.0
Limestone, chalky, soft, massive; cream color.....	3.7
Shale, laminated; buff gray; limonite-stained.....	.5
Limestone, chalky, soft, massive; cream white.....	3.4
Shale, laminated; buff.....	.2
Limestone, chalky, massive; cream white; limonitic zone near base....	3.9
Shale, laminated; buff gray.....	.1
Limestone, chalky, massive, soft; cream white.....	2.2
Shale, laminated; buff gray.....	.2
Limestone, chalky, soft, massive; cream white.....	.8
Shale, laminated; buff gray.....	.2
Limestone, chalky, massive; buff; limonite-stained.....	.8
Shale; gray.....	.1
Limestone, chalky, massive; buff; limonite-stained.....	2.0
Shale; gray; limonite-stained.....	.1
Limestone, chalky, massive; cream color; limonite-stained.....	.3
Shale; dark gray green.....	.2
Limestone, chalky, soft, massive; cream color; <u>Inoceramus</u> and <u>Ostrea</u>	2.2
Shale; dark gray.....	.1
Limestone, chalky, soft, massive; cream color; <u>Inoceramus</u> and <u>Ostrea</u>	2.1
Shale, platy; gray.....	.1
Limestone, chalky, soft, massive; cream color; <u>Inoceramus</u>	1.5
Shale, platy; dark gray, weathers buff.....	.5
Limestone, chalky, soft, massive; cream color; <u>Inoceramus</u>	2.8
Shale; cream color.....	.2
Limestone, chalky, soft, massive; buff cream; <u>Inoceramus</u>	1.5
Shale; greenish gray.....	.5
Limestone, chalky, soft, massive; cream color.....	.6
Shale; cream color.....	.1

	Feet
Fort Hays limestone member of Niobrara formation--Continued.	
Limestone, chalky, soft, massive; buff cream; <u>Inoceramus</u>	1.7
Shale; buff.....	.2
Limestone, chalky, soft, massive; cream color; <u>Inoceramus</u>	3.6
Shale.....	.1
Limestone, chalky, soft, massive; cream color; <u>Inoceramus</u>	1.0
Base covered.....	40.5

Thickness.--Outcrops of the Fort Hays limestone member average between 15 and 20 feet thick in Smith County. The maximum thickness of the member probably is about 45 feet.

Construction materials.--

Structural stone.
Road metal.
Calcareous binder.

Smoky Hill chalk member of Niobrara formation

Areal distribution.--The Smoky Hill chalk member crops out most extensively of all the Upper Cretaceous units in Smith County. (See pl. 1.) It is exposed at the surface in the headward portions of most tributary valleys and on many of the divides. It is especially conspicuous in the east-central part of the county and in the western half. This member is covered by younger formations (Ogallala and Sanborn) in many of the divide areas but has been eroded from the lower parts of most of the stream courses, thus exposing the underlying Fort Hays limestone member of the Niobrara formation.

General description.--The Smoky Hill chalk member is the youngest of the marine deposits cropping out in Smith County. Its contact with the underlying Fort Hays limestone member is without an erosional break, but erosional breaks do intervene in its contacts with younger deposits of the Tertiary and Quaternary periods. (See fig. 3.) The Smoky Hill member consists of interbedded layers of chalky shale and shaly chalk. The lower part of the member is characteristically blue gray and weathers buff gray. The remainder is orange gray and weathers orange buff. The chalk layers are quite shaly and are massive or slabby. The shale layers contain a high percentage of chalk and tend to be blocky. There are occasional thin seams of rust-brown bentonitic shale in the member. Fossil shells of Inoceramus and Ostrea are abundant in some zones, and fragments of fossil vertebrates and plants were noted by the field party.

Extensive outcrops of the Smoky Hill chalk member tend to erode to form a badland type of topography. There are probably ancient badland areas buried beneath younger stratigraphic units in many places in the county.

Where the Smoky Hill chalk underlies the Ogallala formation, as in the northern part of Smith County, the chalk may be silicified. Silicified chalk typically is pale green or yellow orange, dense and hard, and it occurs in lenticular masses. In one place (NW $\frac{1}{4}$ sec. 26, T. 1 S., R. 14 W.) a road cut shows the gradation of the silicified zone into the

underlying soft orange-colored chalky shale. Frye and Swineford 2/ suggest that the silicification of the Smoky Hill chalk was accomplished by silica-rich percolating sub-surface waters, which had dissolved the silica from stratigraphically higher beds of volcanic ash. An exchange of dissolved silica for calcium carbonate may have been made as these waters percolated through the Smoky Hill chalk.

Representative measured section.--An outcrop of the Smoky Hill chalk member in the north wall of the valley of North Fork Solomon River in the NW 1/4 sec. 30, T. 4 S., R. 15 W., reveals the following section:

	<u>Feet</u>
Smoky Hill chalk member of Niobrara formation:	
Shale, chalky; badly weathered, with thin soil zone at top.....	7.0
Chalk, massive; light pinkish gray.....	1.0
Shale, chalky, thin-bedded; light orange brown.....	16.0
Shale, chalky, thin-bedded; alternating blue-gray and pink bands, which weather buff.....	1.7
Chalk, slabby; blue gray, weathers buff.....	.5
Shale, chalky, thin-bedded; streaked orange and gray, weathers buff.....	1.1
Chalk, slabby; light blue gray, weathers buff.....	1.6
Shale, somewhat clayey; light chocolate to orange brown, weathers buff.....	.4
Shale, chalky, very thin-bedded; blue gray, weathers buff; thin orange-brown bentonitic streaks; <i>Inoceramus</i> , <i>Ostrea</i>	2.0
Chalk, shaly, thin-bedded; orange brown, weathers buff; <i>Inoceramus</i> , <i>Ostrea</i>	1.4
Chalk, massive, soft; light bluish orange, weathers buff; <i>Inoceramus</i> , <i>Ostrea</i>4
Shale, very chalky, light blue gray, weathers buff; thin, dark orange-brown bentonitic seam near top; <i>Ostrea</i>	3.7
Base covered.....	36.7

Thickness.--Outcrops of the Smoky Hill chalk member vary in thickness from several feet to about 40 feet. The aggregate thickness in Smith County is thought to be between 50 and 500 feet.

Construction materials.--

Road metal.
Calcareous binder.
Riprap.
Structural stone.

Ogallala formation

Areal distribution.--The Ogallala formation, of Pliocene age, crops out most widely in Smith County in the northern half of the county, principally in the headward parts of

tributary valleys. (See pl. 1 and fig. 3.) It is present in the divide areas between valleys but is concealed by the overlying Sanborn formation. Several small outcrops of the formation are mapped in the southeast corner of the county (T. 5 S., R. 11 W.). Undoubtedly the Ogallala formation once extended over the entire area of the county but subsequently has been eroded completely along the streams.

Certain zones in the Ogallala formation are similar in physical characteristics to zones in the overlying Sanborn formation, and in some places only arbitrary formational contacts can be drawn. The mapped contacts are based on the presence of quartzite and mortar-bed ledges and thicker lenses of sand and gravel in the Ogallala formation. Quartzite and mortar-bed ledges do not occur in the Sanborn formation, which is predominantly a silt with only thin local lenses of sand and gravel in the basal part.

General description.--The Ogallala formation is in contact with both members of the Niobrara formation in Smith County but is separated from them by a pronounced erosional break. In most places it is underlain by the Smoky Hill chalk member of the Niobrara. An erosional break intervenes between the Ogallala formation and the Sanborn formation, which overlies the Ogallala throughout most of this county.

The Ogallala formation consists of inter-bedded lenses of sand, clay, silt, and some gravel. The lenses are variable in both thickness and extent and reflect the stream-deposited origin of the formation. The lower part of the formation appears to have been deposited, for the most part, in pre-Ogallala channels and is appreciably coarser than the upper part. One such channel deposit, most of it buried under the Sanborn formation, was found in secs. 17, 18, and 19, T. 2 S., R. 13 W. Another buried channel deposit was found by a geological field party of the State Highway Commission of Kansas in secs. 33 and 34, T. 2 S., R. 13 W., while working out the engineering geology along a proposed realignment of U. S. Highway 281. Other channels undoubtedly occur within the county but are too well obscured by the Sanborn formation for any but accidental discovery. The basal sands and their included gravels are composed predominantly of fragments of quartz, feldspar, local limestone, and igneous rock particles. Clay layers in this formation are light gray to greenish gray, are often bentonitic, and may be as much as 5 or 6 feet thick.

The Ogallala formation includes lenticular layers of massive, light-gray, lime-cemented sand and/or gravel. Such lenses are termed mortar beds and form conspicuous outcrops on some of the hillsides in the northwestern part of the country. The firmness of a mortar bed varies directly with the amount of lime-cement it contains.

At many places there is a massive ledge of very dense, hard, buff-gray limestone at the top of the Ogallala formation. The thickest ledge in Smith County is about 3 feet. This material crops out most extensively in the northwest corner of the county, but in the southeast corner there are several small outcrops of a thin (usually less than 0.5 foot)

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

light brownish-gray limestone that is somewhat less dense and contains scattered sand grains and irregular tan-brown siliceous concretions.

One bed of volcanic ash of the Ogallala formation is mapped as a prospect pit (va 1, pl. 1) in the NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 32, T. 1 S., R. 14 W. The material is light gray, very fine-textured, and in a lenticular layer. The beds of volcanic ash are accumulations of wind-blown particles ejected during the explosive phase of a volcanic eruption. The ash tends to settle in the low places of the land surface, such as valley floors and lake bottoms. It is probable that other lenses of volcanic ash occur in the Ogallala within the county but are concealed by younger stratigraphic units.

Lenses of quartzite are numerous and conspicuous in the Ogallala formation in other parts of north-central Kansas. In Smith County, however, this phase of the formation is poorly represented. Several small ledges project from the floor of a sand and gravel pit (ma 5, table 1 and pl. 1) in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 19, T. 2 S., R. 13 W. The quartzite consists of sand and gravel rather firmly cemented by interstitial deposits of silica. The color is greenish yellow. The most extensive outcrop of quartzite caps a low hill 6 miles east of Smith Center in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 3 S., R. 12 W. The ledge, about 3 feet thick, is composed of silica-cemented sand with some included gravel-size particles and occasional blocks of silicified chalk. The quartzite is green, quite hard, and forms a massive layer. The quantity of quartzite is too limited to consider this outcrop as a source of construction materials, although there is evidence that the ledge was once quarried.

Representative measured section.--The following section of the Ogallala formation was measured in a road cut in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 1 S., R. 15 W.:

	<u>Feet</u>
Soil, numerous included mortar-bed fragments.....	<u>0.5</u>
Ogallala formation:	
Sand, fine-grained, calcareous but poorly consolidated; buff.....	0.4
Mortar bed, soft, only loosely cemented; light gray to brown.....	.5
Sand, fine-grained, calcareous but poorly consolidated; light gray brown.....	.6
Mortar bed, lime-cemented sand, massive; greenish buff; weathered surfaces coarsely pitted.	1.8
Sand, fine, somewhat clayey and calcareous, poorly consolidated; light buff.....	2.4
Mortar bed, lime-cemented silty sand, massive; light gray; weathered surfaces irregular; interbedded lenses of fine green sand.....	4.4
Clay, somewhat silty and calcareous, nodular; light gray.....	1.3
Clay, somewhat silty, noncalcareous but including nodular concretions of calcium carbonate; greenish gray.....	6.0
Base covered.....	<u>17.4</u>

Thickness.--Outcrops of the Ogallala formation in Smith County range in thickness

from several inches to a maximum of about 20 feet. The estimated aggregate thickness of this formation is 100 feet.

Construction materials.--

Aggregate for concrete.
Road metal.
Mineral filler.
Volcanic ash.
Riprap.
Structural stone.
Calcareous binder.

Sanborn formation

Areal distribution.--The Sanborn formation of Pleistocene and Recent(?) age is the most extensive in its outcrop area of all mapped stratigraphic units in Smith County. (See pl. 1.) It conceals older units in many of the divide areas in the county. It is thought that silts of the Sanborn formation at one time covered the entire area of the county but subsequently have been eroded completely from many of the stream courses.

General description.--The Sanborn formation is composed of materials deposited by streams, slope wash, wind, and through the action of gravity. Frye and Fent have subdivided the formation into members.^{3/} It was not feasible to attempt the mapping of these members in the reconnaissance type of field work on which this report is based, as to do so would have required a greatly expanded field program. The treatment of the Sanborn formation, as an undivided unit seems adequate to serve the purpose of this inventory of construction materials.

The upper part of the formation is predominantly silty with occasional particles of sand and gravel size scattered throughout. Color variations, from medium gray to brown, appear to reflect ground-water drainage conditions. Where drainage is good, the formation tends to be gray, whereas in places where the subsurface drainage is less rapid, the formation tends to be brown. There is a well-developed soil zone at the top of the formation, and Hibbard, Frye, and Leonard ^{4/} have reported one or more buried soil zones in the formation. One such buried soil zone is indicated in the representative measured section of this formation. There are conspicuous amounts of calcium carbonate in the upper part of the Sanborn formation in the form of pipeline structures, concretions, or disseminated impregnation. The formation tends to stand in vertical faces, which may exhibit a crudely developed columnar structure.

Locally the basal part of the Sanborn may be coarser than the upper part, and basal lenses of sand and gravel are fairly numerous in the northern part of the county. Lenses of gravel-size particles of rounded chalky limestone occur in the base of this formation at many places where it is in contact with the Carlile shale, as it is in the southeast corner of the county.

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

^{4/} Hibbard, C. W., Frye, J. C., and Leonard, A. B., Reconnaissance of Pleistocene deposits in north-central Kansas: Kansas Geol. Survey Bull. 52, pt. 1, p. 13, 1944.

Lenses of volcanic ash were found in the basal part of the Sanborn formation in the northern half of the county. The largest of these (va 2) is listed in table 1 and mapped on plate 1. The material is light gray, exceedingly fine-textured, and relatively free from extraneous particles. Other lenses noted in the field are too small to be exploited.

Shells of fossil snails (gastropods) were collected from several outcrops of the formation. Fragments of fossilized vertebrate skeletons, including the complete skull of a lion and several camel teeth, were found by the field party.

It is probable that the Sanborn formation was deposited during at least two different depositional cycles. That part of the formation lying on the higher divides may have been deposited first by streams, slope wash, and the wind. A lower and more recent level of deposition by the same agents may have resulted in the somewhat less extensive deposits along the sides of the larger stream valleys and over the crests of the lower divides. The two levels of deposits of the Sanborn are mapped as a single unit because, in many places, the contact between the two is indistinguishable, owing to the transportation of material from the upper level onto the border area of the lower level.

Representative measured section.--The Sanborn formation, in a typical expression, is exhibited in a road cut in the SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 8, T. 2 S., R. 2 W.

	<u>Feet</u>
Sanborn formation:	
Silt; dark brown; soil zone developed in the upper part.....	3.0
Silt, somewhat clayey, powdery, pipe-like concretions of calcium carbonate scattered irregularly throughout; weathered surface develops crude columns; fossil shells of snails.....	5.4
Soil zone; brown to dark brown; calcium carbonate streaks.....	1.0
Silt, rather porous; brown.....	4.6
Silt; light brown; numerous pipe-like concretions and nodules of calcium carbonate.....	1.0
Base covered.	15.0

Thickness.--Outcrops of the Sanborn formation vary considerably in thickness but usually are less than 25 feet. It is estimated that the formation is thickest in the north-central part of the county, where a maximum of about 100 feet may be reached.

Construction materials.--

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

Terrace deposits

Areal distribution.--Extensive terrace deposits have been laid down in the valleys of the North Fork Solomon River and its principal tributaries. (See pl. 1.) The terraces reflect two well-defined depositional cycles but are mapped as a single stratigraphic unit because their constituent materials are similar. The upper terrace level is the more extensive.

The deposits in the valley of the North Fork Solomon River vary in width from 1.5 to 3 miles. Those in Oak Creek Valley are about 2 miles wide in the mouthward part of the valley and become progressively narrower toward the head of the creek. The terraces of Beaver Creek are about 1.5 miles wide at the maximum. Terraces in the valleys of the other principal tributaries generally are less than a mile wide. Small fingerlike deposits extend into the valleys of many of the smaller tributaries.

General description.--The terrace deposits overlie all older formations with an intervening erosional break. (See fig. 2.) The exposed part of the terrace is composed predominantly of silt, with interbedded lenses of fine sand and, occasionally, clay. The basal part of the formation does not crop out, but from evidence gathered along other streams in north-central Kansas it appears to be somewhat coarser than the upper part, including more extensive lenses of interbedded sand and some of gravel.

Representative measured section.--The following section was measured in a cut bank in the terrace deposits along the North Fork Solomon River in the SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 6, T. 5 S., R. 14 W.:

	<u>Feet</u>
Soil zone.....	1.2
Terrace deposits:	
Silt, some very fine sand, powdery; dark gray.....	1.1
Silt; gray brown; appears to be a buried soil zone.....	1.3
Silt, powdery, stains and streaks of calcium carbonate; light gray...	.6
Silt, powdery; light gray.....	1.8
Clay, blocky; gray brown.....	.9
Silt; light gray; limonite-stained; stains and streaks of calcium carbonate.....	.6
Clay, blocky; gray brown.....	1.1
Silt, powdery; light gray; stains and streaks of calcium carbonate.....	3.0
Base covered.	10.4

Thickness.--The thickness of the terrace deposits could have been determined accurately only by test drilling, and test-hole data are not available for Smith County. The total thickness of the terrace deposits in the valley of North Fork Solomon River is estimated to be about 100 feet. The maximum thickness in the tributary valleys probably does not exceed 40 or 50 feet, except near the junctions of the tributary valleys with the main valley.

Construction materials.--

Aggregate for concrete.
Road metal.
Mineral filler.

Alluvium

Areal distribution.--The deposits formed by streams in their present gradational cycles are mapped as alluvium and constitute the most recent stratigraphic unit in the county. (See pl. 1 and table 1.) Alluvium is defined in this report as the material underlying the present floodplain of a stream. The floodplain is the area adjacent to the stream channel that is covered by water during a normal flood stage. Alluvium is mapped along the Solomon River only. Alluvial deposits are present along parts, at least, of some of its

larger tributaries but are generally so narrow they could not be mapped on the scale of the base map, plate 1 (1 inch equals 1 mile). The alluvium in the valley of the North Fork Solomon River varies in width from about 0.1 to 0.9 mile.

General description.--The material composing the alluvium of the valley of the North Fork Solomon River is quite sandy but locally may be composed predominantly of silt. There are interbedded lenses of chalk and shale fragments. The color of the material indicates in a general way the sand content. Where sandy, the alluvium is tan; where silty, the alluvium is brown.

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

Thickness.--It is estimated that the maximum thickness of the alluvium in the river valley is about 60 feet.

Construction materials.--
Aggregate for concrete.
Road metal.

INVENTORY OF CONSTRUCTION MATERIALS

General

This part of the report inventories the construction materials in Smith County. Its objectives are to establish the bases upon which the construction materials are classified and to analyze the relations of the various materials to the stratigraphic units in which they occur.

All available laboratory test data have been introduced into the report to aid in the evaluation of the materials. This information, given in table 1 is based on standard testing procedures of the American Association of State Highway Officials and the State Highway Commission of Kansas.^{5/} It is expected that the 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 exploitation for specific uses.

Although numerous prospect pits and quarries were located in the field, no attempt was made to complete an exhaustive survey.

^{5/} 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.

The purposes of this report are to inventory the construction materials that occur in Smith County and to establish the geologic pattern required for the location and development of materials at the places in the county where they may be needed. A certain stratigraphic unit may contain one or more construction materials; if the geologic factors of that occurrence are established, the resultant knowledge of the geologic pattern will facilitate the discovery of additional sites.

Aggregate for concrete

Engineering and geologic characteristics

Aggregate for concrete is distinguished as fine aggregate and mixed aggregate in table 1 and on plate 1. The distinction is an arbitrary one based on the percentage of material retained on a standard no. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. The material sampled is classified as a mixed aggregate if the coarse fraction is 5 percent or more by weight of the whole sample; as a fine aggregate if the coarse fraction is less than 5 percent. Fine and mixed aggregates will be discussed together under the heading Aggregate for concrete, because the grading of almost any aggregate material may be changed by sweetening or by screening to conform to required specifications.

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

The materials reported in this classification are exposed at the surface or are under unconsolidated overburden sufficiently thin that they may be economically exploited. Relatively inaccessible deposits or deposits of sand and gravel overlain by thick or consolidated beds are not included in this classification because of the added expense in the removal of the material.

Stratigraphic sources and performance characteristics

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

(1) Ogallala formation.--Three operated or prospect pits for fine aggregate (fa 2 to 4) are listed in table 1 and mapped on plate 1. Six actual or potential pit sites for mixed aggregate (ma 2 to 7) are also listed and mapped. The Ogallala formation is probably the most important source of aggregate for concrete in Smith County. Many deposits of material of this classification probably are present in the northern half of the county but lie concealed beneath an overburden of Sanborn formation. Prospecting undertaken near the heads of the draws in the

northern half of the county where the overburden of Sanborn is thinnest probably would prove profitable.

The coarse fraction of the Ogallala formation samples analyzed is composed predominantly of fragments of soft, rounded local chalk (Niobrara formation), and subordinately of fragments of basic igneous rocks and chert and minor amounts of feldspar and quartz particles and limonite nodules. The high percentages of local chalk fragments and of chert particles probably would mitigate against the use of this material as aggregate for concrete. Chert is usually considered to be a deleterious substance because of its chemical reactivity with standard cement. The unusual concentration of chalk fragments in the Ogallala formation probably is related to its contact with the underlying Niobrara formation, the source of the chalk, and to the fact that, in Smith County, sand and gravel zones occur only in the basal part of the Ogallala. Farther west in Kansas sand and gravel zones are found at higher levels within the Ogallala and include markedly lower percentages of deleterious local materials. The fine fractions of the Ogallala samples analyzed are composed predominantly of quartz, some feldspar and chalk, and minor amounts of particles of carbonate minerals and basic igneous rock and chert.

The test characteristics of the materials sampled indicate an average weight of 107 pounds per cubic foot; an average specific gravity of slightly less than 2.6; a compression ratio after one day of about 1.15, after three days of about 1.2; and a gradation factor of about 2.1. One sample (ma 4) tested for loss by the Los Angeles abrasion method showed 34.2 percent and a soundness ratio of 0.73 after 25 freeze-and-thaw cycles. The average gradation factor for the samples of fine aggregate tested is 2.4; weight per cubic foot, 102 pounds; specific gravity, 2.56; and compression ratio after one day, 1.05, after three days, 1.5.

(2) Sanborn formation.--Two samples of fine aggregate (fa 5 and 6) and one of mixed aggregate (ma 1) were taken from the Sanborn formation. The mineral analyses indicate that the coarse fraction is composed almost entirely of fragments of either mortar-bed or chalk and that the particles of which the fine fraction is composed are predominantly quartz, with some mortar-bed and chalk and minor amounts of feldspar. The results of tests on the 3 samples (table 1) are not considered adequate as a basis for computing average values of aggregate materials from the Sanborn.

The sources of the aggregate materials in the Sanborn formation are lenses, usually in its basal part. Additional pit sites may be found where streams have cut well down into this formation and have exposed the basal part. It is doubtful if the Sanborn formation would be the source of high quality aggregate for concrete.

(3) Terrace deposits.--No materials classified as mixed aggregate were found in the terrace deposits, but two of the samples analyzed (fa 1 and 7) are classified in table 1 as fine aggregate. Test data for sample fa 1 indicate that the fine fraction is composed predominantly of particles of quartz, with

only minor amounts of carbonate mineral and feldspar. A mineral analysis of sample fa 1 was not made. Laboratory test data, based on 2 samples only, are not adequate to indicate the average characteristics of sands and gravels in the terrace deposits.

(4) Alluvium.--One attempt to develop alluvial deposits for aggregate was observed in the Solomon River flood plain, but apparently the material was so unsatisfactory that the operation was abandoned. Examination of spoil from the pit indicates that alluvium at this place (center SW $\frac{1}{4}$ sec. 5, T. 5 S., R. 14 W.), contained too many fragments of shale and soft limestone. It is possible that very local lenses of material of a quality satisfactory for aggregate might be found in the alluvial deposits of the valley of North Fork Solomon River by augering or test drilling to some distance below the surface. The upper part of the alluvium is composed of very fine sand or of silt, neither of which is suitable aggregate material.

Road metal

Engineering and geologic characteristics

Road metal, known also as surfacing material, is defined in this report as any material that may be applied to a road to improve the performance characteristics of the road surface. Many geologic materials fulfill this requirement, and the list of such materials will vary from one area to the next. The following geologic materials have been used or are available for use in Smith County as road metal:

(1) Aggregate.--The mixed and fine aggregates discussed as materials for concrete, as well as other similar materials, have been used as road metal. The present practice, however, is to procure aggregates for road construction from pits along the Republican River in Nebraska because of the limited quantities of suitable materials now known in Smith County.

(2) Crushed rock.--Indurated rocks that have been used or are available in Smith County for use as road metal are (a) limestone, a compact, massive layer of calcareous material; (b) mortar bed, a compact, massive layer of sand and/or gravel firmly cemented by calcium carbonate; (c) silicified chalk, a calcareous rock that has been altered to silica by the action of percolating ground water; and (d) quartzite, a massive hard rock in which sand and/or gravel have been firmly silica-cemented by the action of percolating ground water.

These materials are listed in table 1 and mapped on plate 1 under their names limestone, mortar bed, silicified chalk, and quartzite because, in addition to their use as road metal, they may be used as structural stone and riprap.

(3) Limestone gravel.--Limestone gravel, as defined by the State Highway Commission of Kansas, is a sedimentary material composed of rounded fragments of local limestones, usually about 3/4 of an inch long, incorporated in a matrix of silt-size particles. Limestone gravel is extensively used throughout north-central Kansas as road metal, especially on secondary roads.

Stratigraphic sources and
performance characteristics

(1) Aggregate for concrete.--The materials discussed previously as aggregate for concrete have been used as road metal on secondary roads in Smith County, and field observation indicates that they are adequate for this purpose. There is no record, however, of the use of such aggregate in the construction of roads of the black-top type. The sources of these materials have been discussed under Aggregate for concrete.

(2) Crushed rock.--

(a) Niobrara formation. The Fort Hays limestone and Smoky Hill chalk members of the Niobrara formation have been quarried, crushed if necessary, and applied to local secondary roads. The Fort Hays limestone has been used as road metal on two county roads, one extending east from U. S. 281 along the northern boundary of the southernmost tier of townships and the other extending south from U. S. 36 along the line between secs. 20 and 21, T. 3 S., R. 12 W., to the south boundary of the county. The limestone usually is quarried from the shattered zone of the Fort Hays limestone and applied directly to the road. It is rolled in place, wetted down, and bladed to form a traffic-bound macadam. The road is maintained by blading only. The Fort Hays limestone, from field observation, forms an excellent all-weather road. Even during and after a heavy rain it stands up well with only a slight tendency toward sloughing and rutting. Its only disadvantage is that after prolonged spells of dry weather the macadam tends to powder and be blown away from the road as each vehicle passes over it. It is possible that a seal coat might be adequate to control the dusting tendency. Experimental construction in which a bituminous-mat wearing course was placed on the limestone macadam indicates that when so covered the limestone tends to accumulate moisture in its upper part with the result that the road fails. Apparently some moisture must be permitted to escape from the macadam by transpiration. Calcium chloride is sometimes used on roads of similar type as an anti-dusting agent, but to be effective, the humidity must be 50 percent or more, an unusual climatic condition in north-central Kansas. In addition to using rock from the shattered zone in the Fort Hays limestone, the massive layers might be quarried, crushed to the proper size, and applied. This practice has been observed in other counties in north-central Kansas.

Traffic-bound macadam constructed of the Smoky Hill chalk member was observed on portions of a county road extending east and west for short distances from the north edge of Lebanon. This macadam seems to perform adequately in dry weather, but it is thought, though not observed in the field, that its wet-weather characteristics would be inferior to those of macadam constructed of the Fort Hays limestone member. The test characteristics of the Fort Hays limestone are indicated for one sample, ls 4, in table 1 and those of the Smoky Hill chalk by samples ls 2 and 3. Many operated and prospect pits are scattered throughout the county in both members of the Niobrara formation, and additional quarries could be opened at any convenient site within the area of outcrop. The quantity of material available is almost unlimited.

Material from the silicified zone often found in the Smoky Hill chalk has been quarried, crushed, and applied to two of the county roads in Smith County. One road metaled with silicified chalk extends east and west from Reamsville. The chalk was quarried in the NW $\frac{1}{4}$ sec. 26, T. 1 S., R. 14 W. (sc 2, table 1 and pl. 1). The other road extends 9 miles westward from U. S. 281 along the line between secs. 10 and 15, T. 1 S., R. 11 W. The silicified chalk for it was quarried in the SW $\frac{1}{4}$ sec. 18, T. 1 S., R. 12 W. (sc 1, table 1 and pl. 1). Field examination indicates that the crushed silicified chalk performs very well as a loose surfacing agent, although the sharp edges of the particles might cut tires excessively.

(b) Ogallala formation. A county road extending north from Kensington to the Nebraska line along the section line between secs. 20 and 21, T. 3 S., R. 15 W., was metaled with crushed limestone taken from the top of the Ogallala formation. This limestone, however, is so hard that it does not break down under traffic to form a macadam. Field observation indicates that loose road metal of this type performs adequately on secondary roads. One sample of the material (ls 1) was tested and the results recorded in table 1.

Mortar-bed ledges in the Ogallala formation in Kansas have been quarried and the crushed material applied to secondary roads in other north-central Kansas counties. The sand and gravel particles in the mortar bed are bound by calcium-carbonate cement to form a low-grade traffic-bound macadam. Mortar-bed ledges crop out on many hillsides in the north-west corner of the county, and one sample (mb 1) has been analyzed and reported in table 1. Several additional prospects are mapped on plate 1.

Ledges of quartzite in the Ogallala formation in other counties in north-central Kansas have been quarried, and the resultant material has been crushed and applied as a surfacing agent to secondary roads. Such use of the quartzite in this county was not observed. The only known local deposit of quartzite in which there is an adequate amount of material available is listed in table 1 (q 1) and mapped on plate 1. The quartzite as it has been observed in other areas makes an adequate road metal. Field observation indicates, however, that the quartzite should be crushed so that the largest dimension of the particles is less than half an inch. Particles larger than this tend to kick out from the road. Field observations also indicate that a binder material should be added to the crushed quartzite.

(3) Limestone gravel.--Material classified as limestone gravel has been taken principally from pits opened in the Sanborn formation, but some has been taken from the terrace deposits. The test characteristics of this material are indicated in table 1 (terrace deposits, lg 2; Sanborn formation, lg 1, 3-6). Additional pits, other than those mapped on plate 1, might be located wherever limestone gravel lenses occur in the base of the Sanborn formation or in terrace deposits. Such lenses generally overlie the Carlile shale. Field observation indicates that the limestone gravel, under traffic, compacts to form a type of traffic-bound macadam. Its wet-weather characteristics, despite the high

silt content, are only slightly inferior to those of a traffic-bound macadam of the Fort Hays limestone. It has been observed, however, that roads surfaced with limestone gravel are not so subject to dusting as those on which crushed Fort Hays limestone or Smoky Hill Chalk have been 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 and/or clay. The State Highway Commission of Kansas 6/ states that the material will qualify for mineral filler only if laboratory tests indicate a low coefficient of cementation. Deficiencies of the tested samples in this characteristic are noted under Remarks in table 1. Failure of the material to pulverize easily, a factor of cementation, increases the difficulty of obtaining its uniform distribution throughout the structure.

Stratigraphic sources and performance characteristics

The analyses of four samples of material classified as mineral filler are listed in table 1. Two of these, mf 1 and 2, were obtained from the Sanborn formation and two others, mf 3 and 4, from the terrace deposits.

(1) Sanborn formation.--The sieve analyses of the samples of mineral filler from the Sanborn formation indicate that this material is acceptable, but in both samples the cementation factor is probably excessive. The cementing substance is calcium carbonate, material often found disseminated through the B zone of the soil profile. The B zone is a relatively heavy-textured zone characterized by the accumulation of salts, colloids, and particles of clay size as a result of the action of percolating subsurface waters. It is probable that the material in the formation below the B zone has only limited amounts of calcium carbonate and that its cementation factor, therefore, is relatively low. Because the Sanborn formation is so widespread in Smith County, only a few of the mineral-filler prospects are mapped on plate 1. Pits can be opened in this formation at almost any convenient site throughout the northern half of the county. In the southern half, however, the Sanborn is markedly thinner and probably contains excessive amounts of calcium carbonate.

(2) Terrace deposits.--Terrace deposits are the second most important source of mineral filler in Smith County. The sediments composing these deposits are predominantly of silt size. One sample tested, mf 3 in table 1, shows a high cementation factor, but the other, mf 4, is acceptable in this respect. Both of the samples tested fall within the required gradings for mineral filler. Pits could be opened throughout most of the outcrop area of the terrace deposits.

(3) Alluvium.--A third potential source of mineral filler is in the alluvial deposits of the larger streams in Smith County. These deposits are composed predominantly of silt-size particles. In view of the widespread availability of mineral filler in the Sanborn formation and the terrace deposits, it is doubtful that it would be economical to open pits in the alluvium, as much of the material includes lenses of sand and gravel and is below the local water table.

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 can be put to certain uses for which the usual silty filler is unsuitable. Volcanic ash consists predominantly of the fine, glass-like shards ejected during the explosive phase of a volcanic eruption. The material may include silt-size particles of other origins and occasional thin seams of gravel and sand.

Stratigraphic sources and performance characteristics

(1) Ogallala formation.--Lenticular beds of volcanic ash of very local extent were found in the Ogallala and Sanborn formations in Smith County. One prospect pit in the Ogallala formation (va 1) in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 32, T. 1 S., R. 14 W., is listed in table 1 and mapped on plate 1. The ash is light gray and powdery but contains about 3 percent of coarse sand and gravel particles. The bed, which is about 3 feet thick, is covered by a very thin overburden. Other lenses of volcanic ash probably occur in the basal part of the Ogallala formation and may be located by intensive exploration of this formation in the northern half of the county, particularly near the heads of draws where the overburden of Sanborn is relatively thin.

(2) Sanborn formation.--A thick lens of volcanic ash in the Sanborn formation in the NW $\frac{1}{4}$ sec. 31, T. 3 S., R. 15 W., is listed in table 1 (va 2) and mapped on plate 1. The ash is light gray, powdery, and composed predominantly of material that has washed through the no. 200 sieve. Other lenses of volcanic ash of very limited extent were observed in the base of this formation in Smith County. Additional sources probably can be located if the basal part of the Sanborn formation is explored intensively in places where streams have cut deep valleys into the formation.

Riprap

Engineering and geologic characteristics

Riprap, as defined in this report, is any material suitable for protecting earthen fills from erosion. To be acceptable for this use the material must be relatively sound and free from cracks and other structural defects or impurities that would cause it to disintegrate through erosion, slaking, or freeze-and-thaw. It is desirable that the material be in blocks having approximately rectangular faces 7 inches or more in width

6/ Horner, S. E., chief geologist, State Highway Commission of Kansas, letter dated Jan. 4, 1947.

and that the specific gravity be 2.0 or higher.

Stratigraphic sources and performance characteristics

(1) Ogallala formation.--Several materials in the Ogallala formation might be suitable for use as riprap. Laboratory test data for these materials, quartzite (q 1), mortar bed (mb 1), and limestone (ls 1), are listed in table 1. The soundness ratio of the quartzite is 0.95 and the specific gravity is sufficiently high that the material is satisfactory in these respects for use as riprap on a dam. Field observations of dams in north-central Kansas riprapped with quartzite indicate that it is eminently satisfactory in its performance characteristics. Quartzite riprap of a dam examined in Phillips County shows no appreciable deterioration 6 years after its installation.

The test characteristics of a sample of mortar bed from the Ogallala formation, as given in table 1, indicate that it is sound (ratio of 0.92 after 25 freeze-and-thaw cycles) and has a sufficiently high specific gravity (2.3) to be used as riprap. Water absorption is only moderate (4.53 percent). A slaking test was not run on this sample, but field observation of weathered mortar-bed ledges indicates that some of this material might disintegrate if immersed in water and that most mortar-bed ledges are less compact than the one sampled. Mortar beds are widespread throughout the northwest corner of the county, and the material is available in at least moderate quantities. Before being accepted as a riprap for dams, however, samples should be subjected to the standard laboratory tests for slaking, abrasion, and soundness.

The nodular limestone layer found locally at the top of the Ogallala formation might also be considered as riprap material. As indicated in table 1 (ls 1), its soundness ratio is 0.53, its Los Angeles abrasion loss is 52.8 percent, its water absorption is 10.8 percent, and its specific gravity is 1.9. These test data indicate that the nodular limestone is a riprap material of doubtful value. It is abundantly available in the northwestern part of Smith County, but samples should be laboratory tested before the material is accepted as riprap.

(2) Smoky Hill chalk member of Niobrara formation.--The silicified chalk zone found locally at the top of the Smoky Hill chalk member is a potential source of material for riprap. The test characteristics of the samples (sc 1 and 2) are listed in table 1. Its specific gravity is sufficiently high, its water absorption is quite low, and it is sound. This stratigraphic unit appears to be the one of greatest potential value as a source of riprap in Smith 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 cut to desired size and shape. Materials fulfilling these requirements occur in the Fort Hays limestone member of the Niobrara formation and in the Ogallala formation.

Stratigraphic sources and performance characteristics

(1) Fort Hays limestone member of Niobrara formation.--Blocks of Fort Hays limestone are used extensively throughout north-central Kansas as structural stone for the construction of dwellings and farm buildings. The limestone is quite soft but hardens after being cut, and structures built of it seem to stand up well in the relatively dry climate of north-central Kansas. Field observations indicate that the Fort Hays limestone should not be used in any place where it will be subjected to water saturation unless it has been protected by a cement cover coat. This stone deteriorates rapidly in the presence of water, either by slaking or freeze-and-thaw. The test characteristics are given for one sample of limestone collected from this stratigraphic unit (table 1, ls 4).

(2) Smoky Hill chalk member of Niobrara formation.--The test characteristics of the silicified material locally present at the top of the Smoky Hill chalk member (table 1, sc 1 and 2) indicate that this material is acceptable as structural stone. In the quarrying operation, however, the stone appears to shatter excessively because of its brittleness. This characteristic, in addition to the difficulty of shaping the stone because of its hardness, would probably make the material of doubtful value for use as structural stone.

(3) Ogallala formation.--Quartzite ledges in the Ogallala formation have been quarried extensively in north-central Kansas for structural stone. Numerous city and county buildings and several bridges constructed of this material were observed in the field. The opinion has been expressed that the opal in the quartzite is reactive with standard cement to the detriment of the structure in which the quartzite is used as a structural stone or as a constituent of concrete aggregate. No field evidence of this type of failure was observed, however. The stone is sufficiently hard to cause difficulty in cutting it to required size and shape.

Occasional use of hard mortar-bed ledges in the Ogallala formation as structural stone for farm buildings, such as barns, was observed in north-central Kansas. Its test characteristics (table 1, mb 1) indicate that it might be acceptable for this use, but field observations show that the ledges are not uniformly hard and that structures built of mortar bed may deteriorate appreciably within a relatively short time if the stone used is below standard.

The hard compact limestone layer locally present at the top of the Ogallala formation has been used occasionally as a structural stone. The test characteristics of the material indicate that it is acceptable for this use. A church in New Almelo, in the southwest corner of Norton County, was built of this material, and although the stone is not especially pleasing in appearance, it has stood up very well over a long period of time.

Calcareous binder

Engineering and geologic characteristics

To be classified as calcareous binder a 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. Two local stratigraphic units are sources or potential sources of calcareous binder.

Stratigraphic sources and
performance characteristics

(1) Niobrara formation.--Both the Smoky Hill chalk and the Fort Hays limestone members of the Niobrara formation have been accepted by the State Highway Commission of Kansas as sources of material suitable for use as calcareous binder. The test characteristics of selected samples from the Niobrara formation are presented in table 1 (ls 2 to 4).

The chalks and chalky limestones are soft, easily pulverized, and free from deleterious substances. The Niobrara formation is the most widespread source of calcareous binder in Smith County and quarries could be opened in the formation at any convenient site throughout the area of its outcrop. (See pl. 1.)

(2) Ogallala formation.--Mortar-bed ledges in the Ogallala formation have been accepted as calcareous binder by the State Highway Commission of Kansas. Although the one ledge sampled in Smith County is too hard for this use, many others are soft enough to be easily pulverized and would serve adequately as a binder material.

Table 1. Summary of materials tests

(Blank spaces indicate data not available)

Classification of the material	Number on plate	Location				Estimated quantity of material (cubic yards)	Average thickness (feet)	Accessibility	Geologic formation or member	Authority for test data	Date of test	Sieve analysis							Description of the material ²										Laboratory test data										Remarks										
		1/4 fraction	1/4 section	Section	Township (S)							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 (Fines)	Fraction	Quartz	Feldspars	Acid rocks	Basic rocks	Mortar bed	Carbonate	Chalk	Silicified chalk	Quartzite	Chert and/or chertstone	Complete sample	Weight per cubic foot (pcf)	Specific gravity (saturated)	Gravimetric factor	Compressive strength ratio	Factor	Day	Day	Day	Los Angeles (percent loss)		Soundness (25 cycles)	Toughness	Cementation	Absorption	Liquid limit	Plasticity index				
Fine aggregate	fa1	NW	NE	30	1	14	10,000	5	2-4	Good	Terrace deposits	SHCK	1-46	0	2	4	14	72	21													1070	2.6										Excessive percentage of wash.						
	fa2	SW	SW	30	2	11	10,000	10	0-1	do	Ogallala	SHCK USGS	7-47	0	1	2	10	91	8.06		C 4												1019	2.59	2.3	1.08	1.07							Concealed by Sanborn formation; high percentage of wash.					
	fa3	SW	NW	36	2	12	15,000	10	0-3	do	do	do	do	0	1	2	22	96	2.2		C 10	3			15	55							1078	2.6	2.84	1.19	1.11												
	fa4	NW	NW	17	2	13	5,000	8	0-4	do	do	do	do				0	10	89	7.74		C 7	7			33								99.6	2.49	2.32	0.88	0.97							High percentage of wash.				
	fa5	SW	NW	4	3	13	5,000	5	0-4	do	Sanborn	do	do	0	1	3	13	91	5.77		C 1	1													101.1	2.58	2.13	0.91	0.97							High percentage of wash.			
	fa6	NW	NW	31	3	15	2,000	3	2-4	Fair	do	SHCK	4-43				0	2	33	56.2														93.4	2.52	0.62									Excessive percentage of wash; probably should be classified as mineral filler.				
	fa7	NW	SW	3	5	15	5,000	4	0-1	Good	Terrace deposits	SHCK USGS	7-47				0	89	6.86		C 9	3												100.3	2.58	1.58	0.87	0.81							High percentage of wash.				
Mixed aggregate	ma1	NE	NE	5	1	15	10,000	4-5	1-3	do	Sanborn	do	6-47	1	5	9	32	92	6.86		C 2													103.5	2.09	2.84	1.12	0.97							High percentages of wash and, in coarse fraction, mortar-bed fragments.				
	ma2	NE	NW	31	2	12	40,000	6	2-5	do	Ogallala	do	do	0	2	6	36	93	6.24		C 3	8	8	18										108.2	2.56	3.06	1.04	1.06							Concealed by Sanborn formation; high percentages of wash and, in coarse fraction, chalk fragments and limonite nodules.				
	ma3	SW	NW	17	2	13	10,000	5	0-5	do	do	do	do	0	3	5	28	91	6.9		C 3	9					3	70							106.2	2.49	2.81	1.22	1.21							Concealed by Sanborn formation; high percentages of wash and, in coarse fraction, chalk and chert fragments.			
	ma4	NE	SE	18	2	13	8,000	4-5	2-4	do	do	SHCK	11-41	0	1	5	36	96	3.4		C 6	6													105.0	2.6	3.25	1.25	0.87	34.2	0.73					Concealed by Sanborn formation; unsound in freeze-and-thaw test.			
	ma5	NW	NE	19	2	13	150,000	6	0-3	Fair	do	SHCK USGS	7-47	0	2	5	39	96	3.17		C 6	6													105.3	2.54	3.17	1.28	1.27							Concealed by Sanborn formation; high percentages of chalk and chert fragments in coarse fraction.			
	ma6	C	SW	35	2	13	30,000	5	2-4	Good	do	do	do	do	0	1	5	41	97	2.23		C 1	9												110.7	2.62	3.32	1.18	1.24							Concealed by Sanborn formation; high percentage of chalk fragments in coarse fraction.			
	ma7	NE	NE	36	2	13	10,000	4	1-2	do	do	do	do	1	4	9	32	94	5.09		C 10	3													107.8	2.6	2.93	1.01	1.23							Concealed by Sanborn formation; high percentages of wash and, in coarse fraction, chalk and chert fragments and limonite nodules.			
Mineral filler	mf1	SW	SE	26	1	12	150,000	10	3-4	do	Sanborn	do	8-47				0	1	97.2														83.9	2.52											High cementation factor.				
	mf2	NW	SE	31	1	14	150,000	10	1-2	do	do	do	do				0	3	96.0																76.2	2.56											High cementation factor.		
	mf3	NE	SW	5	5	14	150,000	10	0-1	do	Terrace deposits	do	7-47				0	7	88.6																	76.7	2.6											High cementation factor.	
	mf4	NW	NW	13	5	14	150,000	10	1-2	do	do	do	8-47				0	2	95.2																	85.5	2.53												
Volcanic ash	va1	NW	SW	32	1	14	1,500	3	0-2	do	Ogallala	SHCK	11-41	0	1	3	11	79.0																56															
	va2	NW	NW	31	3	15	10,000	10	2-4	do	Sanborn	SHCK USGS	6-47				0	3	90.8																58.3	2.35													
Limestone gravel	lg1	SE	SE	8	2	13	5,000	4	1-3	do	do	do	7-47	0	5	17	55	96	3.29															109.6	2.57	3.73	1.04	1.05								18	17		
	lg2	NW	NW	26	4	14	15,000	4-6	0-3	do	Terrace deposits	do	do	2	14	29	56	91	8.0																	95.3	2.49	3.93										17	5
	lg3	SE	NW	35	5	11	5,000	4	0	do	Sanborn	do	8-47	4	13	34	66	76	21.7																	3.91												2.6	13
	lg4	NE	NE	23	5	13	5,000	4	0	do	do	do	do	0	9	27	53	62	36.4																	3.10												2.8	11
	lg5	NW	SE	29	5	13	20,000	4-6	0-1	do	do	do	7-47	4	20	39	57	63	36.1																	3.55												3.2	17
	lg6	SE	NE	9	5	14	3,000	3-4	1	Fair	do	do	do	8-47	15	31	50	76	90	9.1															5.00												3.6	14	
Limestone	ls1	NW	NE	28	1	15	20,000	3	1-3	do	Ogallala	do	6-47																					1.9												10.8			
	ls2	SW	SW	14	2	11	40,000	10	0-3	Good	Smoky Hill chalk	do	7-47																							1.61												23.3	
	ls3	NW	SW	32	2	14	30,000	10	0-3	do	do	SHCK	11-41																							89.6												100	
	ls4	SW	NW	36	4	15	150,000	42	0-3	do	Fort Hays limestone	SHCK USGS	7-47																							1.77											1796		
Studies in chalk	sc1	SW	SE	18	1	12	100,000	3-6	0-4	Fair	Smoky Hill chalk	SHCK	4-37																					2.22													Sound at 50 cycles; Deval abrasion loss, 7.3 percent.		
	sc2	NW	NE	26	1	14	150,000	12	0-2	Good	do	do	5-46																							2.42												1.61	
Mortar bed	mb1	NW	SW	28	1	13	100,000	3	0-3	do	Ogallala	SHCK USGS	6-47																							2.3												4.53	
	qt1	NE	NE	21	3	12	5,000	3	1-3	do	do	do	do																						2.32												1.73		
Quartzite																																					2.32												

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.

² C, Coarse fraction, retained on No. 4 sieve; F, fine fraction, passed through No. 4 sieve; Tr, trace.

