GEOLOGICAL SURVEY CIRCULAR 24

April 1949

CONSTRUCTION MATERIALS IN NORTON COUNTY, KANSAS

By

Frank E. Byrne, Henry V. Beck, and Charles H. Bearman

PREPARED IN COOPERATION WITH
STATE HIGHWAY COMMISSION OF KANSAS
R. C. Keeling, State Highway Engineer
S. E. Horner, Chief Geologist

UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary
GEOLOGICAL SURVEY
W. E. Wrather. Director

WASHINGTON, D. C.

Free on application to the Director, Geological Survey, Washington 25, D. C.

CONSTRUCTION MATERIALS IN NORTON COUNTY, KANSAS

By

Frank E. Byrne, Henry V. Beck, and Charles H. Bearman

CONTENTS

ILLUSTRATIONS

Page

TABLES

Page

INTRODUCTION

Purpose of the investigation

The State Highway Commission of Kansas and the United States Geological Survey are cooperating in the compilation of a Statewide inventory of construction materials. A field party composed of personnel from the two cooperating agencies was sent into Norton County, Kans., in the summer of 1947 to investigate sources of engineering construction materials. This report of the Norton County investigation is a part of the Statewide inventory and a contribution to the geologic mapping and mineral resource investigations 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 Norton 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 materials required for future engineering needs.

Area covered by the investigation

Norton County is in the first 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 885 square miles. The country is bounded by parallels 39°34' and 40°00' north latitude and meridians 99°37.5' and 100°11' west longitude. It is bounded on the east by Phillips County, on the west by Decatur County, on the south by Graham County, all in Kansas, and on the north by Furnas County, Nebr.

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

Geography of the area

Norton County is near the eastern edge of the Great Plains physiographic province. It has been dissected somewhat by streams flowing from the west toward the Central Lowlands physiographic province, which is to the east. The divide areas between streams usually are flat or gently rounded. The valleys of many of the principal streams and their larger tributaries are cut 150 feet or more below the general upland surface. The maximum dissection of the upland surface is in the eastern half of the county, particularly in the southeast corner. The dissection is least along the western border. The average altitude of the county is about 2,300 feet. The lowest point, about 1,980 feet, is along the North Fork of the Solomon River at the eastern boundary of the county, and the highest point, about 2,500 feet, is along the western border.

The largest stream in Norton County is the North Fork of the Solomon River, which rises about 60 miles to the west in Thomas County, Kans. This stream enters Norton County about a mile north of the southern boundary, flows slightly north of east, and leaves the county about 6 miles north of the southern boundary. Its northward-flowing tributaries are rather numerous but short, most of them 3 to 5 miles in length. The southward-flowing tributaries are longer, 7 to 10 miles, and are only about half as numerous. Prairie Dog Creek, the next most important stream, also rises in Thomas County, enters Norton County about 12 miles north of its southern boundary, flows northeastward, and leaves the county about 6 miles from the northern border. Its tributaries exhibit the same size relationships noted for the tributaries of the North Fork of the Solomon River. The third largest stream is Sappa Creek, which rises about 90 miles to the west in Sherman County, and flows slightly north of east, cutting across the northwest corner of Norton County. The northward-flowing tributaries of Sappa Creek are relatively longer than those flowing toward the south, which is rather unusual for streams in north-central Kansas. Both Prairie Dog Creek and Sappa Creek discharge into the Republican River in Nebraska a short distance north of the Kansas-Nebraska boundary.

Norton County is served by three railways. A branch line of the Chicago, Burlington & Quincy Railroad enters from the east and

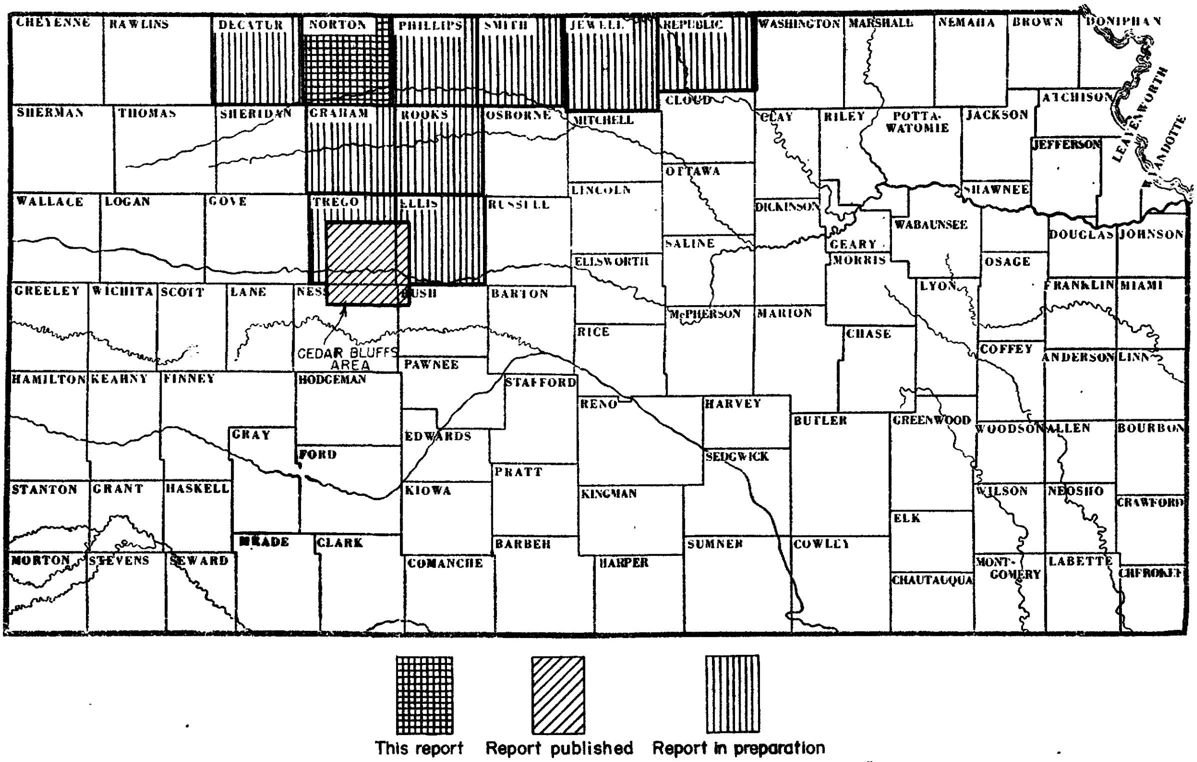


Figure 1.—Index map of Kansas showing areas covered by this and by other construction materials investigations

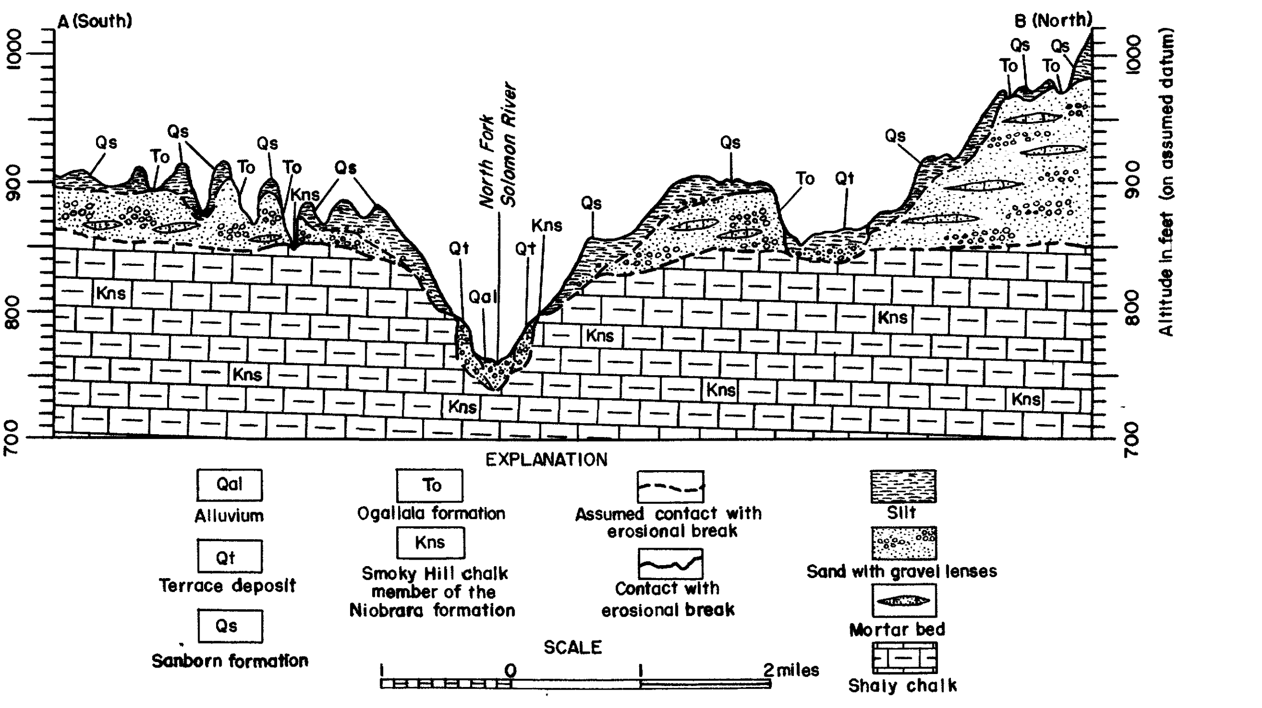


Figure 2.—Geologic cross section of the valley of North Fork Solomon River along the line between secs. 31 and 32, T. 5 S., R. 23 W., and secs. 29 and 30, T. 4 S., R. 23 W.

parallels Prairie Dog Creek to Oronoque, at which point it swings toward the north and leaves the county slightly above the midpoint of the western boundary. One of the main lines of the Chicago, Rock Island & Pacific Railroad enters the county slightly above the midpoint of the east boundary, trends toward the northwest for several miles, turns west for several more miles, and then southwest to follow Prairie Dog Creek the remainder of the way across the county. Norton, the principal city and county seat, Almena, Dellvale, and Clayton are served by these two railways. The third railway, a branch line of the Missouri Pacific Railroad, enters the county from the east and follows the Solomon River. Its terminus is in the city of Lenora. In addition to Lenora, the cities of Edmond and Densmore are located along this railroad.

Three Federal highways cross the county. U. S. 36, a major east-west transcontinental highway, enters slightly north of the center of the east boundary of the county and trends west across the county. U. S. 283 extends north and south through the center of the county and intersects U. S. 36 at Norton. U. S. 383 enters the county from the east about 6 miles south of the northern border, parallels Prairie Dog Creek until it intersects U. S. 36, follows that highway to a point 6 miles west of Norton where it turns toward the south for 3 miles, turns west again and follows Prairie Dog Creek to the west boundary of the county. Kansas Highway 9 roughly parallels the Solomon River most of the way across the county, but about 1 mile west of New Almelo it turns north for 2.5 miles before again turning west. Kansas 9 and the part of U. S. 383 in the western third of the county are metalled, all-weather roads. The rest of U. S. 383 and the other Federal highways are of the black-top type of construction. County and township roads for the most part follow section lines. Some of them are metalled with materials available locally, whereas others are maintained by grading only.

Investigation procedure

This report is based on field work of the reconnaissance type. The base map was provided by the State Highway Commission of Kansas (Highway planning map, scale 1 inch equals 1 mile). Drainage lines were added to the base map for greater ground control in mapping; these were taken from a map 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 Norton 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 subjected to routine laboratory tests at the Highway Testing Laboratory of the State Highway Commission of Kansas in Manhattan, Kans. A portion of each sample of aggregate material was analyzed under a binocular microscope in the laboratory of the Department of Geology, Kansas State College, and the constituent rock and mineral grains determined. The laboratory tests and mineralogical analyses, together with 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 his associates; State Geological Survey of Kansas, J. C. Frye, executive director; and the Norton County office of the Soil Conservation Service, U. S. Department of Agriculture.

This report, in manuscript form, was reviewed critically by S. E. Horner and by various members of the U. S. Geological Survey. Illustrations were prepared by N. Ruth Lee of the U. S. Geological Survey and by Max S. Houston 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 and C. W. Matthews of the U. S. Geological Survey. The manuscript was typed by Ruth M. Soelter of the State Highway Commission.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

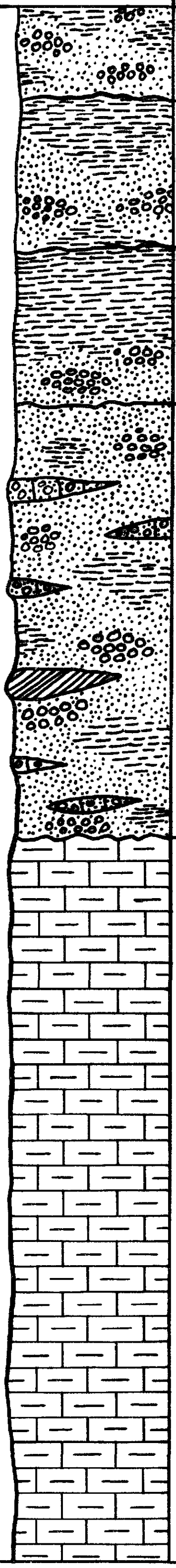
General

This discussion of the geologic formations cropping out in Norton County emphasizes the areal distribution, the general characterisitcs, and the thickness of each stratigraphic unit. One or more representative measured sections are given for each formation or member. The construction materials in each unit are listed. The measured sections are not necessarily intended to be complete but were selected to show typical outcrops of the unit in the county. The principal purpose of this part of the report is to present the geologic information required for the location and effective development of the construction materials.

The relations of the stratigraphic units to one another are illustrated on 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 Norton County, Kans.

The areal distribution of the local stratigraphic units is shown on plate 1, Map showing construction materials and geology of Norton County, Kans. Each 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 rough basis for evaluating the accessibility of sources of construction materials.

The locations of pits and quarries also are shown on plate 1. The symbols indicate whether the pit or quarry is or has been operated or is a prospect, the type of



Section	Outcrop thickness (feet)	Stratigraphic units: System	Series	Formations and members	Generalized description	Construction materials
	0-40	Quaternary	Pleistocene and Recent	Alluvium	Tan to brown silt; some sandy zones and occasional lenses of gravel.	Aggregate Road metal
	0-65	Quaternary	Pleistocene and Recent	Terrace deposits	Light-gray to brown silt; buried soil zone; basal part is more sandy and includes gravel lenses.	Aggregate Mineral filler Road metal
	0-75	Quaternary	Pleistocene and Recent	Sanborn	Light-gray, tan, and brown silt with occasional sand and gravel particles; buried soil zones; columnar structure often developed; lenses of volcanic ash, sand, and gravel in lower part.	Mineral filler Volcanic ash Aggregate Road metal
	0-200	Tertiary	Pliocene	Ogallala	Interbedded lenses of sand, gravel, silt, and clay; tan, green, and brown; thick green or brown clay shales locally present in basal part; lenticular ledges of gray mortar beds and light-green quartzites; lenses of light-gray to white volcanic ash; hard limestone locally at top.	Volcanic ash Structural stone Riprap Road metal Aggregate Calcareous binder
	600	Cretaceous	Upper Cretaceous	Niobrara formation: Smoky Hill chalk member	Chalky shales interbedded with chalks and shaly chalks; tan to blue gray in some areas, orange-colored in others; interbedded thin layers of bentonite and bentonitic shale; silicified zone locally present just below outcrop surface.	Calcareous binder Road metal Structural stone Riprap

Figure 3._Outcropping stratigraphic units in Norton County, Kans., and their construction materials

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

Smoky Hill chalk member of Niobrara formation

Areal distribution.—The Smoky Hill chalk member of the Niobrara formation (Upper Cretaceous) is the only stratigraphic unit of Cretaceous age that crops out in Norton County. (See fig. 3.) It probably underlies the entire area of the county but is concealed by younger overlying formations except along stream courses. The outcrops are most numerous along the valley walls of tributaries to the Solomon River (see pl. 1), particularly in the southeastern quarter of the county. Several small outcrops are mapped near the mouths of the streams tributary to Prairie Dog Creek in the vicinity of Norton, as in the NE¼ sec. 33, T. 2 S., R. 23 W., and the W½ sec. 10, T. 3 S., R. 23 W. Near the mouths of many other tributaries to Prairie Dog Creek this member lies close to the surface but is concealed beneath the younger formations. There are several small outcrops along the base of the valley wall of Sappa Creek, in the northwest corner of the county.

General description.—The Smoky Hill chalk member of the Niobrara formation is the only marine deposit cropping out in Norton County. Its contact with the underlying Fort Hays limestone member of the same formation is probably only a short distance below the present land surface in the southeastern corner of the county, but because the Cretaceous beds dip toward the northwest, the depth of the plane of contact increases in the same direction. An erosional break (unconformity) intervenes between the Smoky Hill and the younger beds that overlie it. At one time a still younger Cretaceous formation, the Pierre shale, was present conformably above the Smoky Hill. During a long subsequent erosional interval the Pierre shale was removed from most of the county; small erosional remnants of it are probably still present but are hidden beneath younger formations.

The Smoky Hill chalk member consists of interbedded layers of chalky shale and shaly chalk. Some of the chalk beds are massive and may be as much as 4 feet thick. The color varies markedly over the county. In the area east of Densmore the beds are light orange or yellow. North of Densmore the chalk becomes darker and ranges from a dark grayish tan to blue gray. The chalk in the vicinity of Lenora is orange-colored and locally is tinted with red. The outcrops observed along Prairie Dog and Sappa Creeks are predominantly orange yellow. The oldest beds are those in the southeast corner of the county, and the youngest are in the northwest corner.

Local lenses in the Smoky Hill chalk member have been silicified. Frye and Swineford 2/ suggest that the silicification was accomplished by downward-percolating waters which had dissolved silica from stratigraphically higher beds of volcanic ash. An exchange of dissolved silica for some or all of the calcium carbonate in the chalk may have been made as the subsurface waters percolated through this member. The silicified lenses vary from a greenish tan to a medium brown, are composed of very brittle material, and are from 2 to 7 inches thick. Concretionary masses of a chertlike material, sometimes as large as 1.5 feet in diameter, also have been formed in the member.

Local lenses of bentonite, presumed to be weathered volcanic ash, are characteristic of the Smoky Hill chalk member. Lenses of bentonite and thin layers of bentonitic shale are interbedded with the chalky shale and are especially numerous in the outcrops of the chalk beds around Lake Lenora (see measured section).

Fossil shells of a clam (*Inoceramus*) and an oyster (*Ostrea*) are abundant in some zones. Fragmentary or complete fossilized skeletons of vertebrate animals are reported from this member.

Weathering and erosion of the more massive chalk layers may produce low bluff-like outcrops, but the member generally is sufficiently soft so that it erodes to a "badland" type of topography. Although badland areas in the Smoky Hill chalk have been noted in other north-central Kansas counties, such areas are not characteristic of the member in Norton County. It seems probable, however, that older badlands are concealed by the overlying formations.

Representative measured section.—A cut bank near the northwest corner of Lake Lenora in the SW¼NE¼ sec. 24, T. 5 S., R. 24 W., shows the following section of the chalk beds:

	Feet
Smoky Hill chalk member of Niobrara formation:	
Chalk, weathered; cream color; somewhat silicified..........	1.5
Chalk, powdery; light cream color, weathers white........	.25
Chalk, somewhat silicified; light and dark brown, weathers to light cream color.........	.7
Shale, chalky; light cream color, weathers white..............	.15
Chalk, platy, somewhat siliceous, light buff with brown streaks, weathers light tan..........	2.3
Chalk, soft, powdery; light cream color with tan streaks, weathers light gray..........	.4
Chalk, thin silicified zones; light tan with brown streaks, weathers light buff..........	.7
Chalk, massive; buff, weathers light gray..................	.65

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

	Feet
Smoky Hill chalk member of Niobrara formation—Continued	
Shale, chalky, laminated; buff, weathers light gray	0.2
Chalk, blocky, some chert nodules; light tan to buff, weathers light gray	1.1
Shale, chalky, finely laminated; light tan, weathers buff	.1
Chalk, massive, some cherty concretions as much as 1.5 feet in diameter; light tan to buff, weathers light gray	2.2
Shale, chalky, laminated, scattered small chert nodules; light tan and buff, weathers light cream color	.5
Chalk, massive, some chert nodules; light brown and tan, weathers buff	2.4
Shale, chalky, laminated, brown, weathers light buff	.15
Chalk, massive, some large chert nodules; buff to tan, weathers gray	1.7
Chalk; cream color; thin bands of dark brown chert	.8
Chalk, massive; cream color, weathers dark tan; numerous geodes and small chert nodules	4.0
Shale, clay, somewhat bentonitic; light gray, weathers light green; limonite-streaked	.1
Chalk, massive; cream colored and tan; some chert nodules; powders upon weathering	1.9
Shale, clay, bentonitic, thin-bedded; light and dark gray, weathers yellow gray	.3
Chalk, massive; rose-colored and gray tan	1.3
Shale, clay, somewhat bentonitic, flaky; white, weathers light green	.2
Base covered	23.6

Thickness.—Individual outcrops of the Smoky Hill chalk member range in thickness from 5 to 75 feet. The thickest exposures are along the south wall of the valley of North Fork Solomon River just east of Lenora. The aggregate thickness of the chalk in Norton County, as estimated from outcrop width and regional dip, is about 600 feet.

Construction materials.—
Calcareous binder.
Road metal.
Structural stone.
Riprap.

Ogallala formation

Areal distribution.—Discontinuous patches of the Ogallala formation of Pliocene age crop out over most of the area of Norton County. (See fig. 3 and pl. 1.) Outcrops usually are restricted to stream valleys and are the result of present-day streams having cut through a younger formation, the Sanborn. The Ogallala is best exposed in the valleys of the northward-flowing tributaries of the Solomon River, Prairie Dog Creek, and, to a lesser extent, Sappa Creek. Undoubtedly the Ogallala formation underlies most of the remainder of the county but is buried to a variable depth by the overlying Sanborn formation.

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

General description.—The Ogallala formation is underlain throughout the county by the Smoky Hill chalk member of the Niobrara formation. (See fig. 2.) The contact is unconformable, as is that between the Ogallala and the overlying Sanborn formation.

The Ogallala formation consists of interbedded lenses of sand, gravel, silt, and clay, which indicate the stream-deposited origin of most of the formation. The lenses vary in both thickness and extent. The bulk of the material composing this formation was eroded by streams that headed in the Rocky Mountains, was transported eastward by these same streams, and was deposited as a sedimentary mantle over the surface of the High Plains.

This formation includes lenticular layers of light-gray, massive, lime-cemented sand and/or gravel. Such layers are termed mortar beds. A mortar bed is harder than other materials in the formation, so that differential erosion usually leaves it projecting in the form of a conspicuous hillside ledge. Some ledges may be less than a foot thick, others as much as 6 feet.

A lens of sand and intermixed coarse gravel was found in the NE¼NE¼ sec. 27, T. 4 S., R. 22 W., the material having been rather firmly cemented by limonite to form a conglomeratic sandstone (ss 1, table 1) which might qualify as road metal. The deposit is thought to be a channel fill in the basal part of the Ogallala formation. Other such channel deposits undoubtedly occur in the basal part of the formation in other parts of the county but are obscured by overlying younger sediments.

Ledges of quartzite have been developed in the Ogallala formation, but the outcrops are less numerous than those of mortar bed. The quartzite is a sand or gravelly sand that has been very firmly cemented through the deposition of silica in the original pore spaces of the material. Presumably the silica was deposited by percolating surface waters and had previously been dissolved from stratigraphically higher beds of volcanic ash. The quartzite typically is light green to medium green. It is found near the base of the formation, although in one locality, the SW¼NW¼ sec. 34, T. 4 S., R. 24 W., there is a quartzite ledge more than 50 feet above the base of the formation. Most of the outcrops occur in the area south of the Solomon River. The most extensive exposure noted by the field party was in the NE¼SE¼ sec. 15, T. 5 S., R. 21 W. (q 5, table 1).

A massive ledge of very dense, hard, buff-gray limestone locally occurs at the top of the Ogallala formation. This material was observed in an abandoned quarry in the NE¼NW¼ sec. 21, T. 2 S., R. 21 W., and as the cap rock of a hill in the NW¼ sec. 33, T. 5 S., R. 24 W. The average thickness is about 2 feet. It is thought that the material represents a surface or near-surface caliche deposited through the subsurface waters heavily charged with dissolved calcium carbonate.

Lenses of volcanic ash occur in the Ogallala formation. The volcanic ash represents material discharged into the atmosphere during the explosive phase of a volcanic eruption and carried by the wind to be deposited in sheltered places on the land surface, as in stream valleys and lake basins. The ash beds consist of shards of glass-like material, are white to light gray in color, and sometimes contain extraneous particles of sand, gravel, and silt washed in by streams or slope-wash during the period of ash fall. The beds average about 6 feet in thickness but may be more than 12 feet thick, as in the vicinity of Calvert.

Several thick deposits of clay shale were found in T. 4 S., R. 22 W. One of these, in the NE¼NW¼ sec. 20, T. 4 S., R. 22 W., (see measured section) is 22 feet or more thick. The material varies in color from light gray through greenish brown to brown. It is massive but develops a blocky structure when weathered. The age of the clay shale is open to question. When first seen by the field party, it was classified as part of the Pierre shale (the Cretaceous formation conformably overlying the Smoky Hill chalk member of the Niobrara formation). Later an outcrop of light-green clay was found in the SW¼NW¼ sec. 23, T. 4 S., R. 22 W., which is overlain and underlain by typical mortar beds of the Ogallala formation. On the basis of this observation, the clay shale and similar materials are here classified as Ogallala. They possibly represent a basal phase of the formation not generally found in northcentral Kansas.

Representative measured section.—
(1) A cut bank and auger samples in the NE¼NW¼ sec. 20. T. 4 S., R. 22 W., show the following section of the Ogallala formation:

	Feet
Soil	1.4
Sanborn formation: Silt	4.2
Ogallala formation:	
Shale, clay; light gray; scattered calcium carbonate concretions in upper part	1.8
Shale, clay; greenish tan	2.8
Shale, clay; greenish brown weathers gray brown; limonite-stained (upper 4 feet exposed; lower 4 feet and underlying materials sampled by augering)	8.0
Shale, clay; greenish gray; limonite-stained bands and scattered calcium carbonate nodules	4.0
Shale, clay; light greenish gray; slightly limonite-stained	5.0
Base covered.	21.6

(2) The following section of the Ogallala formation, in a more typical development, was measured in a road cut in the SW¼NW¼ sec. 11, T. 3 S., R. 23 W.:

	Feet
Sanborn formation: Silt	9.7
Ogallala formation:	
Mortar bed, soft; light gray; weathered surface irregular	1.4
Sand, light grayish green; loosely cemented by calcium carbonate	1.0
Mortar bed, fine sand poorly cemented by calcium carbonate; light gray; weathers irregularly; thin-bedded clay zones	3.0
Sand, fine, loosely cemented by calcium carbonate; greenish tan; numerous streaks of calcium carbonate.	1.9
Mortar bed, fine sand loosely cemented by calcium carbonate; light tan	4.5
Mortar bed, soft; pale green	3.4
Sand, fine, somewhat clayey; greenish tan, weathers gray; some calcium carbonate cement	.7
Sand, fine, fairly well cemented by calcium carbonate and containing small concretions of the same material; tan	3.4
Sand, silty, loose; tan; occasional stringers of calcium carbonate	1.9
Mortar bed, soft; light gray	7.8
Base covered.	29.0

Thickness.—The thickness of the Ogallala formation varies greatly throughout the county. Average outcrops measure about 30 feet. The aggregate thickness is estimated to be about 200 feet.

Construction materials.—
Volcanic ash.
Structural stone.
Riprap.
Road metal.
Aggregate for concrete.
Calcareous binder.

Sanborn formation

Areal distribution.—The Sanborn formation of Pleistocene and Recent age is the most widely distributed formation cropping out in Norton County. (See pl. 1 and fig. 3.) At one time the formation undoubtedly extended over the full area of the county, but it subsequently has been eroded from the courses of many of the streams. The formation caps the divide areas, principally, where it conceals older stratigraphic units.

General description.—The Sanborn formation is composed of materials deposited by streams, slope wash, wind, and through the action of gravity. Frye and Fent 3/ have

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.

subdivided the formation into members. It was not feasible to attempt the mapping of these members in the reconnaissance type of field work on which this report is based. To do so would have required a greatly extended 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.

The upper part of the formation is predominantly silt with occasional particles of sand and gravel size scattered throughout. The color is generally light gray, tan, or brown. Where the drainage of subsurface water is good, the formation tends to be gray, whereas in places where the subsurface drainage is less well developed, it tends to be brown. There is a prominent soil profile at the top of the formation, and Hibbard, Frye, and Leonard 4/ have reported one or more buried soil zones in the formation. The A zone of the soil profile characteristically is rather thin, ranging from about 4 to 14 inches, is medium brown or dark brown, and is underlain by a fairly thick B zone. The relatively heavy-textured B zone is characterized by the secondary deposition of calcium carbonate by downward-percolating subsurface waters. The calcium carbonate is disseminated throughout the zone or is locally concentrated within the zone in the form of nodules or pipelike concretionary masses. A crude columnar structure, the result of the intersection of irregular joint planes, is very often developed in this zone.

There may be local lenses of sand and/or gravel in the basal part of the formation. They are usually no more than 4 feet thick, pinch out laterally within short distances, and contain appreciable percentages of materials derived through the weathering and erosion of the Ogallala formation. Such lenses are deposits laid down along streams or materials carried from higher levels by slope wash and are usually markedly cross-bedded.

A deposit of volcanic ash was found in the basal part of the Sanborn formation in the SE¼SE¼ sec. 16, T. 1 S., R. 21 W.. The ash is light gray, contains some fine sand, and is in a lens about 6 feet thick. It is underlain by fine, light tan sand belonging to the Sanborn.

Shells of fossil snails (gastropods) were collected from several outcrops of the formation, including the volcanic ash noted above. Fragments of fossilized vertebrate skeletons also are reported from the Sanborn but were not found by the field party in Norton County.

The Sanborn formation occurs in two topographic situations—as a blanket of unconsolidated material covering the divide tops and as a relatively thin veneer of material lying about halfway up the valley walls of the larger streams in the county. The part of the formation that occurs on the tops of the divides probably is to be correlated with Terrace 6 in the adjacent portion of Nebraska, as defined by Condra, Reed, and Gordon,5/ while the part lying on the valley walls probably is to be correlated with their Terrace 5. Because the contact between these two levels of Sanborn deposition has been obscured over much of the county through the action of slope wash, the deposits at the two levels are mapped as a single stratigraphic unit. Generally the Sanborn formation erodes to form a gently undulating surface. The headward parts of some stream valleys that have been cut back into the Sanborn, however, exhibit a phenomenon known as "catstep erosion," which is probably the result of gravity sliding of water-saturated silt down toward the streams. The catsteps are bounded by scarps a foot or two high and are slump blocks from several feet to about 20 feet wide developed along gently sloping valley walls.

Representative measured sections.—
(1) The following section is exposed in a road cut in the NW¼NW¼ sec. 20, T. 5 S., R. 24 W.:

	Feet
Soil, silty; dark gray	1.3
Sanborn formation:	
Silt; tan; lightly impregnated with calcium carbonate; abundant roots	2.0
Silt; tan; impregnated with calcium carbonate and with nodules of the same material in the lower part; columnar structure	5.6
Silt; dark gray (buried soil zone); columnar structure; impregnated with calcium carbonate	2.1
Silt, fine sand in basal part, tan; disseminated calcium carbonate and occasional nodules of the same material.	1.5
Silt andfine sand; tan; nodular and disseminated calcium carbonate	4.4
Silt; tan gray; numerous calcium carbonate nodules in basal part	3.6
Lime caliche, soft; light gray to white; lenticular	0.7
Silt and fine sand; tan; disseminated calcium carbonate in lower part and nodules of the same material in the upper part	3.3
Base covered.	23.2

(2) A cut bank in the SE¼NE¼ sec. 27, T. 4 S., R. 23 W., exposes the following section of the Sanborn formation:

	Feet
Soil, silty; gray	1.5
Sanborn formation:	
Silt; tan gray; somewhat impregnated with calcium carbonate; columnar structure	3.9
Silt; brown, weathers brownish gray; impregnated with calcium carbonate and with numerous pipes and nodules of the same material; shows columnar structure	2.3

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.

5/ Condra, G. E., Reed, E. C., and Gordon, E. D., Correlation of the Pleistocene deposits of Nebraska: Nebraska Geol. Survey Bull. 15, pp. 48-49, 1947.

	Feet
Sanborn formation—Continued.	
Silt, some sand; brown, weathers gray brown; heavily impregnated with calcium carbonate and contains abundant nodules of the same material	1.8
Silt, numerous sand grains scattered throughout; tan, weathers tan gray; occasional calcium carbonate nodules	1.3
Silt, some scattered sand grains; tan, weathers tan gray; heavily impregnated with calcium carbonate and contains occasional nodules of the same material	1.0
Silt, sand and gravel particles scattered throughout; tan, weathers gray tan; lightly impregnated with calcium carbonate	1.8
Silt, occasional sand grains; tan; lightly impregnated with calcium carbonate	1.6
Silt, scattered sand and gravel particles in lower part; tan, weathers tan gray; lightly impregnated with calcium carbonate	1.6
Silt, occasional scattered gravel particles; dark brown, weathers gray; lightly impregnated with calcium carbonate	1.7
Silt, sandy, occasional gravel particles; gray to buff, weathers dark gray (probable buried soil zone)	1.1
Silt, sandy, some scattered gravel particles, including mortar-bed fragments; light tan, weathers gray	2.0
Sand and gravel, somewhat silty; light tan	1.1
Sand, fine, and silt, highly calcareous; gray green; calcium carbonate nodules in basal part	1.9
Base covered.	23.1

Thickness.—The thickness of the formation varies greatly over the county. It has been eroded completely from the valleys of many of the streams. It is thought to reach its greatest thickness, about 75 feet, in the divide area between Sappa and Prairie Dog Creeks. Its average thickness is about 25 feet.

Construction materials.—
- Mineral filler.
- Volcanic ash.
- Aggregate for concrete.
- Road metal.

TERRACE DEPOSITS

Areal distribution.—Terrace deposits characterize the valleys of the Solomon River, Prairie Dog Creek, and Sappa Creek. (See fig. 3 and pl. 1.) Narrow extensions of the terraces project into the valleys of streams tributary to these three major drainage lines. The terrace deposits vary considerably in width within relatively short distances. Those of the Solomon River Valley average about 1 mile wide in the eastern part of the county and narrow westward to about 0.5 mile. The terraces of Prairie Dog Creek are about 2 miles wide along the eastern border of the county and narrow to about 1 mile at the western border. The terrace of Sappa Creek has an average width of about 1 mile. Two well-defined terrace levels and one less well defined were observed in the field. Inasmuch as the sediments composing the several terraces are similar, the terrace levels are mapped as a single stratigraphic unit. The uppermost terrace, however, is the most extensive.

General description.—The terrace deposits overlie all older formations with an intervening erosional break (fig. 2). The deposits are composed predominantly of silt in the upper part and become somewhat more sandy in the basal part. Local lenses of cross-bedded gravel occur in the sandy phase. The basal part of the deposits is poorly exposed in Norton County.

The terrace silts range from light gray through tan to brown. There is a well-developed soil zone at the top of each outcrop area of the terrace deposits and, in characteristic sections, there may be a buried soil zone at a variable distance below the top of the deposits. B zones are present below the dark-brown to black A zones of the soil profile. Occasional fossilized shells of snails are found in the terrace deposits. Most of the sediments composing the terrace deposits are material from the Sanborn formation reworked by streams in later depositional cycles.

Representative measured sections.—
(1) The following section was measured in a terrace deposit along a road cut in the NE¼SE¼ sec. 13, T. 2 S., R. 22 W.:

	Feet
Soil; dark gray	1.4
Terrace deposits:	
Silt; light tan; heavily impregnated with calcium carbonate	2.2
Silt; dark gray; small calcium carbonate nodules	.6
Silt; light tan; disseminated calcium carbonate	.8
Silt; gray; heavily impregnated with calcium carbonate	1.1
Silt; tan; stained with calcium carbonate	1.0
Soil zone (buried)	.9
Silt; gray	1.2
Silt and fine sand; tan	.4
Silt; light tan	6.5
Base covered.	14.7

(2) A road cut in the SE¼SE¼ sec. 12, T. 5 S., R. 22 W., shows the following section of terrace deposits in the valley of North Fork Solomon River:

	Feet
Soil zone: Silt, dark gray	3.1
Terrace deposits:	
Silt, calcareous; gray tan	1.3
Silt, sandy; tan, weathers gray; numerous chalk fragments	2.3

	Feet
Terrace deposits—Continued	
Sand, fine and somewhat silty; tan; numerous rounded chalk fragments.....	2.4
Silt, calcareous; light tan, weathers gray; forms a vertical bank...............	8.4
Silt, some very fine sand, calcareous; light tan, weathers gray; numerous rounded chalk fragments.....	2.9
Silt, calcareous; tan, weathers gray; occasional thin lenses of chalk fragments......................	6.7
Silt, calcareous; gray brown, weathers gray...............	2.7
Silt; dark brown gray, weathers gray...............	1.8
Silt and clay, slightly calcareous; gray tan, weathers gray...............	3.9
Base covered.	32.4

Thickness.—The height of the terraces above the present floodplains of streams in the county, as well as above lower terrace levels, is somewhat variable but usually is greatest in the eastern part of the county. The full thickness of the terrace deposits is estimated to be about 65 feet along the three principal streams. Extensions of the terrace deposits into the tributary valleys, of course, decrease in thickness away from the junctions with the larger streams.

Construction materials.—
Aggregate for concrete.
Mineral filler.
Road metal.

Alluvium

Areal distribution.—The deposits formed by streams in their present gradational cycle are mapped as alluvium. (See fig. 3 and pl. 1.) They constitute the most recent stratigraphic unit in the county. 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 normal flood stage. Alluvium is mapped along the three major streams in the county, but because of the map scale very narrow alluvial deposits along some of the tributary streams could not be shown. The width of the alluvium in the valley of North Fork Solomon River varies greatly within short distances and ranges from 0.25 to 0.75 mile. The average width of the alluvial deposits in the valleys of Sappa and Prairie Dog Creeks is somewhat less, about 0.3 mile.

General description.—Alluvial deposits of the North Fork Solomon River are composed predominantly of silt but include considerable sand. Occasional gravel lenses occur in some places. The alluvium of Prairie Dog Creek is composed predominantly of silt, has a moderate percentage of sand, and contains lenses of limestone and mortar-bed gravel. The alluvium in Sappa Creek Valley is almost entirely silt with only occasional sand lenses present. The color of the alluvium reflects, in a general way, the sand content of the material; the zones in which the alluvium is sandy tend to be tan while those composed predominantly of silt tend to be brown.

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

Thickness.—The alluvial deposits of the North Fork Solomon River are estimated to have a maximum thickness of about 40 feet. Those of Prairie Dog and Sappa Creeks are thinner, perhaps no more than 20 feet. Accurate determinations of thickness could have been made only by test drilling.

Construction materials.—
Aggregate for concrete.
Road metal.

INVENTORY OF CONSTRUCTION MATERIALS

General

The objectives of this inventory on construction materials in Norton County are to establish the bases upon which the materials are classified and to analyze the relations of the various materials to the stratigraphic units in which they occur.

Whenever available, laboratory test data have been included in the report to aid 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 and the State Highway Commission of Kansas.6/ 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 of all possible sources. The purposes of this report are to inventory the available construction materials that occur in Norton County and to establish the geologic pattern required for the location and development of materials at those 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

6/ 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.

occurrence are established, the resultant geologic pattern will facilitate the discovery of additional sources.

Aggregate for concrete

Engineering and geologic characteristics.—Aggregate for concrete is distinguished as fine aggregate and mixed aggregate in table 1 and on plate 1. The distinction is an arbitrary one based on the percentage of material retained on a standard no. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. The material is classified as a mixed aggregate if the coarse fraction is 5 percent or more by weight of the whole sample; as a fine aggregate if the coarse fraction is less than 5 percent. Fine and mixed aggregate will be considered together because the grading of almost any aggregate material 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 in the aggregate of the following deleterious substances, if in quantities thought to be excessive, is noted under Remarks in table 1: Material passing the no. 200 sieve (wash); shaly, soft, or flaky fragments; sticks or other organic debris; clay lumps; and minerals which, because of their chemical composition, may react with the cement to the detriment of the concrete.

The materials reported in this classification are exposed at the surface or are under unconsolidated overburden sufficiently thin that they may be economically exploited. Relatively inaccessible deposits of sand and gravel overlain by thick or consolidated beds usually are not included in this classification because of the added expense in the removal of the material; exceptions to this practice are noted under Remarks in table 1.

Stratigraphic sources and performance characteristics.—The following stratigraphic units are actual or potential sources of aggregate for concrete in Norton County:

(1) Ogallala formation. Three operated or prospect pits for mixed aggregate (ma 4, 9, 16) and one for fine aggregate (fa 12) are listed in table 1 and mapped on plate 1. Field and laboratory evidence indicate that the sands and gravels of this formation are composed predominantly of materials probably carried in from the west by streams. Only small percentages of local materials are included. Data on the mineral composition of the samples of mixed aggregate are not available. The laboratory tests indicate that these aggregates probably would be satisfactory for concrete.

In addition to the mapped operated or prospect pits, other prospects probably can be found by intensive exploration of the mapped outcrop areas of the formation. Some prospective sites observed in the field were rejected and are not included in this report because of the presence of mortar-bed ledges above the sand and gravel. The Ogallala formation is probably the source of the highest quality aggregate that occurs in Norton County.

(2) Sanborn formation. The Sanborn formation is an important actual or potential source of aggregate for concrete. Numerous operated or prospect pits for mixed aggregate (ma 1, 7, 8, 9-13, 15, 17, 18) and for fine aggregate (fa 2-4, 7, 9-11) are listed in table 1 and mapped on plate 1. The samples tested show that the material is composed predominantly of quartz fragments, contains a fairly high percentage of mortar-bed fragments, and minor amounts of feldspar, quartzite, and limonite particles. The fine fraction is composed almost entirely (about 90 percent) of fragments of quartz. The laboratory tests indicate that this material may be an acceptable aggregate for concrete but of rather low quality, as the mineral analyses indicate the possibility of excessive percentages of deleterious substances of local origin.

Additional sources of sand and gravel undoubtedly can be located by intensive exploration of the basal part of this formation, particularly in the marginal areas of its mapped outcrops. Such deposits probably will be in limited quantities, however, because of their lenticular character.

(3) Terrace deposits. Three samples from terrace deposits are classified as mixed aggregate (ma 5, 6, 14) and three as fine aggregate (fa 5, 6, 8). These are listed in table 1 and mapped on plate 1. Data on mineral tests are inadequate for these samples, but field observations indicate that the material is composed predominantly of fragments of quartz and feldspar and that the coarse fraction might have a fairly high percentage of soft limestone pebbles. Laboratory tests indicate that this material may be acceptable as low-quality aggregate for concrete.

There are additional sources of aggregate for concrete in the basal part of the terrace deposits, but the quantity is probably limited because of the lenticular character of the sands and gravels.

(4) Alluvium. Two samples of alluvium are classified as fine aggregate. (See table 1 and pl. 1.) Data on the mineral composition are not available, as these samples were collected and processed before 1947. Laboratory tests indicate that the material may be satisfactory for use as aggregate for concrete but that its quality is rather inferior.

Sand and gravel lenses occur at many places in the alluvium of North Fork Solomon River and Prairie Dog Creek. The lenses may be at the surface or at shallow depths. Deeper beds of alluvial sand and gravel probably are saturated with ground water, a condition that would have to be considered in their development.

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 that road. The geologic materials classed as road metal vary from one area to another. The following materials have been used in Norton County or are available for use as road metal:

(1) Aggregate for concrete.

(2) Crushed rock. Indurated rocks that have been or are available in Norton County for use as road metal are (a) limestone, a compact, massive layer of calcareous material, variable in its hardness; (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 subsurface waters; (d) quartzite, a massive, compact, hard rock in which sand and/or gravel have been firmly cemented by silica in percolating ground water.

The materials included here under crushed rock are listed in table 1 and mapped on plate 1 under the more specific designations 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.

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

(2) Crushed rock.

(a) Smoky Hill chalk member of the Niobrara formation. The more chalky beds in this member have been quarried in other counties in northcentral Kansas, crushed, and applied to light-traffic roads. The material is watered, rolled, and under traffic it self-cements to become a traffic-bound macadam. Field observations of such roads indicate that they are good all-weather roads and are easily maintained by blading. It is thought, however, that chalk from the Smoky Hill member is not quite so satisfactory for this use as chalk from the Fort Hays limestone member of the Niobrara formation. This use of soft limestones of the Smoky Hill chalk was not observed in Norton County.

The principal disadvantage in the use of chalk as a traffic-bound macadam is that, in dry weather, the macadam tends to powder and blow from the road as each vehicle passes over it. Calcium chloride is sometimes used as an anti-dusting agent on roads of similar type, but to be effective, the humidity must be 50 percent or more. 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 chalky limestone macadam indicates that when so sealed 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.

Material from the silicified chalk zone that occurs in many places at the top of the Smoky Hill unit has been quarried, crushed, and applied to some of the county roads in Norton County, such as the road extending east from the city of Norton along the line between sec. 35, T. 2 S., R. 25 W., and sec. 2, T. 3 S., R. 25 W. The test characteristics of this material are given in table 1 and prospect or operated quarries are mapped on plate 1. Field observation indicates that the crushed silicified chalk performs as a loose surfacing agent just as does crushed quartzite and that the same construction techniques should be used. Fragments of both materials typically are sharp-edged and may cut tires excessively.

(b) Ogallala formation. Crushed quartzite from the Ogallala formation has been used as metal on some of the secondary roads in this county. The county road north of Edmond was metalled in this way for a distance of about 4 miles, but the result has not been entirely satisfactory. Field observation indicates that the material was not crushed fine enough. Particles larger than 0.5 inch tend to kick out from the road or are removed in the blading of the road. The performance of both crushed quartzite and crushed silicified chalk as road metal will be improved if a binder material is added to the crushed rock.

On the same county road, the next 3 miles beyond the part metalled with crushed quartzite was metalled with mortar bed from the Ogallala, crushed to 0.5 inch size. The performance characteristics of this material are more satisfactory than those of the quartzite. The sand and gravel particles in the mortar bed are bound by the calcium carbonate cement to form a low-grade traffic-bound macadam. Mortar-bed ledges crop out on many hillsides of the county, and two samples of the material have been tested (mb 1 and 2, table 1) and their locations mapped (pl. 1).

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. The State Highway Commission of Kansas states (letter from S. E. Horner dated January 4, 1947) that material will qualify for mineral filler 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 mixture.

Stratigraphic sources and performance characteristics.—(1) Sanborn formation. Four samples of material classified as mineral filler were obtained from the Sanborn formation (mf 1, 2, 4, 6). The test data for these samples are listed in table 1 and the localities are mapped on plate 1. All samples tested are seemingly satisfactory insofar as the size of the material is concerned, but in all samples the cementation factor (100) may be excessive. The cementing substance is calcium carbonate, a material disseminated at many places through the B zone of the soil profile. It is probable that material in the formation below the B zone has only limited amounts of calcium carbonate and that its cementation factor, therefore, is lower. Because the Sanborn formation is so widespread in Norton County, pits could be opened in it at almost any convenient site. The restricting factor in the exploitation of the Sanborn formation for mineral filler is cementation. Although material from the deeper zones is less firmly cemented, the overburden might prove too thick for economical development.

(2) Terrace deposits. Three terrace deposit samples (mf 3, 5, 7) are classified as mineral filler, and test data are given in table 1 and the localities mapped on plate 1. The grading characteristics are within the required limits but, as was the case with the Sanborn formation, the cementation factor may prove excessive. Pits could be opened in the terrace deposits throughout most of their outcrop area but the cementation factor should be determined by laboratory testing prior to development of the site.

(3) The alluvial deposits of the larger streams in Norton County are a third potential source of mineral filler. These deposits are composed predominantly of silt-size particles, but there may be heavy intermixtures of particles of sand and gravel size not characteristic of the Sanborn formation or of the terrace deposits. In view of the widespread availability of mineral filler of better gradings in these two other formations, it is doubtful that it would be economical to open pits in the alluvium.

Volcanic ash

Engineering and geologic characteristics.—Volcanic ash is sometimes classified as mineral filler, but in this report it is distinguished as a special type of mineral filler because it is suitable for certain uses that the usual silty filler is not. Volcanic ash consists predominantly of the fine, glass-like shards ejected during the explosive phase of a volcanic eruption. The 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. Several pits for volcanic ash have been opened in the Ogallala formation in Norton County and are mapped on plate 1 as operated or prospect pits. The test characteristics for materials from two localities of the Ogallala formation (va 2 and 3) are listed in table 1. One of these, va 2, has appreciable percentages of particles of the size of gravel and coarse sand, perhaps enough to be considered deleterious for certain uses. The other ash sample from the Ogallala, va 3, contains only a small amount of coarse sand as a possible deleterious substance. The cementation factor (42) of this sample is fairly high. Other deposits of volcanic ash undoubtedly can be located within the mapped outcrop areas of this formation. All will be lenticular in form, and they can be concealed by younger materials.

One very extensive deposit of volcanic ash contemporaneous with the Ogallala in the NW¼SW¼ sec. 25, T. 2 S., R. 22 W., is under lease to the Wyandotte Chemical Co., Kansas City, Mo. This is an unusually thick deposit, about 16 feet, and is continuous under fairly thick overburden a short distance toward the west, where there is an abandoned pit (SE¼SE¼ sec. 26, T. 2 S., R. 22 W.) in the same lens.

(2) Sanborn formation. The field party found only one deposit of volcanic ash in the Sanborn formation of Norton County. This is located in the SE¼SE¼ sec. 16, T. 1 S., R. 21 W., and is listed in table 1 (va 1) and mapped on plate 1. A small amount of ash has been removed from this deposit but it is estimated that an additional 6,000 cubic yards is still available under relatively thin overburden. The material is of rather low quality because it contains an unusually high percentage (53 percent) of silt and fine sand-size particles. Other small lenses of volcanic ash undoubtedly occur in the basal part of the Sanborn formation in other parts of Norton County. It is probable that exploration for additional deposits should be undertaken first in areas near the heads of tributary streams that have cut well down into the basal part of this formation.

Riprap

Engineering and geologic characteristics.—Riprap, as defined in this report, is any material suitable for protecting 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 and that the specific gravity be 2.0 or higher.

Stratigraphic sources and performance characteristics.—(1) Smoke Hill chalk member of the Niobrara formation. The silicified chalk zone found locally at the top of the Smoky Hill unit is a source of material for riprap. Samples from four localities were tested and the results tabulated in table 1 (sc 1-4). Their locations are mapped on plate 1. The test samples indicate that the silicified chalk is adequate for this use because the specific gravity of all samples is above 2.0; the Los Angeles abrasion loss for three of the samples (sc 2 was not tested) is relatively low; the material is satisfactory insofar as soundness is concerned; and absorption is relatively low. The only deficiency of this material is that, because of its brittleness, it may break into fragments too small for use on large earthen dams. Part of the riprap installed on the Lake Lenora dam is silicified chalk in fragments 1/8 of a cubic foot in volume. Its performance has been satisfactory.

Other occurrences of silicified chalk were noted in the Smoky Hill chalk member at or near the outcrop surfaces. Although many of these zones were too thin for development, intensive exploration of the outcrop areas of this member probably would reveal other adequate sources.

(2) Ogallala formation. Several materials are included in the Ogallala formation which might be suitable for use as riprap. The test characteristics of these materials are listed in table 1, and operated or prospect quarries are mapped on plate 1. Quartzite of the Ogallala has been quarried and used in Norton County and other counties of Kansas as riprap on the upstream face of earthen dams. The Lake Lenora dam was riprapped in part with quartzite fragments averaging about 6 inches in diameter. The riprap was installed in 1938, and investigation in 1947 indicates that it

has not deteriorated appreciably in the 9-year period.

Rock from the ledge-forming mortar beds of the Ogallala has been used as riprap in other Kansas Counties and appears to perform satisfactorily. The test characteristics of mortar bed indicate that it has a sufficiently high specific gravity, that the abrasion loss is only moderate, and that it is relatively sound. In all likelihood, however, this material would not prove quite so satisfactory when used as riprap as do quartzite and silicified chalk, because it is composed largely of calcium carbonate, a substance somewhat more soluble than the silica of which the quartzite and silicified chalk are composed. Mortar bed, however, is the most widespread potential riprap material in Norton County, for ledges crop out in all parts of the county.

The dense limestone layer that may occur at the top of the Ogallala formation is also a potential source of riprap material. This limestone is not so widespread in Norton County as in other counties of northcentral Kansas, and field observation indicates that in a water-saturated environment it may deteriorate excessively. In view of these two facts, it is doubtful that this material would be an adequate local source of riprap.

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) Smoky Hill chalk member of the Niobrara formation. Occasional uses of structural stone from the massive chalk beds in the Smoky Hill chalk member have been observed in northcentral Kansas, although there is no record of this use in Norton County. Field observations in other counties indicate that the material is satisfactory as a structural stone providing it is not used in a place where it will be subjected to water saturation. The chalk deteriorates rapidly in the presence of water, either by slaking or freeze-and-thaw. Structures built of Smoky Hill chalk are not as pleasing in appearance as as those built of chalks quarried from the Fort Hays limestone member of the same formation.

The silicified zones locally present at the top of the Smoky Hill chalk member (sc 1-4, table 1 and pl. 1) are potential sources of structural stone. However, as noted previously, the brittleness of the material may cause it to shatter excessively during the quarrying operation, and this characteristic, in addition to the difficulty of shaping the stone because of its hardness, would probably make the silicified chalk undesirable as structural stone. Its chemical properties are probably similar to those of quartzite.

(2) Ogallala formation. Quartzite ledges in the Ogallala formation have been quarried extensively in northcentral Kansas for structural stone. Numerous city and county buildings and several bridges constructed of this material were observed. It is the opinion of some 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 conclusive field evidence of this type of failure was observed, however.

The building housing the County Highway shops in the city of Norton was constructed of quartzite of the Ogallala. The building was constructed in 1939, and though there is evidence of some failure, that failure is not excessive and may not be due to the reactivity of the opal cement with the quartzite. The quartzite, however, is so hard that cutting it to required size and shape is difficult.

Occasional use of material from ledge-forming mortar beds in the Ogallala formation as structural stone for farm and school buildings has been observed in northcentral Kansas though not in Norton County. Its test characteristics (table 1) indicate that it may be acceptable for this use, but field observations show that the mortar-bed ledges are not uniformly hard, a fact that must be considered in evaluating this material for acceptance as structural stone. The finished appearance of structures built of this material may be marred by the differential weathering of some of the blocks.

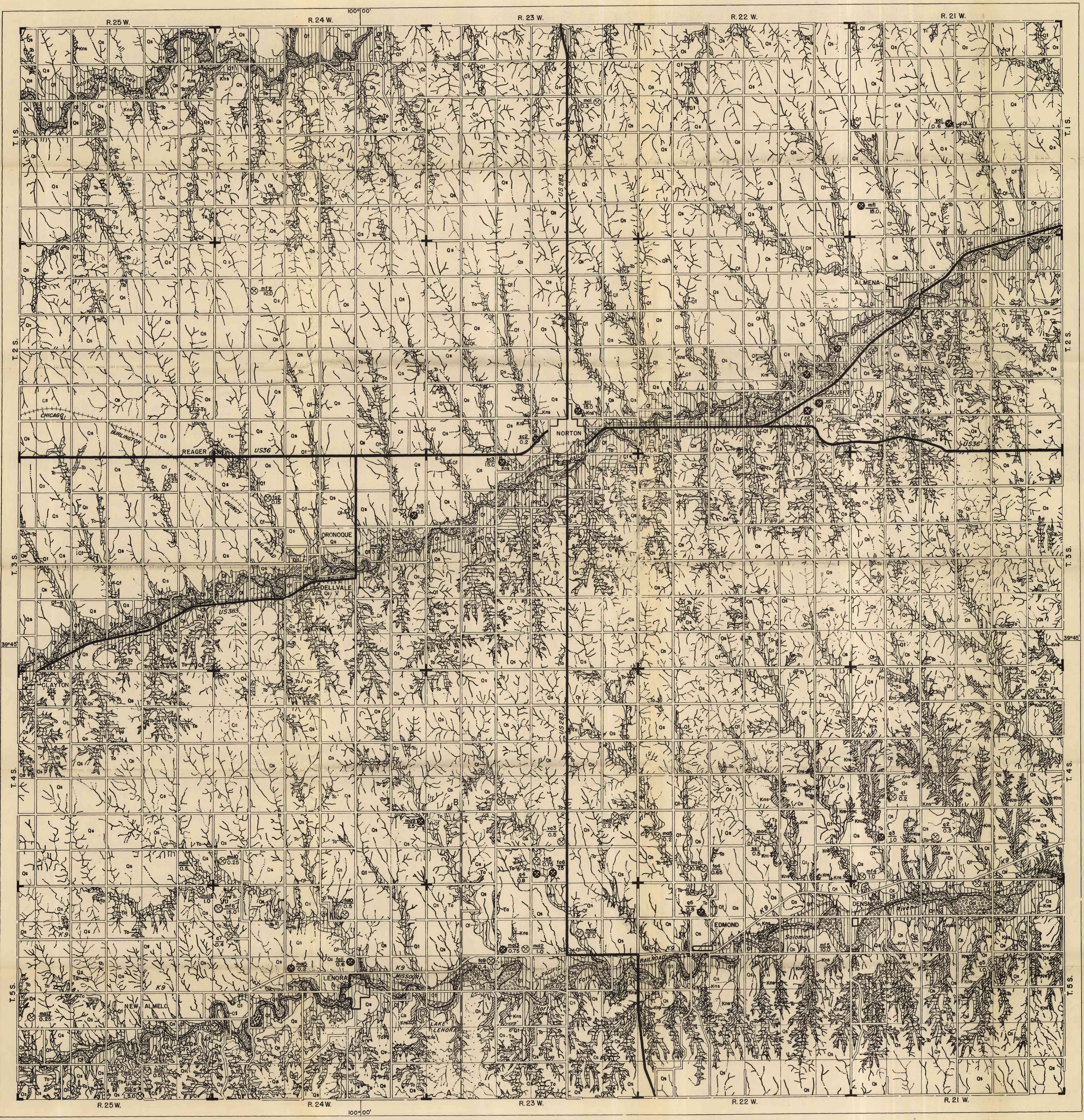
The hard, compact limestone layer locally present at the top of the Ogallala formation has been used as structural stone in Norton County, as well as in other counties of northcentral Kansas. The test characteristics of the material (table 1) indicate that it is acceptable for this use. The church in New Almelo, near the southwest corner of Norton County, was built of limestone of the Ogallala at the beginning of this century, and although not too pleasing in appearance, the stone has stood up very well. Quarries that supplied stone for this church are located in Graham County. A small quarry formerly operated in the SE¼SW¼ sec. 16, T. 2 S., R. 21 W., supplied similar stone for the construction of numerous farm buildings in the vicinity of Almena, but not enough limestone remains for that site to be indicated on plate 1 as a source of materials.

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. Two local stratigraphic units are sources or potential sources of calcareous binder.

Stratigraphic sources and performance characteristics.—(1) Niobrara formation. The Smoky Hill chalk member of the Niobrara formation has been accepted by the State Highway Commission of Kansas as a potential source of material suitable for use as calcareous binder. The member contains numerous beds of chalky limestone that are soft, easily pulverized, and free from deleterious substances. This material can be obtained from most of the mapped outcrop areas of the Smoky Hill chalk member in the county.

(2) Ogallala formation. Mortar beds in the Ogallala have been accepted as calcareous binder by the State Highway Commission of Kansas. The mortar-bed ledges sampled in Norton County (mb 1, 2, table 1 and pl. 1) are too hard for this use but the material in many other ledges is soft enough to be easily pulverized and should serve adequately as a binder.



EXPLANATION

PLEISTOCENE AND RECENT — QUATERNARY

Qal — **Alluvium**

(Tan to brown silt; some sandy zones and occasional lenses of gravel. Source or potential source of aggregate, road metal.)

Qt — **Terrace deposits**

(Light-gray to brown silt; buried soil zone; basal part is more sandy and includes gravel lenses. Source or potential source of aggregate, mineral filler, road metal.)

Qs — **Sanborn formation**

(Light-gray, tan, and brown silt with occasional sand and gravel particles; buried soil zones; columnar structure often developed; lenses of volcanic ash, sand, and gravel in lower part. Source or potential source of mineral filler, volcanic ash, aggregate, road metal.)

PLIOCENE — TERTIARY

To — **Ogallala formation**

(Interbedded lenses of sand, gravel, silt, and clay; tan, green, or brown; thick green or brown clay shales locally present in basal part; lenticular ledges of gray mortar beds and light-green quartzite; lenses of light-gray to white volcanic ash; hard limestone locally at top. Source or potential source of volcanic ash, structural stone, riprap, aggregate, calcareous binder.)

UPPER CRETACEOUS — CRETACEOUS

Kns — **Niobrara formation**
Smoky Hill chalk member

(Chalky shales interbedded with chalks and shaly chalks; tan to blue gray in some areas, orange-colored in others; interbedded thin layers of bentonite and bentonitic shale; silicified zone locally present just below outcrop surface. Source or potential source of calcareous binder, road metal, structural stone, riprap.)

Geologic boundary
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
lg Limestone gravel
sc Silicified chalk
ma Inclined letters indicate materials not tested
ma2 Vertical letters indicate materials listed in Table 2 and their sample number
1.0 Quantity of material available (in units of 10,000 cubic yards)

Federal (US) highway
Other roads, all classes
Railway
City
Section line
Township corner
Stream, permanent
Stream, intermittent
A — B Line of cross section, figure 2 (along the line between secs. 31 and 32, T.5 S., R.23 W., and secs. 29 and 30, T.4 S., R.23 W.)

11°

Approximate mean declination, 1947

MAP SHOWING CONSTRUCTION MATERIALS AND GEOLOGY OF NORTON COUNTY, KANSAS

Base adapted from maps provided by the State Highway Commission of Kansas

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 (cubic yards)	Average thickness: Material (feet)	Average thickness: Overburden (feet)	Accessibility	Geologic formation or member	Authority for test data[1]	Date of test	Sieve analysis: % on 1/2 inch	% on 3/8 inch	% on No.4	% on No.16	% on No.100	% passing No. 200 (wash)	Description of the material[2]: Fraction	Quartz	Feldspars	Acid rocks	Basic rock	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)	Soundness (25 cycles)	Toughness	Cementation	Absorption	Liquid limit	Plasticity index	Remarks
Fine aggregate	fa 1		SE	23	2	22	15,000			Fair	Alluvium	SHCK	11-41		0	2	23	92	6.4	Granitic and calcareous particles.												107.0	2.60	2.53	1.64	1.41	36.8	0.77						
	fa 2	NE	NW	8	3	24	1,500	3	1	Good	Sanborn	do	do		0	2	29	96	3.3	Siliceous sand.												110.0	2.60	2.82	1.10	1.03								
	fa 3	NW	SE	12	3	24	5,000	6	2	Fair	do	do	do	1	2	4	17	85	12.0	Siliceous sand, soft limestone pebbles, and silt.													2.60	2.18	1.22	1.10								
	fa 4	NE	SE	32	4	22	6,500	9	8	Good	do	SHCK USGS	7-47		0	1	12	86	11.1	C	30	17			50				1		2	99.0	2.55	1.95	0.88	0.84								Overburden predominantly silt; low compressive strength; high percentage of wash.
																				F	94	3				2			1															
	fa 5	SW	NW	34	4	23	7,500	6	2	do	Terrace deposits	SHCK	2-29	0	1	4	61	99	1															3.57	1.46	1.44								High percentage of wash.
	fa 6	NW	SE	34	4	23	75,000	8	4	Fair	do	do	2-46	1	2	4	38	94	4.6													110.1	2.58	3.00	1.24	1.12	34.9	0.91						
	fa 7	NW	NE	3	5	21	10,000	6	1-2	Good	Sanborn	SHCK USGS	7-47	0	1	2	13	97	2.04	C	37	19		1	17		12		1	13		105.2	2.58	2.41	1.00	1.05								High percentages of mortar bed, chalk, and chert fragments in coarse fraction.
																				F	92	8								Tr														
	fa 8	NE	SE	15	5	23	50,000	6	1	do	Terrace deposits	do	do	2	2	3	5	96	4.11	C	25	10					65					100.9	2.60	2.25	0.93	0.88								Low compressive strength; high percentage of chalk fragments in coarse fraction.
																				F	95	3				2																		
	fa 9	NE	NE	17	5	23	4,000	6	1-3	do	Sanborn	do	do		0	1	17	93	4.3	C	75	10	1	3	9				2			105.4	2.60	2.34	1.32	1.08								
																				F	93	3				Tr			4															
	fa 10	SW	SE	3	5	24	5,000	5	0-6	do	do	do	do	0	1	3	31	94	4.7	C	47	45	1		1				1	5		103.6	2.58	2.73	1.04	1.07								
																				F	97	5							2															
	fa 11	NE	NE	15	5	24	6,000	7	2-8	do	do	do	do	1	1	4	26	92	5.3	C	35	18			41				1	5		107.2	2.56	2.64	1.12	1.10								High percentage of mortar bed fragments in coarse fraction.
																				F	92	4				3			1															
	fa 12	NW	NW	35	5	25	5,000	8	1-2	do	Ogallala	do	6-47	0	1	3	22	90	7.09	C	65	26			5			2	1	1		97.2	2.54	2.50	0.68	0.74								Low compressive strength.
																				F	95	3		1						1														
Mixed aggregate	ma 1	NE	NE	14	1	23	3,000			Fair	Sanborn	SHCK	2-34	1	2	10	47	99	1	Siliceous and granitic; some flint (chert).													2.6	3.64	1.26	1.07								Some chert noted, presumably in coarse fraction.
	ma 2	NW	NE	24	2	22	1,300			do	Alluvium	do	4-31	0	7	15	57	98	1.5	Siliceous; limestone pebbles.																								Limestone pebbles noted in coarse fraction.
	ma 3	SE	NE	14	3	24	30,000			Good	do	do	11-41	0	1	5	27	94	3.6													112	2.62	2.64	1.44	1.10	38.4	0.90						
	ma 4	SE	SE	27	4	22	11,000	12	4	do	Ogallala	do	7-47	3	8	15	52	92	5.9													107.4	2.56	3.56	1.05	1.05								
	ma 5		S½	30	4	22	2,000	4	2	Fair	Terrace deposits	do	5-41	0	1	11	60	97	2.0													109	2.6	3.71	1.7	1.23								
	ma 6	NE	SW	32	4	22	1,500	3	2	Good	do	do	4-38	0	2	8	56	99	0.9	Siliceous; hard and soft limestone pebbles.												112	2.58	3.69	1.11	1.01								Some soft limestone pebbles.
	ma 7	NW	SW	21	4	23	7,000	6	6	Fair	Sanborn	do	11-41	1	2	6	55	98	1.7													111	2.60	3.61	2.02	1.55								
	ma 8	NE	NW	25	4	23	2,000	4	2	do	do	do	do	2	4	8	43	86	12.2	Granitic sand and gravel; less than 10% limestone gravel.													2.58	3.31	1.41	1.16	34.8							High percentage of wash.
	ma 9	SE	NE	25	4	24	25,000	25	12	Good	Ogallala	do	do	0	9	11	46	91	8.5															3.33	0.72	0.83	37.0							Overburden may be too thick for economic removal of any more material from this operated pit; low compressive strength.
	ma 10	SE	NW	31	4	24	2,500	4-7	1-4	Fair	Sanborn	SHCK USGS	7-47	2	4	9	40	93	5.97	C	37	20			35		2		6			103.0	2.57	3.16	1.07	1.0								High percentage of mortar bed fragments in coarse fraction.
																				F	91	6		Tr		3																		
	ma 11	NW	SE	36	4	25	5,000	6	4-5	Good	do	do	do	1	2	6	43	95	4.19	C	50	19	6		1				12		12	105.8	2.56	3.21	1.02	0.97		0.94						High percentages of quartzite fragments and limonite nodules in coarse fraction; compressive streng rather low.
																				F	90	8							2															
	ma 12	SE	SE	9	5	23	10,000	9	3	do	do	do	do	1	5	10	30	87	10.3	C	30	15			52				3			112.6	2.56	2.70	1.14	1.3								High percentage of mortar bed fragments in coarse fraction; high percentage of wash.
																				F	85	5				7			3		Tr													
	ma 13	SW	SW	9	5	23	7,500	9	2-10	do	do	do	do	0	1	5	39	94	5.18	C	40	20	2	1	20				3	9	5	104.4	2.56	3.00	1.15	1.27								Fairly high percentages of mortar bed and chert fragments in coarse fraction.
																				F	93	3		1	3																			
	ma 14	SE	NW	11	5	23	20,000	7	4	do	Terrace deposits	SHCK	7-37	0	3	7	50	99	0.2	Granitic sand and gravel with small portion of soft and hard limestone fragments.												112.0	2.58	3.53	1.2	1.27								
	ma 15	SW	NW	16	5	24	2,000	6-8	2-4	do	Sanborn	SHCK USGS	7-47	4	7	13	43	90	8.67	C	50	5	10		30				5			108.6	2.56	3.35	1.23	1.13								High percentage of mortar bed fragments in coarse fraction.
																				F	92	2			4				2															
	ma 16	NW	NE	1	5	25	10,000	20	3-8	do	Ogallala	do	10-47	0	1	5	50	95	4.25													111.1	2.59	3.25	0.93	1.0								Concealed beneath Sanborn formation.
	ma 17	NE	SE	19	5	25	2,500	4	2	Fair	Sanborn	SHCK	11-41	1	4	9	51	98	2.0	Granitic sand and gravel.												106	2.6	3.64	1.0	1.02	37.0							Less than 5 percent limestone gravel in coarse fraction.
	ma 18	NE	NW	34	5	25	2,000	3	1	do	do	do	do	0	1	7	47	89	9.0	Granitic sand with some calcareous particles.												106	2.62	3.18	1.25	1.16	35.6	0.66						
Mineral filler	mf 1	NE	NW	31	1	21	150,000	10	1	Good	do	SHCK USGS	8-47				0	15	76.8	Light gray sand, silt, and clay.												76.3	2.59							100				Cementation factor may be excessive.
	mf 2	SW	NW	8	2	24	100,000	10	1	do	do	do	7-47				0	4	91.8	Yellowish-gray silt and clay.												75.3	2.55							100				Cementation factor may be excessive.
	mf 3	NW	SW	19	3	24	5,000	6	1	do	Terrace deposits	do	do				0	3	95.6	Yellowish-gray silt and clay.												83.0	2.56							100				Cementation factor may be excessive.
	mf 4	SE	SW	31	4	21	10,000	6	1	do	Sanborn	do	8-47			0	1	29	66.4	Brown silty clay.												86.3	2.59							100				Cementation factor may be excessive.
	mf 5	SE	SE	12	5	22	100,000	25	8	do	Terrace deposits	do	do				0	7	90.6	Yellowish-gray silty clay.												82.5	2.55							100				Cementation factor may be excessive; overlain by soil and sand layers.
	mf 6	NW	SW	6	5	24	150,000	10	3	Fair	Sanborn	do	do				0	3	95.0	Light brown silt and clay.												77.2	2.57							100				Cementation factor may be excessive.
	mf 7	SW	SW	19	5	24	150,000	6	4	Good	Terrace deposits	do	do				0	2	96.8	Yellowish-gray silty clay.												82.4	2.5							100				Cementation factor may be excessive.
Volcanic ash	va 1	SE	SE	16	1	21	6,000	6	4	do	Sanborn	do	7-47			0	1	53	25.0													71.2	2.5							2				High percentage of silt.
	va 2	SW	SE	2	3	25	2,500	6	0-3	do	Ogallala	SHCK	11-41		0	3	7	18	70.0	Gray.												43.0								1				Some gravel and sand.
	va 3	SE	SE	27	4	23	5,000	6	3	do	do	SHCK USGS	7-47			0	4	17	62.6	Light gray.												58.8	2.38							42				Cementation factor fairly high; concealed beneath Sanborn formation.
Quartzite	q 1	NW	SW	20	4	21	2,000	3	1	do	do	SHCK	2-46							Green; coarse to fine-grained.													2.35				44.3	OK	6		1,2			
	q 2	SE	SW	28	4	21	3,000	3	0	Fair	do	do	do							Green; coarse grained.													2.34				47.6	0.98	8		1.07			
	q 3	SE	SE	30	4	21	10,000	9	4	Good	do	SHCK USGS	7-47							Light gray-green; fine-grained.													2.25				60.5	0.91			4.35			
	q 4	NW	SW	34	4	23	8,000	4	2	do	do	SHCK	2-46							Light green; conglomeratic.													2.31				46.7	0.90			2.02			
	q 5	SE	NE	15	5	21	10,000	6	2	do	do	SHCK USGS	7-47							Gray.													2.34				38.7	0.95			1.44			
	q 6	SW	SE	5	5	22	8,000	4	3	do	do	do	do							Light greenish gray; coarse-grained.													2.35				40.8	0.96			1.25			
	q 7	SE	NW	7	5	24	4,000	4	0	Poor	do	SHCK	2-46							Green; crystalline.													2.35				41.9	0.95			1.50			
Silicified chalk	sc 1	E½	SW	26	2	23	150,000	12	2	Good	Smoky Hill	do	3-46							Siliceous chalk; brown, white, and yellow.													2.29				24.4	0.91			3.20			
	sc 2	NW	SW	34	2	23	2,000	6	2	Fair	do	do	12-37							Siliceous chalk; dense; deep red.													2.23					OK	23		1.25			
	sc 3	NW	NW	4	3	23	150,000	14	3	Good	do	do	3-46							Siliceous chalk; brown, white, and yellow.													2.28				26.9	0.82			2.12			
	sc 4	SW	SW	1	4	21	7,500	9	2	do	do	SHCK USGS	7-47							Siliceous chalk; brown, white, and yellow.													2.19				31.5	0.81			3.8			
Mortar bed	mb 1	SE	NE	34	5	25	10,000	8	0	do	Ogallala	SHCK	8-37																				2.03					OK	4		7.4			
	mb 2	SE	SE	34	5	25	50,000	8	2	do	do	SHCK USGS	8-47																				2.18				76.0	0.77			6.09			
Sandstone	ss 1	SE	SE	27	4	22	5,000	6-8	4-14	Fair	do	do	7-47							Brown-gray; loosely cemented.													2.31				65.9	0.90			4.54			

[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.