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CONSTRUCTION MATERIALS IN ELLIS COUNTY, KANSAS

By

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INTRODUCTION

Purpose of the investigation

The State Highway Commission of Kansas and the United States Geological Survey are cooperating in the compilation of a State-wide inventory of engineering construction materials. In the summer of 1946, the U. S. Geological Survey sent a field party into Ellis County, Kans., to investigate sources of such materials. This report on Ellis County is a part of the general inventory and a contribution to the studies of the mineral resources 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 Ellis County which could be used in the construction of dams, irrigation canals, highways, airports, or other engineering projects. Additional geologic data are included in the present report only to the extent of providing information useful in the development of the prospects reported or in the location of other sources of materials required to fulfill engineering needs.

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

Area covered by the investigation

Ellis County is in the third tier of counties south of the Kansas-Nebraska border and in the fifth tier east of the Colorado border. (See fig. 1.) Its area is about 900 square miles, and it comprises 25 townships. The county is bounded by parallels 38°39' and 39°08' north latitude and meridians 98°58' and 99°38' west longitude. Ellis County is bordered on the east by Russell County, on the west by Trego County, on the north by Rooks County, and on the south by Rush County.

Geography of the area

Ellis County is in the border region of the Great Plains physiographic province. Streams cutting headward from the Central Lowlands province to the east have dissected the border region to one of low to moderate relief. The streams occupy steep-sided valleys, many of which are cut more than 100 feet below the gently rounded upland surface. The areas of greatest relief in Ellis County are along the Saline River in the northern part of the county, along Big Creek in the western part of the county, and along the Smoky Hill River in the southern part of the county.

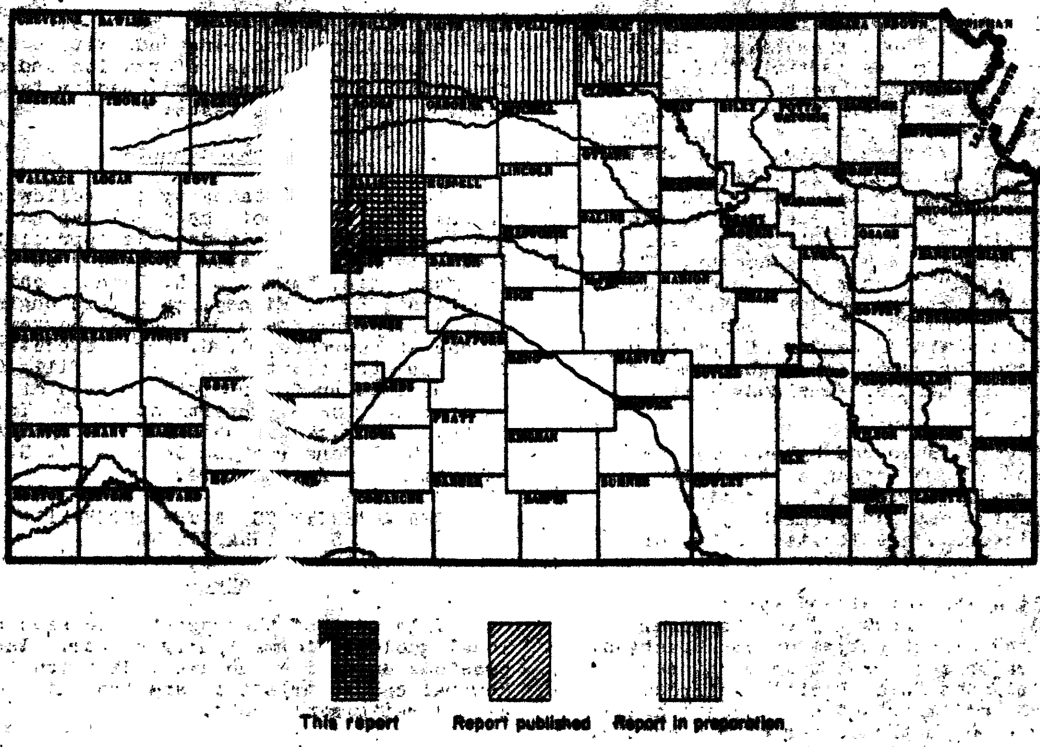


Figure 1.—Index map of Kansas showing areas covered by this report and by other construction materials investigations.

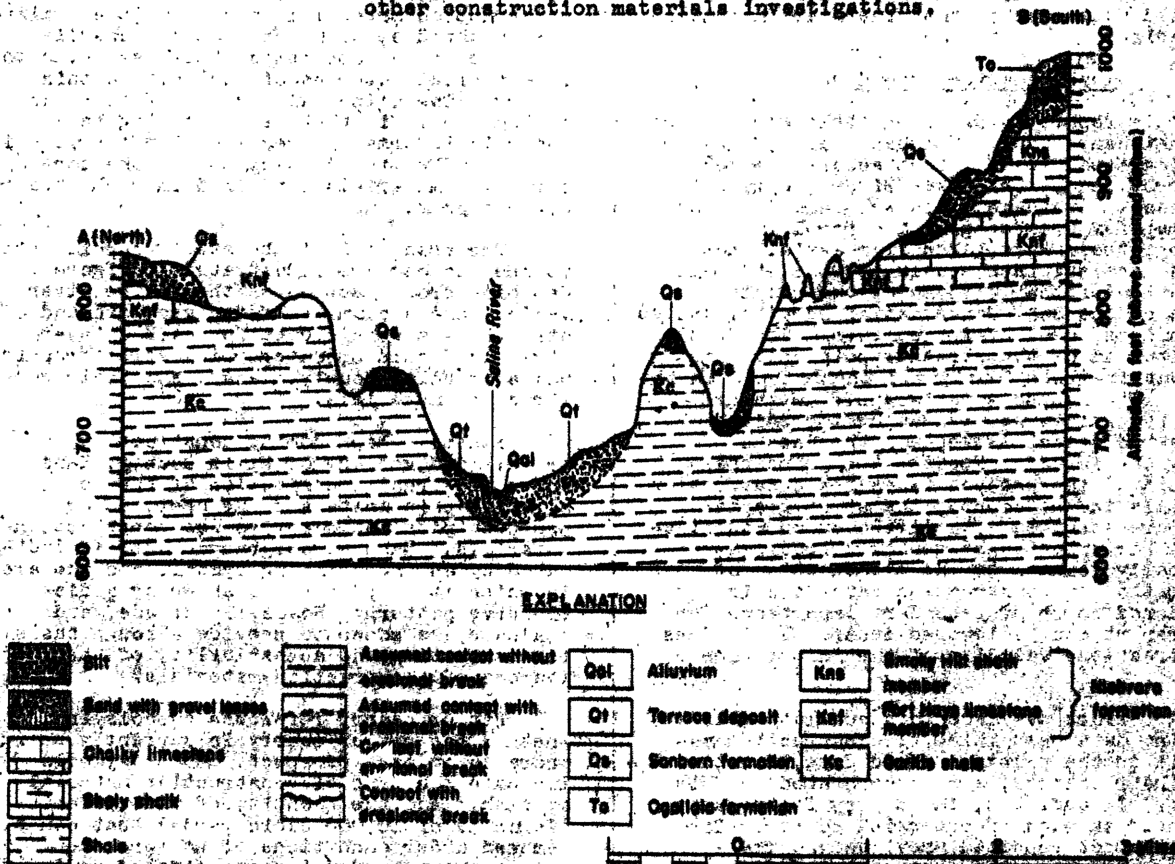


Figure 2.—Geologic cross section of the Saline River Valley along the line A-B (along section line between secs. 3 and 4, T. 11 S., R. 19 W., south to secs. 9 and 10, T. 12 S., R. 19 W.)

Three permanent streams flow eastward across the county. The Saline River, which originates about 90 miles west of Ellis County, enters at the northwestern corner of the county and flows toward the east, its course almost paralleling the northern border of the county. Big Creek, which rises about 40 miles west of Ellis County, enters about midway between the north and south borders, and flows slightly south of east across the county, and joins the Smoky Hill River about 6 miles farther east in Russell County. The Smoky Hill River originates in Colorado. It enters near the southern border of Ellis County and flows eastward in a course almost parallel to the southern border of the county. The larger tributaries to these three major streams enter the main streams nearly at right angles.

Ellis County is served by one railway, the main line through Kansas of the Union Pacific Railroad. The principal cities, Hays (the county seat and largest city), Ellis, and Victoria, are located along this railroad.

There is a well-developed system of highways and county roads. The Federal highways are of the blacktop type of construction. U. S. 40, a major east-west transcontinental route parallels the Union Pacific Railroad, and U. S. 183, an important north-south highway, extends through the center of the county. Most of the roads maintained by the county follow section lines. Many of them 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 maps (Highway Planning Maps, scale 1 inch equals 1 mile) were 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 county office of the Soil Conservation Service, United States Department of Agriculture. The areal distribution of the stratigraphic units that crop out in Ellis County was then mapped in the field. The mapped stratigraphic units are those recognized as of 1946 by the United States Geological Survey and the Kansas Geological Survey. Because the principal emphasis of the project is on the construction materials in the county, the stratigraphic units are accepted with little or no modification. The solution of geologic problems not critically related to the presentation of information on construction materials is considered to be of secondary importance for this report and is ignored insofar as it does not affect the validity of the information given.

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 Survey field party collected samples of potential construction materials not reported previously. The samples of aggregates were analyzed in the laboratory of the Department [illegible] Geology, Kansas State College. The [illegible]yses included a simplified sieve analy[illegible]s a mineralogical analysis of the resultant coarse and fine fractions made with a binocular miscroscope. This information and data from other sources are tabulated in table 1, Summary of materials tests.

Acknowledgments

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

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

General

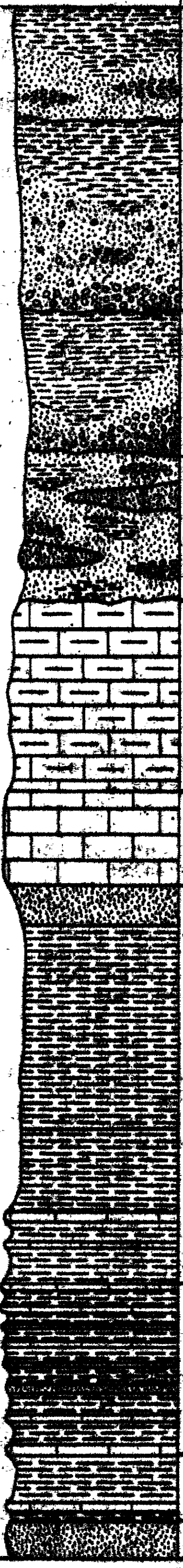
This part of the report discusses each local geologic formation or member. The discussions emphasize the areal distribution, the general characteristics, and the thickness of each stratigraphic unit.

A representative measured section is given for each formation or member, and 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 this county. 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 on figure 2, Geologic cross section of the Saline River Valley, and a summary of the geologic and construction-materials data for each unit are given in figure 3, Outcropping stratigraphic units in Ellis County, Kans., and their construction materials.

Plate 1, Map showing construction materials and geology of Ellis County, Kans., shows the areal distribution of the local stratigraphic units and the operated or prospect pits and quarries for construction materials. Each stratigraphic unit is indicated by an indentifying symbol, and the areas in which it crops out are shown by a distinctive pattern. Roads, railroads, and drainage are shown to provide a rough basis for evaluating the accessibility of the sources of construction materials.

Pit or quarry reference symbols indicate whether the pit or quarry is currently being operated or is a prospect. Other symbols indicate the type of construction material available and the quantity of that material (in units of 10,000 cubic yards) that can be removed under conditions of no more than moderate overburden (unconsolidated sediments less than 5 feet thick). Symbols shown in vertical letters followed by a number (such as ma12) are listed in table 1. The materials



Outcrop thickness (feet)	System	Series	Formations and members		Generalized description	Construction materials
0–60	Quaternary	Pleistocene and Recent	Alluvium		Tan to brown silt with interbedded lenses of sand and gravel.	Aggregate Mineral filler Road metal
0–100	Quaternary	Pleistocene and Recent	Terrace deposits		Upper part, gray-brown silt; lower part, sand and gravel, tan to brown.	Aggregate Road metal Mineral filler Volcanic ash
0–75	Quaternary	Pleistocene and Recent	Sanborn formation		Upper part, brown silt with scattered sand and gravel particles; lower part, gray-brown silt and sand with lenses of sand, limestone gravel, and volcanic ash.	Aggregate Road metal Volcanic ash Mineral filler
0–75	Tertiary	Pliocene	Ogallala formation		Sand, silt, and gravel; gray to brown; light-gray mortar-bed lenses; hard nodular limestone locally at top.	Mortar bed Fine aggregate
100	Cretaceous	Upper Cretaceous	Niobrara formation	Smoky Hill chalk member	Blue-gray chalky shale interbedded with orange shaly chalk; forms badlands.	Calcareous binder Road metal
50	Cretaceous	Upper Cretaceous	Niobrara formation	Fort Hays ls. member	Massive cream to buff limestones separated by thin gray shales.	Structural stone Calcareous binder Road metal
304	Cretaceous	Upper Cretaceous	Carlile shale	Codell sandstone member	Gray, fine-grained sandstone.	
			Carlile shale	Blue Hill shale member	Black, thin-bedded clay shale with zones of septarian concretions and selenite (gypsum) crystals; forms badlands.	
			Carlile shale	Fairport chalky shale member	Orange-gray chalky and clay shale with thin interbedded bentonitic shale and chalky limestone.	
90	Cretaceous	Upper Cretaceous	Greenhorn ls.	Pfeifer shale member	Chalky shale and thin chalky limestone.	Structural stone Road metal
			Greenhorn ls.	Jetmore chalk member	Brown-gray shale and thin chalk.	
			Greenhorn ls.	Hartland shale member	Black shale, thin limestone and sandstone.	
			Greenhorn ls.	Lincoln limestone member	Chalky shale and crystalline limestone.	
35	Cretaceous	Upper Cretaceous	Graneros shale		Dark shale and thin sandstone.	
20	Cretaceous	Upper Cretaceous	Dakota sandstone		Fine-grained, gray to brown sandstone.	

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

sources indicated by inclined symbols are not listed in table 1. The materials listed in the table are numbered within each 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; the numbering 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. The construction materials sources within a township are numbered in the same sequence as are the sections.

Dakota sandstone

Areal distribution.—The Dakota sandstone, of Upper Cretaceous age (see fig. 3), is the oldest formation cropping out in Ellis County and is therefore the lowest unit in the local stratigraphic column exposed at the surface. This formation crops out only in the southeastern corner of the county. (See pl. 1.) The Dakota sandstone is present at the base of the south bank of the Smoky Hill River in secs. 24, 25, 26, 34, and 35, T. 15 S., R. 16 W., and in a draw tributary to the Smoky Hill River in the SE¼NW¼ sec. 34, T. 15 S., R. 16 W. Well logs show that the Dakota sandstone is buried beneath younger formations in nearly all of the remainder of the county.

General description.—A small part of the Dakota sandstone probably was deposited in marine waters but most of the formation was laid down by streams. Only the uppermost part of the Dakota sandstone crops out in Ellis County. The formation is a massive, fine-grained quartz sandstone. The color ranges from light gray through gray green to dark brown. Weathered surfaces are generally coarsely pitted and the bedding occasionally is etched in relief. Carbonized fragments of fossil plants and numerous concretions of limonite or pyrite occur in the sandstone.

Representative measured sections.—Two sections of the Dakota sandstone measured in Ellis County are as follows:

(1) A cut bank along the south side of the Smoky Hill River in the NE¼NE¼ sec. 34, T. 15 S., R. 16 W., shows the following section of the formation exposed above the level of the river:

	Feet
Graneros shale.	
Dakota sandstone:	
Sandstone, fine-grained, massive, dark brown......................	3.0
Sandstone, fine-grained, massive, gray green......................	1.5
Sandstone, fine-grained, massive, dark brown......................	1.0
Sandstone, fine-grained, massive, gray green......................	5.0
Base covered.	10.5

(2) A ledge of the Dakota sandstone that crops out in the SE¼NW¼ sec. 34, T. 15 S., R. 16 W., presents the following section:

	Feet
Terrace deposits:	
Erosional break.	
Dakota sandstone:	
Sandstone, massive, fine-grained, light gray, weathers gray; weathered surface coarsely pitted or with bedding etched in relief; scattered limonite stains and pyrite concretions..	9.0
Base covered.	

Thickness.—The aggregate thickness of the two outcrops of the Dakota sandstone found in Ellis County is about 20 feet and appears to represent the uppermost part of the formation only. The basal part of the formation does not crop out in this county. Bass 2/ reports that a well drilled in the northeast corner of Rush County penetrated 140 feet of white sandstone thought to be the upper part of the Dakota sandstone.

Construction materials.—The Dakota sandstone is not used in Ellis County as an engineering construction material. Although available only in limited quantities, rock from this formation might be quarried, crushed, and used as a road metal if laboratory tests show that the material is adequate for this use. The formation is a source of water for both domestic and stock uses over much of this part of north-central Kansas.

Graneros shale

Areal distribution.—The Graneros shale, of Upper Cretaceous age, crops out in the southeast corner of the county. (See fig. 3 and pl. 1.) The formation is found at or near the base of the Smoky Hill River terrace along both sides of the valley in secs. 24 to 29 inclusive, and secs. 34 and 35, T. 15 S., R. 16 W. It is present throughout much of the remainder of the county but is concealed beneath younger formations.

General description.—The Graneros shale was deposited under marine waters. The formation is predominantly a very thin bedded clay shale, but there are numerous interbedded sandy shales and sandstones. One zone, at least, contains abundant selenite (gypsum) crystals. The shales are black or brown, and the sandstones and sandy shales are brown or rust-colored. The beds in the formation weather gray, blue-gray, or light brown. No fossils were found in outcrops of the Graneros shale in Ellis County. The formation grades into the underlying Dakota sandstone.

Representative measured section.—The following typical section of the Graneros shale is exposed in a cut bank along the Smoky Hill River in the NE¼NW¼ sec. 34, T. 15 S., R. 16 W.:

2/ Bass, N. W., Geologic investigations in western Kansas, part 1, Geology of Ellis County: Kansas Geol. Survey Bull. 11, pp. 36-37, 1926.

	Feet
Terrace deposits:	
Erosional break.	
Graneros shale:	
Shale, very thin bedded; black, weathers gray	2.0
Shale, brown, weathers light brown; contains buff sandstone concretions	1.5
Shale, very thin bedded; black, weathers gray	1.5
Shale, sandy; brown; forms ledge	0.6
Shale, very thin bedded; black, weathers blue-gray; basal 3.0 feet contains numerous crystals of selenite	7.0
Sandstone, poorly cemented; rust-colored	1.0
Shale, very thin bedded; black, weathers blue-gray	3.0
Shale; black, weathers blue; interbedded thin layers of brown sandstone	2.5
Sandstone, soft; brown, weathers rust-colored	.3
Shale, very thin-bedded; black, weathers blue-gray	2.5
Dakota sandstone.	21.9

Thickness.—The aggregate thickness of the Graneros shale in Ellis County is estimated to be about 35 feet. Bass 3/ cites a measured section of the formation having a total thickness of 32 feet.

Construction materials.—The Graneros shale is not a source of construction materials in Ellis County.

Greenhorn limestone

Areal distribution.—The Greenhorn limestone of Upper Cretaceous age is divided into (1) the Lincoln limestone member (the oldest and lowest in the stratigraphic column, see fig. 3), (2) the Hartland shale member, (3) the Jetmore chalk member, and (4) the Pfeifer shale member (the youngest). Although the "Fencepost" limestone bed at the top of the Pfeifer shale member is the most important engineering construction material in the formation, the Pfeifer shale is not separately distinguished on plate 1, the Greenhorn limestone being mapped as a single stratigraphic unit. General descriptions and representative measured sections will be given, however, for all members in the formation as aids to field recognition.

The Greenhorn limestone (see pl. 1) crops out most extensively in Ellis County in the eastern half of the Smoky Hill Valley; finger-like outcrops project from this valley into some of the tributary valleys. The second most important outcrop area is along the south wall of the valley of Big Creek. In the divide area between Big Creek and the Smoky Hill River the Greenhorn limestone is concealed beneath the Sanborn formation. Along the Saline River at the eastern edge of Ellis County there is a small outcrop area in which the Greenhorn limestone lies at or near the base of the valley wall. Elsewhere in Ellis County, where not eroded away, this formation is concealed beneath younger formations.

3/ Bass, N. W., op. cit., pp. 35-36.

General description.—

(1) The Lincoln limestone member of the Greenhorn limestone consists of a series of chalky shales interbedded with thin limestones, bentonitic shales, and shaly sandstones. The hard, dense, crystalline limestones are diagnostic for this member. Crystalline limestones are not so conspicuous in the other members of the Greenhorn limestone or in other Cretaceous formations that crop out in Ellis County. The gray to dark-gray shales are usually very thin-bedded. The thin interbedded bentonites are orange-gray. The shale beds in the lower part of the member are somewhat micaceous.

(2) The Hartland shale member overlies the Lincoln limestone member without an erosional break. It consists predominantly of black, paper-thin beds of shale with some thin beds of chalky limestone. Thin seams of bentonite are interbedded with the shale. The bentonite ranges from white to orange-brown in color and from 0.1 foot to 0.5 foot in thickness. Near the base of the member there is a bed of fine-grained, lime-cemented gray sandstone.

(3) The Jetmore chalk member overlies the Hartland shale member without an erosional break and is overlain similarly by the Pfeifer shale member. The Jetmore chalk member consists of alternating beds of brown or gray, silty or clayey shale, usually thin bedded, alternating with thin beds of chalky gray limestone. The shells of fossil clams (Inoceramus) are found in various zones in the Jetmore chalk member but are most numerous in the upper part. A finely crystalline limestone at the top of the member forms a rounded hillside bench. This bed is locally termed the "shell rock" because of the large content of fossil shells of Inoceramus.

(4) The Pfiefer shale member, the uppermost member of the Greenhorn limestone, is composed of alternating beds of shale and limestone. The chalky shales are light gray or buff. The limestones are chalky and gray to light tan. Both the shales and the limestones contain numerous shells of Inoceramus. The limestone beds in the upper part of the member are concretionary. The "Fencepost" limestone bed is accepted as the top of the member. The name of the bed indicates its widespread use throughout the area as a fencepost material. The bed averages about 0.6 foot in thickness. Characteristically there is a persistent rusty-brown band in the middle part of the bed. The "Fencepost" limestone forms shoulders near the tops of the low hills in the southeastern part of the county.

Representative measured sections.—

Measured sections of the four members of the Greenhorn limestone follow:

(1) A cut bank on the north side of the Smoky Hill River in the [illegible] sec. 27, T. 15 S., R. 16 W. shows the following section of the Lincoln limestone member:

	Feet
Terrace deposits: Sand and gravel....	5.0
Lincoln limestone member of Greenhorn limestone:	
Shale, chalky, very thin bedded; gray to black, weathers light gray; interbedded thin gray chalks and thin orange-gray bentonitic zones..........	7.3
Shale, silty, gray, thin-bedded; orange-gray to dark gray; interbedded thin gray chalks...............	.2
Shale, chalky, very thin bedded; gray to dark gray; interbedded thin gray chalks........................	1.0
Shale, bentonitic; orange-gray..........................	.2
Shale, chalky, very thin bedded; gray to dark gray; interbedded thin gray chalks...	2.0
Sandstone, shaly, calcareous; gray..........................	.1
Limestone, hard, crystalline; gray, weathers buff or light gray; thin shale partings in upper part; numerous fragments of pelecypod shells...........	1.0
Shale, chalky, micaceous; gray; limonite-stained...............	.2
Limestone, dense, hard, crystalline; gray, weathers buff..........................	.2
Shale, chalky, micaceous; gray; limonite-stained...............	.15
Limestone, dense, hard, crystalline, somewhat sandy; thin streaks of limonite.......	.25
Graneros shale.	12.60

(2) A cut bank in the SE¼NW¼ sec. 20, T. 15 S., R. 16 W., shows the following section of the Hartland shale member exposed above the level of the river:

	Feet
Terrace deposits:	
Erosional break.	
Hartland shale member of Greenhorn limestone:	
Shale, paper-thin beds; black, weathers dark gray; interbedded thin limy seams.........	1.1
Bentonite, shaly; orange-brown at top, basal part white..........................	.5
Shale, chalky and somewhat silty, fairly hard, platy; light gray, weathers gray......	.2
Shale, paper-thin beds; black, weathers gray; occasional interbedded calcareous laminae.........................	2.3
Shale, silty, compact, massive; gray..........................	.3
Shale, paper-thin beds; black, weathers gray; occasional interbedded calcareous laminae; thin seams of orange brown bentonite in lower part..	1.7
Limestone, chalky, dense, hard; gray, weathers light gray to buff..........................	.2
Shale, clay; black, weathers gray; interbedded thin seams of orange-brown bentonitic shale..........................	1.1
Hartland shale member of Greenhorn limestone—Continued.	
Bentonite; white to orange-brown..........................	.1
Shale, clay; dark gray, weathers gray..........................	.5
Limestone, chalky, dense, hard; light gray......................	.7
Shale, paper-thin beds; black, weathers gray; occasional interbedded calcareous laminae; calcareous seams become thicker in basal 3.0 feet, more crystalline, and contain numerous fragments of pelecypod shells.............	14.7
Sandstone, fine-grained, heavily lime cemented; gray; numerous partings of black paper shale......................	1.0
Shale, paper-thin beds; black, weathers dark gray; occasional interbedded calcareous laminae.........................	3.0
Base not exposed.	27.4

(3) A roadside ditch in the SE¼SE¼ sec. 21, T. 15 S., R. 16 W. shows the following section of the Jetmore chalk member:

	Feet
Sanborn formation:	
Erosional break.	
Jetmore chalk member of Greenhorn limestone:	
Limestone, finely crystalline, dense, hard; gray, weathers buff; limonite stains; *Inoceramus* abundant.............	2.6
Shale, clay, thin-bedded; light brown-gray, weathers gray; abundant thin zones of pelecypod shell fragments.........	1.2
Limestone, chalky, fine-grained, hard, nodular; gray..............	.2
Shale, clay, thin-bedded; light brown-gray, weathers gray.......	1.1
Limestone, chalky, fine-grained, hard, nodular; gray; *Inoceramus* abundant.............	.2
Shale, somewhat silty, thin-bedded; red-brown, weathers gray; grades laterally into dark-gray shale................	1.1
Limestone, chalky, fine-grained, hard; gray; thickens and thins laterally......................	.2
Shale, silty, thin-bedded; color varies laterally from gray to brown; limonite stains; occasional *Inoceramus*..........	2.2
Limestone, chalky, fine-grained, dense, hard; thickens and thins laterally...................	.5
Shale, silty, thin-bedded; color varies laterally from gray to brown; limonite stains; occasional *Inoceramus*..........	1.1
Limestone, chalky, fine-grained, dense, hard; thickens and thins laterally...................	.4
Shale, silty, thin-bedded; color varies laterally from brown to dark gray, weathers light gray..	2.4
Limestone, chalky, fine-grained, dense, hard; thickens and thins laterally...................	.4
Shale, calcareous, thin-bedded; brown, weathers light gray.......	1.4
Base covered.	15.0

(4) The most representative section of the Pfeifer shale member is one measured by Bass 4/ in a road cut in the SE¼ sec. 21, T. 15 S., R. 17 W.:

	Ft.	In.
Pfeifer shale member of Greenhorn limestone:		
24. "Fencepost limestone," chalky limestone, light tan, even-grained, including near the middle a rusty band about an inch wide and a little lower another rather indistinct band. Contains a few well-preserved fossils (*Inoceramus labiatus*). Top bed of Pfeifer shale member........		8½
23. Soft chalky shale, cream to flesh-colored............		11
22. Chalky limestone, somewhat concretionary; weathers white; contains a few fossils............		1
21. Chalky shale like No. 23.............		10
20. Concretionary chalky limestone, fossiliferous; weathers white...............		4
19. Shale, like No. 23...	1	2
18. Chalky limestone, with no fossils; weathers white.....		1
17. Chalky shale, like No. 23.............		11
16. Chalky limestone, like No. 18,.......		4
15. Shale, like No. 23, with a band of bentonitic clay 4 inches thick at its top. Upper part of clay band gritty and shows orange color,.......	1	2
14. Concretionary fossiliferous chalky limestone..........		2
13. Chalky shale; weathers flaky; light tan; in places contains a thin discontinuous bed of somewhat fossiliferous concretionary chalky limestone...........	1	6
12. White chalky limestone, very few fossils....		3
11. Shale, like No. 13, somewhat fossiliferous, in places has two thin discontinuous beds of fossiliferous concretionary chalky limestone...........	2	4
Pfeifer shale member of Greenhorn limestone—Continued.		
10. Chalky limestone; weathers to rusty brown; ferruginous band near middle; contains many fossils..............		2
9. Shale, like No. 13.....		10
8. Chalky limestone; very few fossils..........		3
7. Shale, like No. 13.....	1	
6. Concretionary chalky limestone; fossiliferous..............		2
5. Shale, like No. 13.....		9
4. Concretionary chalky limestone; fossils abundant..............		2½
3. Shale, like No. 13.....	1	4
2. Concretionary chalky limestone; fossils abundant.............		4
1. Shale, like No. 13.....	3	1
	18	11

4/ Bass, N. W., op. cit., p. 32.

<u>Thickness</u>.—The total thickness of the Greenhorn limestone in Ellis County is about 90 feet. The thickness of the individual members in the formation is as follows: Lincoln limestone, about 20 feet; Hartland shale, about 30 feet; Jetmore chalk, about 20 feet; and Pfeifer shale, about 20 feet. The thicknesses appear to be rather uniform throughout the county.

<u>Construction materials</u>.—
Structural stone.
Road metal.

<u>Carlile shale</u>

<u>Areal distribution</u>.—The Carlile shale, of Upper Cretaceous age (see fig. 3), includes three members, (1) the Fairport chalky shale member (oldest), (2) the Blue Hill shale member, and (3) the Codell sandstone member (youngest), all of which crop out in Ellis County. Inasmuch as no one of the members is especially significant as a source of engineering construction materials, they are mapped together as a single stratigraphic unit, the Carlile shale. As aids to field recognition, however, general descripions and representative measured sections of each member will be given.

The Carlile shale crops out extensively in Ellis County. (See pl. 1.) The principal area of outcrop is in the northeastern corner of the county, where it forms the valley walls of many streams tributary to the Saline River and underlies the divide areas as well. This outcrop area extends westward along the Saline River to a point about 6 miles east of the western county line. A second large area of outcrop is in the southern part of the county along the Smoky Hill River. The Carlile shale appears at the surface several miles west of Pfeifer, and its outcrops become more extensive toward the western border of the county. In the southwest corner of the county the Carlile shale is the only stratigraphic unit cropping out over a badland area of 5 or 6 square miles. Less extensive outcrops of the formation are present along some of the streams tributary to Big Creek.

General description.—The Carlile shale was deposited in marine waters. It is in contact with underlying and overlying Cretaceous formations without intervening erosional breaks, and its several members are in contact in a similar manner. Erosional breaks intervene between the Carlile shale and the Tertiary and Quaternary formations that overlie it in some places.

(1) The Fairport chalky shale member, the oldest and stratigraphically the lowest member of the Carlile shale, consists of clay shales with interbedded thin bentonitic zones. The shale is either thin bedded or somewhat blocky in structure. Its unweathered color is gray, but upon weathering the color is altered to a characteristic orange-gray. This member of the Carlile shale crops out generally in the eastern part of the county and may be identified by its color as well as its position immediately above the "Fencepost" limestone bed in the Pfeifer shale member of the Greenhorn limestone. The lower part of the Fairport chalky shale member contains a number of thin beds of fossiliferous chalky limestone interbedded with the shale.

(2) The Blue Hill shale, the middle member of the Carlile shale, crops out the most extensively of the three members. This member is a dark gray to black clay shale that weathers to a distinctive blue-gray. The shale is generally very thin bedded. There are several zones of septarian concretions in the member as well as zones in which selenite crystals are exceedingly abundant.

The Blue Hill shale member erodes to form a badland type of topography. Selenite crystals scattered over the surface of the badland hills reflect sunlight in such a way as to give the hills a sparkling appearance.

(3) The Codell sandstone member is the youngest member of the Carlile shale and the thinnest. In the northeastern part of the county it is a gray, fine-grained, clean quartz sandstone, but toward the west and south it becomes much thinner and more silty. There is a gradational contact between the Codell sandstone member and the underlying Blue Hill shale member.

Representative measured sections.—The following measured sections indicate the characteristics typical of the several members of the Carlile shale:

(1) This section of the Fairport chalky shale member is exposed in a road cut in the NW¼NE¼ sec. 3, T. 14 S., R. 17 W.:

	Feet
Sanborn formation:	
Erosional break.	
Fairport chalky shale member:	
Shale, clay, conchoidal or blocky structure; thick gray bands alternating with thin orange-brown bentonitic zones..............	5.5
Shale, clay, thin bedded; orange-brown bentonitic zones mottled with dark gray..........................	2.5
Shale, clay, somewhat blocky; dark-gray bands alternating with thinner orange-brown bentonitic bands..........................	6.0
Base covered.	14.0

(2) A road cut in the NE¼NE¼ sec. 3, T. 11 S., R. 17 W., exhibits the following section of the Blue Hill shale member and the Codell sandstone member of the Carlile shale, as well as the basal part of the Fort Hays limestone member of the overlying Niobrara formation:

	Feet
Fort Hays limestone member of Niobrara formation:	
Shattered zone..................	2.5
Limestone, chalky, massive; light yellow-gray, weathers buff-gray...........	2.7
Limestone, chalky, massive; light yellow-gray, weathers buff-gray; limonite-stained; base irregular.....................	8.0
Codell sandstone member of Carlile shale:	
Sandstone, fine-grained, clean, predominantly quartz, compact, hard; gray, weathers buff-gray; irregularly limonite-stained; grades into underlying Blue Hill shale member..................	7.7
Blue Hill shale member of Carlile shale:	
Siltstone, massive; gray, weathers buff.................	2.2
Shale, clay; mottled gray and rust-brown, weathers buff.........................	8.1
Shale, silty, dense; gray, weathers light gray..........	1.2
Shale, clay; mottled gray and rust-brown, weathers buff....	3.1
Shale, clay, thin-bedded; black, weathers dark gray; irregularly limonite-stained; zones of large septarian concretions 18 and 32 feet below top..........................	61.0
Base covered.	
Total Carlile shale.............	83.3

Thickness.—The aggregate thickness of the Carlile shale is thought to be about 304 feet. The Fairport chalky shale member is about 100 feet thick; the Blue Hill shale member is about 200 feet thick; and the Codell sandstone member ranges from nearly 8 feet in the northeastern corner of the county to about 1 foot in the southwestern corner, its average thickness being about 4 feet.

Construction materials.—The Blue Hill shale member is used as material for road fill. Because of its high content of clay, however, it probably is not completely satisfactory for this use in humid regions unless the side slopes are graded to a low angle. Field investigation failed to find any important engineering use of the materials included in this formation. The Codell sandstone member in the northwestern part of the county is said to yield water in domestic and stock wells.

Fort Hays limestone member of the Niobrara formation

Areal distribution.—The Fort Hays limestone and the Smoky Hill chalk constitute the Niobrara formation of Upper Cretaceous age. (See fig. 3) Inasmuch as the former is more important than the latter as a source of construction materials the two members are mapped as individual units and will be described separately. The Fort Hays limestone member crops out extensively over much of the northern half of Ellis County. (See pl. 1.) It forms the walls of the Saline Valley and of many of its tributaries and underlies many divide areas. This member crops out in similar fashion in the western half of the Big Creek drainage basin. It forms a conspicuous escarpment trending southwest across the county.

General description.—The Fort Hays limestone member was deposited under marine waters and is in contact with the underlying Codell sandstone member of the Carlile shale and the overlying Smoky Hill chalk member of the Niobrara formation without intervening erosional breaks. The Fort Hays limestone is predominantly a buff-colored chalk, which weathers to a dirty tan-gray. The chalk beds are massive and quite soft. Thin partings of chalky shale are interbedded with the limestone. The shale partings range from 0.1 to 0.5 foot in thickness.

In the rather dry climate of Ellis County the Fort Hays limestone forms steep hillsides despite its relative softness. The part of the limestone immediately below the land surface shows a tendency to shatter, breaking into irregular flat fragments 4 to 5 inches long and an inch or two thick.

Fossil shells of clams (*Inoceramus deformis*) and oysters (*Ostrea congesta*) are fairly abundant in this member.

The stratigraphic units from the Dakota sandstone up to the Smoky Hill chalk member of the Niobrara formation, inclusive, dip at a low angle toward the north. The general dip is interrupted locally by several broad flexures. Many small faults were observed in the Fort Hays limestone member and adjacent stratigraphic units but are not mapped because they are not important to a construction-materials survey.

Representative measured section.—The face of a quarry in the [illegible] sec. 15, T. 13 S., R. 20 W., shows the following section of the Fort Hays limestone member:

	Feet
Fort Hays limestone member of Niobrara formation:	
Top eroded.	
Shattered zone	1.5
Limestone, chalky, massive, soft; white, weathers grey; *Inoceramus*	1.2
Shale, thin-bedded; gray, weathers dark gray; limonite stained	.1
Limestone, chalky, thin-bedded; white, weathers buff; *Inoceramus*, *Ostrea*	2.0
Shale, calcareous; gray; limonite stained; *Inoceramus*, *Ostrea*	.4
Limestone, chalky, thin-bedded; white, weathers buff; *Inoceramus*	.5
Limestone, chalky, massive; white, weathers gray; *Ostrea*	1.5
Limestone, chalky, soft; buff; limonite-stained	.1
Fort Hays limestone member of Niobrara formation—Continued.	
Limestone, chalky, massive; white, weathers gray; *Inoceramus*	2.5
Shale, calcareous; buff; *Inoceramus*, *Ostrea*	.1
Limestone, chalky; white to buff, weathers gray; *Inoceramus*, *Ostrea*	1.0
Limestone, chalky, dense, soft; white, weathers gray; *Inoceramus*, *Ostrea*	2.3
Shale, chalky; tan, weathers light gray; limonite stains	.5
Limestone, chalky, soft; white, weathers gray; *Inoceramus*	1.5
Shale, calcareous; buff; limonite stains	.1
Limestone, chalky, massive, soft; white, weathers gray; *Inoceramus*	3.5
Shale, thin-bedded; gray, *Inoceramus*	.1
Limestone, chalky, massive, soft; buff to white, weathers gray; *Inoceramus*	3.5
Limestone, argillaceous, soft; buff	.2
Shale; gray	.2
Limestone, chalky, massive; buff to white, weathers gray; *Inoceramus*	4.0
Shale, chalky; buff, weathers gray	.1
Limestone, chalky, massive, soft; white to buff; *Inoceramus*	3.5
Limestone, chalky, massive, soft; buff, weathers brown	2.5
Base covered.	33.2

Thickness.—The Fort Hays limestone member is estimated to have an aggregate thickness of about 50 feet in Ellis County. It has been completely eroded from the southeastern third of the county along the major drainage lines and is concealed beneath younger formations (Ogallala and Sanborn) over much of the remainder of the county.

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

Smoky Hill chalk member of the Niobrara formation

Areal distribution.—Outcrops of the Smoky Hill chalk member of the Niobrara formation in Ellis County are limited in areal extent and are restricted to the northern part of the county. (See fig. 3 and pl. 1.) The Smoky Hill chalk is exposed principally at the heads of some of the tributaries of the Saline River and along some of the streams tributary to Big Creek in the western part of the county. There are a few small outcrops near the heads of the southward-flowing tributaries of the Smoky Hill River near the western boundary of the county. This member presumably underlies many of the divides in the northern and western parts of the county, where it is obscured by younger formations (Ogallala and Sanborn).

General description.—The Smoky Hill chalk member was deposited in marine waters.

It overlies the Fort Hays limestone member of the Niobrara formation without an intervening erosional break, but a pronounced erosional break intervenes between it and the overlying younger formations. (See fig. 2.) The Smoky Hill chalk member consists of layers of blocky or massive chalky shale, blue-gray in the lower part of the member but becoming orange-gray in the upper part. Thin layers of massive chalk are interbedded with the shale. Shells of the fossil clam Inoceramus (Haploscapha) grandis and the fossil oyster Ostrea congesta are numerous in some zones in the member.

The soft beds of chalky shale typically erode to form a badland type of topography.

Representative measured section.—A cut bank in the NE¼SE¼ sec. 19, T. 11 S., R. 20 W., shows the following section of the Smoky Hill chalk member:

	Feet
Smoky Hill chalk member of Niobrara formation:	
Top eroded.	
Chalk; yellowish; limonite concretions; Ostrea, Inoceramus	2.0
Shale, chalky; yellow-gray; Ostrea, Inoceramus	.1
Chalk; yellow-gray	.6
Shale, chalky; yellow-gray; limonite concretions; Ostrea, Inoceramus	1.0
Chalk, shaly; yellow-gray	1.9
Shale, chalky; yellow-gray; limonite concretions; Ostrea, Inoceramus	3.0
Chalk; white, weathers gray	.8
Shale; buff, weathers brown; limonite concretions	.3
Chalk, platy; white, weathers gray	1.0
Shale, chalky; buff, weathers gray; Ostrea, Inoceramus	3.5
Chalk; white	.3
Shale, chalky; buff, weathers gray; limonite concretions; Ostrea, Inoceramus	3.0
Chalk; white	.3
Shale, chalky; buff, weathers light gray; limonite concretions; Ostrea, Inoceramus	6.0
Shale, chalky; dark blue, weathers blue-gray; limonite stains and concretions; Ostrea, Inoceramus	8.0
Base covered.	31.8

Thickness.—Only the basal part of the Smoky Hill chalk member occurs in Ellis County. Bass 5/ reports that the aggregate thickness of the member in this county is about 100 feet. It has been eroded completely from much of the area.

Construction materials.—
Calcareous binder.
Road metal.

Ogallala formation

Areal distribution.—The Ogallala formation, of Pliocene age, crops out in three general areas in Ellis County all of them in the higher divides. (See fig. 3 and pl. 1.) The most extensive outcrop area is the one that extends from the western border of the county almost to the eastern county line at a distance of 3 to 12 miles south of the northern county line. A somewhat smaller outcrop area lies 2 to 5 miles south of Ellis and extends east from the western border of the county for a distance of about 9 miles. Two small outcrops are mapped in the southwest corner of the county. At one time the Ogallala formation undoubtedly covered most of the county, but it has subsequently been eroded completely except in the areas listed above.

The Ogallala formation is generally concealed beneath the Sanborn formation. Certain zones in the Ogallala are very similar in physical characteristics to zones in the Sanborn, and in some places only arbitrary lines of contact can be drawn between the two formations. Such differentiation is based upon the generally more silty character of the Sanborn and its more subdued topographic expression in contrast to the somewhat more sandy character of the Ogallala, its bolder outcrop expression, and the presence of mortar-bed ledges.

General description.—The Ogallala formation is separated from older formations by an erosional break. It is in contact with the underlying Smoky Hill chalk member of the Niobrara formation (see fig. 2) in most places in Ellis County and locally with the Fort Hays limestone member of the same formation.

The Ogallala formation consists of interbedded lenses of sand, gravel, silt, and some of clay. The lenses vary in thickness and extent. Most of the material was stream-deposited, but it is possible that some beds were laid down on the floors of shallow lakes. The lower part of the formation is composed of somewhat coarser mineral and rock fragments than is the upper part. Quartz is the predominant constituent, with fragments of the feldspar minerals present in subordinate amounts. The gravel- and sand-size particles are rounded to subrounded in shape, and the silt- and clay-size particles are subangular to angular.

The Ogallala formation includes lenses of lime-cemented sand, gravel, or sand and gravel. Such lenses are termed "mortar beds"; they range in thickness from less than 1 foot to about 8 feet. The mortar-bed ledges make bold outcrops usually high on the shoulders of the divides. The constituent rock and mineral fragments have been more or less firmly cemented by deposits of calcium carbonate laid down by percolating subsurface waters. The beds are light gray in color. In many places in Ellis County there is a hard, dense, nodular limestone at the top of this formation. It is thought that this limestone might have been deposited as a surface caliche.

Quartzite ledges such as are found in the Ogallala formation in Rooks, Ness, and Rush Counties were not found in Ellis County.

Representative measured section.—A cut bank in the [illegible] sec. 17, T. 12 S., R. 20 W., shows the following section of the Ogallala formation:

5/ Bass, N. W., op. cit., p. 13.

	Feet
Soil	1.5
Ogallala formation:	
Limestone, very hard, dense; light gray	.4
Mortar bed, lime-cemented sand and gravel, hard; gray	2.6
Silt and fine sand, interbedded calcareous zones; gray-brown, weathers gray	2.6
Mortar bed, sand and fine gravel, massive; light gray	3.8
Sand, fine, to fine gravel, highly calcareous; dirty gray	1.7
Mortar bed, sand and fine gravel, hard; gray, weathers dark gray; cavernous appearance	5.8
Silt, calcareous, coarse sand scattered throughout; flesh-colored	2.7
Covered	8.0
Mortar bed, fine gravel and sand, basal part massive; light gray	3.0
Silt, clayey, calcareous; light gray-brown	.8
Clay, calcareous, hard; light gray	.4
Sand, fine, dense, calcareous; light gray, weathers buff	.7
Sand, fine, somewhat silty, calcareous; light gray	2.1
Base covered.	
Total Ogallala formation	34.6

Thickness.—The thickness of the Ogallala formation in Ellis County ranges from a featheredge to 75 feet, as reported by Bass.6/ The average thickness is estimated to be about 40 feet. The formation is thickest in the western part of the county and along the axes of the principal divides.

Construction materials.—
Mortar bed.
Fine aggregate.

Sanborn formation

Areal distribution.—The Sanborn formation, of Pleistocene and Recent(?) age (see fig. 3) is subdivided into members by Frye and Fent.7/ It was not feasible to attempt the mapping of these members, as to do so would have required a greatly extended field program.

The Sanborn formation overlies all other formations with an intervening erosional break (see fig. 2), but the break between the Sanborn and Ogallala formations is not conspicuous because of their similar lithologic character.

6/ Bass, N. W., op. cit., p. 16.
7/ Frye, J. C., and Fent, O. S., Late Pleistocene loesses of central Kansas: Kansas Geol. Survey Bull. 70, pt. 3, pp. 41-51, 1947.

The Sanborn formation is the most widely distributed stratigraphic unit cropping out in Ellis County. (See pl. 1.) It is a blanket of variable thickness capping most of the divide areas in the county. Where a thin layer (less than 3 feet thick) of the Sanborn formation overlies a stratigraphic unit that is a potential source of construction materials, the underlying unit is mapped on plate 3. The formation probably once extended over the entire county, but it has subsequently been removed by erosion along most of the stream courses.

General description.—The Sanborn formation includes unconsolidated sediments deposited by wind, streams, and slope wash and through the action of gravity. The upper part of the formation is predominantly a gray-brown or brown silt with particles of sand and fine gravel scattered throughout. There is a well-developed soil zone at the top of the formation, and Hibbard, Frye, and Leonard 8/ have reported one or more buried soil zones. The upper part of the formation contains conspicuous amounts of calcium carbonate, either in the form of pipe like structures or as concretionary masses.

The basal part of the Sanborn formation generally is more coarse than the remainder and includes local masses of interbedded sand and gravel. Such lenses are gray to tan and include gravel-size fragments of local limestone, mortar bed, calcite, feldspar, quartz, and granite. The fine fraction is composed predominantly of particles of quartz, feldspar, and calcite. Bedding is locally well-developed in this part of the formation.

One operated pit for volcanic ash (see pl. I and table 1) is located in the [illegible] sec. 17, T. 14 S., R. 19 W. The material is used as binder in the construction of blacktop highways in the area. The ash is very fine-grained and almost entirely free of extraneous materials. Undoubtedly other lenses of volcanic ash occur in the Sanborn formation, presumably in the basal part.

Silt of the Sanborn formation contains scattered fossil snails (gastropods) and is reported to contain fossil vertebrates.

It is probable that the Sanborn formation was deposited during at least two different depositional cycles. The part of the formation lying on the higher divides may have been deposited first by the action of streams, slope wash, gravity, and the wind. Deposition by the same agencies working at a lower level resulted in extensive deposits on the flanks of most of the hillsides and on the crests of the lower divides.

8/ 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.

Representative measured section—A road cut in the NE¼NW¼ sec. 3, T. 14 S., R. 17 W., shows the following section of the Sanborn formation:

	Feet
Soil, silty, dark gray-brown.........	0.8
Sanborn formation:	
Sand, coarser in basal part, occasional particles of fine gravel; brown............	0.5
Silt, clayey; brown; nodules and stringers of secondary calcium carbonate scattered throughout upper part and calcium carbonate zone 0.5 feet thick at top.........	12.4
Silt, clayey, abundant particles of fine gravel largely from local chalky limestone.....................	2.5
Base covered.	
Total Sanborn formation.........	16.2

Thickness.—The thickness of the Sanborn formation is highly variable in Ellis County. The average is estimated to be about 30 feet, and the maximum about 75 feet. The formation has been completely eroded from the valleys of many of the streams in the county.

Construction materials.—
- Mixed aggregate.
- Fine aggregate.
- Road metal.
- Volcanic ash.
- Mineral filler.

Terrace deposits

Areal distribution.—Terrace deposits are conspicuous in the valleys of the Saline River, Big Creek, and the Smoky Hill River. (See fig. 3 and pl. 1.) Fingerlike extensions of the deposits project into the valleys of the larger tributaries to the major streams. The terrace deposits were laid down by these same streams in earlier gradational cycles and appear to represent at least two levels of deposition. Because the materials composing the two or more terrace deposits are similar in composition the terraces are mapped as a single stratigraphic unit.

General description.—The terrace deposits overlie older formations with an intervening erosional break. The upper part of the terrace deposits is composed predominantly of brown or gray-brown silt. The material grades downward into a fine sand and, in the basal part, to a medium gravel and coarse sand. The basal part usually is red brown as the result of limonite coatings on the constituent particles. The coarse fraction of the basal part of the terrace deposits is composed predominantly of fragments of granite, quartz, and feldspar with a minor amount of plates of local limestone as much as 4 or 5 inches long and particles of chert and calcite. The fine fraction is composed predominantly of quartz grains with minor amounts of calcite, feldspar, granite, and chert. Table 1 gives the components of both the fine and coarse fractions in terms of percentage.

The basal sand and gravel phase of the terrace deposits crops out along the Saline River and the Smoky Hill River, the terraces being well-defined topographic features of the valleys. The terraces of the valley of Big Creek are equally well defined but are composed almost entirely of silt. The fingerlike extensions of the terrace deposits into tributaries of the principal streams are composed of coarser materials of very local origin and are poorly sorted.

Representative measured section.—A typical section of a terrace deposit is exposed in a cut bank along the north side of the Smoky Hill River in the SE¼SW¼ sec. 30, R. 15 S., R. 16 W.:

	Feet
Soil, brown......................	0.5
Terrace deposit:	
Silt, high clay content; brown, weathers light brown.........	3.0
Volcanic ash intermixed with clay; green-gray, weathers light gray..................	1.5
Silt and fine sand, somewhat clayey; tan-brown, weathers tan-gray.....................	2.0
Sand, fine to coarse, and gravel, fine to medium with numerous large platy fragments of limestone and chalk; brown.......	4.0
Total terrace deposit..........	10.5
Hartland shale member of Greenhorn limestone.	

Thickness.—The terrace deposits in the valley of Smoky Hill River are estimated to have a maximum thickness of about 100 feet; those in the valley of the Saline River, about 65 feet; and those in the valley of Big Creek, about 45 feet. The deposits become thicker toward the eastern border of Ellis County. The fingerlike deposits in tributary valleys are probably less than 25 feet thick.

Construction materials.—
- Mixed aggregate.
- Fine aggregate.
- Road metal.
- Mineral filler.
- Volcanic ash.

Alluvium

Areal distribution.—The deposits formed by streams in their present gradational cycles (fig. 3) are mapped as alluvium. (See fig. 3 and pl. 1.) They constitute the most recent stratigraphic unit in the county. The alluvial deposits are conspicuous along the Saline and Smoky Hill rivers. The width of the floodplains ranges from an eigth of a mile to almost a mile. The present floodplain of Big Creek is unusually narrow, and in the mapping of Ellis County, a low terrace standing several feet above the floodplain was mapped with the floodplain as alluvium. Alluvium has been deposited along the mouthward parts of many of the tributary streams.

General description.—The alluvium of the major streams in Ellis County is generally quite silty. Only locally is it sandy. It is probable that lenses of sand and gravel are present in the alluvium at some depth below the surface of the floodplain.

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 alluvial deposits in the valleys of the Saline and Smoky Hill Rivers have a maximum thickness of 50 to 60 feet. The alluvium deposited by Big Creek probably is less than 25 or 30 feet thick.

Construction materials.—
Mixed aggregate.
Fine aggregate.
Road metal.
Mineral filler.

INVENTORY OF CONSTRUCTION MATERIALS

General

This part of the report inventories the construction materials in Ellis County. Its objectives are to establish the bases upon which the construction materials are classified and to discuss the various materials in their relations to the stratigraphic units from which they may be obtained.

Whenever available, laboratory test data have been introduced into the report to aid the engineer in his evaluation of the materials. This information is tabulated in table 1, Summary of materials tests. Data on samples collected by the Geological Survey field party from prospects visited are not so precise as the data on grading and test characteristics developed in a materials-testing laboratory. It is expected that the materials 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 development.

Although numerous prospect pits and quarries were located in the field, no attempt was made to make an exhaustive survey. The purposes of this report are to inventory the materials that occur in Ellis County and to establish the geologic pattern required for the location and development of the materials at those places in the county where they may be needed. A certain stratigraphic unit may contain one or more construction materials and if the geologic factors of that 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 listed in table 1 as fine aggregate or as mixed aggregate. The distinction is based on the percentage of material retained on the no. 4 screen, those materials in which 5 percent or more of the sample was retained being classified as mixed aggregate. It will be more convenient, however, to discuss these under the single heading, Aggregate for concrete, inasmuch as fine aggregate may be "sweetened" to the gradings required for mixed aggregate.

Aggregate for concrete consists of particles of hard, durable minerals or rocks of sand or gravel size. The constituent particles are free from adherent coatings that would interfere with the bonding of cement with the material. The operated or prospect pits listed in table 1 or located on plate 1 are those in which the overburden is thin enough so that the material may be obtained economically.

Stratigraphic sources and performance characteristics

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

(1) Ogallala formation.—Two samples of aggregate materials collected from the Ogallala formation are classified as fine aggregate and are listed in table 1 (fa 4 and 5) and mapped on plate 1. The material is composed predominantly of sand-size particles of quartz and, subordinately, feldspar. The gravel content of the Ogallala formation in Ellis County apparently is so limited that this material cannot be used as a mixed aggregate unless it is sweetened to the desired grading. Additional pits may be opened in the Ogallala in Ellis County in most places where the base of the formation crops out.

(2) Sanborn formation. The Sanborn formation is an important source of aggregate for concrete in Ellis County. Six samples from the Sanborn classified as mixed aggregate (ma 1, 2, 5, 7, 8, and 14) and five samples classified as fine aggregate (fa 1, 2, 6, 7, and 12) are listed in table 1 and mapped on plate 1. The coarse fraction of the mixed aggregate samples analyzed is composed predominantly of fragments of local chalky limestone with minor quantities of chert, granite, and quartz particles and silt and clay nodules. The fine fraction of both mixed and fine aggregates is composed principally of quartz particles and, to a lesser extent, of fragments of feldspar, local limestone, and calcite. Some of the samples contain minor amounts of chert. The high percentage of fragments of soft local limestone, particles of shale, and silt and clay balls might prove disadvantageous for the use of this material as aggregate for concrete.

Laboratory test data indicate that the average weight of the aggregate material from the Sanborn formation is about 110 pounds per cubic foot, the average specific gravity is about 2.6, the percentage of loss in the Los Angeles abrasion test is about 41, and the loss ratio averages about 0.9 after 25 freeze-and-thaw cycles.

The basal part of the Sanborn formation could be prospected for additional aggregate. The sand and gravel occur as lenses of local extent only, and are restricted to the basal part of the formation. The most likely pit sites in the Sanborn formation would be in places where streams have cut well down into the formation, thus exposing the coarser basal part.

(3) Terrace deposits.—The terrace deposits constitute the principal source of concrete aggregate in Ellis County. Thirteen samples classified as mixed aggregate (ma 3, 4, 6, 9-13, and 15-19) are listed in table 1 and mapped on plate 1. Samples of fine aggregate from this stratigraphic unit are fa 3 and fa 8-11. Where the coarse fraction contains a fairly high percentage of fragments of soft local limestone. These need not be deleterious in aggregate for concrete, as they are large enough to be removed easily

by screening. In some places the terrace deposits appear to be relatively free from limestone fragments. Chert is present but in percentages small enough (table 1) so that it is not considered a deleterious constituent of the material. The fine fraction of both mixed and fine aggregate in the terrace deposits is composed predominantly of quartz, with some feldspar and calcite, and minor amounts of chert, hornblende, and magnetite.

The test characteristics of the terrace-deposit materials sampled are as follows: weight, 110 pounds per cubic foot; specific gravity, about 2.6; loss in the Los Angeles abrasion test, about 40 percent; and loss ratio after 25 freeze-and-thaw cycles, about 0.9.

Additional aggregate prospects could be located most easily at or near the contact of the terrace deposits and the alluvium in the valley of the Smoky Hill River. The amount of aggregate material contained in the terrace deposits of the Smoky Hill Valley is almost unlimited; pits could be opened at almost any convenient site within the area of its outcrop. In the Saline River Valley the terrace deposits are generally silty, and only locally in the basal part of the formation is the material coarse enough to be classified as an aggregate.

(4) Alluvium.—No prospect or operated pits for either mixed or fine aggregate were found in the alluvial deposits of present-day Ellis County streams. It is probable, however, that material in these classifications can be found locally in the floodplains of both the Saline and Smoky Hill Rivers.

Road metal

Engineering and geologic characteristics

As defined in this report, road metal is any material that may be applied to roads as a surfacing agent. The materials are widely diverse in their engineering and geologic characteristics; some are quartz sand with a varying content of gravel, others are crushed rocks of various composition. The engineering requirement is that the material added to the road improve the performance characteristics of the road. Many geologic materials fulfill this requirement.

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 Ellis County, especially in the southern part. Field observation indicates that, generally, they are adequate for this purpose and that the road metal taken from the terrace deposits of the Smoky Hill Valley gives excellent service.

(2) Greenhorn limestone.—In other north-central Kansas counties, such as Mitchell and Republic, the upper part of the Greenhorn limestone has been used successfully as road metal. The thin chalky limestone and the interbedded shale are quarried, crushed, thoroughly mixed, and applied to the road. The material, under traffic, self-cements to form a macadam. The outcrops of the upper part of the Greenhorn limestone in the southeastern part of Ellis County might be used similarly. Field observation indicates that material from the Greenhorn limestone performs somewhat more satisfactorily as a traffic-bound macadam than material from the Niobrara formation because the former is less subject to dry-weather "dusting."

(3) Niobrara formation.—The two members of the Niobrara formation, the Fort Hays limestone and the Smoky Hill chalk, have been used on secondary roads in Ellis County. The Fort Hays limestone is used more extensively as road metal, however, and apparently is somewhat better for this use than the Smoky Hill chalk. The material as crushed and applied to the road ranges in size from fragments several inches long to blocks 5 or 6 inches on a side. The crushed rock is wetted down and further crushed under a roller. Traffic over the road then binds the material to a dense, fairly hard macadam which is readily maintained by road patrol.

Roads metaled in this way appear to stand up well in all types of weather. The one important disadvantage inherent in this type of construction is that, in dry weather, traffic causes clouds of fine, white dust to be blown free from the road surface. The dusting characteristic might be controlled by a seal coat. It is thought, however, that a bituminous mat would not prove satisfactory as a wearing course because of the tendency of moisture to accumulate beneath the impervious mat. Moisture so accumulated in the Niobrara base course would cause the limestone to become soft, with consequent failure of the road.

Additional quarries, as needed, could be opened in this formation throughout most of the area of its outcrop. (See pl. 1.)

(4) Ogallala formation.—Mortar bed in the Ogallala formation might be used as metal on secondary roads. This use has been observed in other counties in north-central Kansas. Mortar-bed ledges are fairly well distributed over the outcrop area of the Ogallala formation. The rock can be crushed in a portable jaw crusher and the crushed material applied to the roads. The sand and gravel particles in the mortar bed would be bound by the calcium carbonate cement to form a traffic-bound macadam.

(5) Sanborn formation.—The basal part of the Sanborn formation yields a material classified by the State Highway Commission of Kansas as "limestone gravel." This material consists of rounded fragments of soft local limestone (Niobrara formation) about three-fourths of an inch long with intermixed silt. Limestone gravel is extensively used throughout north-central Kansas as road metal on secondary roads.

Deposits of limestone gravel are local in extent. The material occurs only as lenses in the basal part of the Sanborn formation. The greatest concentration of this material in the Sanborn formation is in those areas in which the formation overlies the Carlile shale. The limestone particles were derived from beds of the Fort Hays limestone exposed nearby and, to a lesser extent, from chalk beds in the Smoky Hill chalk.

Four samples of this material (lg 1-4)

are listed in table 1 and mapped on plate 1.

Mineral filler

Engineering and geologic characteristics

The material known as mineral filler is composed of mineral fragments of silt size. A small percentage of fine sand and a subordinate percentage of clay may be present. To be accepted in this category the material must not contain more than a trace of sticks or other organic debris. The State Highway Commission of Kansas recommends 9/ that silt from the Sanborn be used as mineral filler only if tests indicate a low coefficient of cementation.

Stratigraphic sources and performance characteristics

Sources of mineral filler crop out extensively in Ellis County. The stratigraphic units that provide this material are as follows:

(1) Sanborn formation.—The upper silty part of the Sanborn formation is the most widespread source of mineral filler in Ellis County. The material is so widely distributed that it was thought unnecessary to map prospective pit sites. The upper part of the formation is composed predominantly of silt-size particles with minor amounts of particles of sand or gravel size intermixed with the silt. Typically there is a well-developed soil zone at the top of the Sanborn, and there may be one or more buried soils at various distances below the top of the formation. The "B" zone of the soil profile may contain deleterious amounts of calcium carbonate disseminated throughout the zone or in the form of nodules or pipes.

(2) Terrace deposits.—The upper silty part of the terrace deposits is a source of mineral filler, particularly in the valley of Big Creek. Prospect or operated pits in this material are not mapped because of the widespread availability of the material. Material from the upper part of the formation might also be used satisfactorily as binder material or in the puddle core of an earthen dam.

(3) Alluvium.—A large proportion of the alluvial material deposited by streams in their present cycles of erosion probably would prove satisfactory as mineral filler. With ample supplies available from the Sanborn formation and the terrace deposits, however, it would not seem expedient to exploit the alluvium for this purpose.

Volcanic ash

Engineering and geologic characteristics

Volcanic ash consists predominantly of the fine, glass-like shards ejected during the explosive phase of a volcanic eruption. It may include silt-size particles of other origins. Occasional thin seams of gravel and sand are interbedded with the volcanic ash.

Stratigraphic sources and performance characteristics

Lenses of volcanic ash occur in Ellis County in the following stratigraphic units:

(1) Sanborn formation.—One pit in the volcanic ash of the Sanborn (table 1, va 1) has been operated by the State Highway Commission of Kansas. The ash appears to be of high quality and is entirely satisfactory for use as mineral filler in certain types of road construction. Intensive exploration of the basal part of this formation undoubtedly would result in the locating of additional lenses of ash.

(2) Terrace deposits.—No deposits of volcanic ash were found in the terrace deposits of Ellis County. The occurrence of this material in the same formation in nearby counties, such as Trego County, indicates that it might also be present in Ellis County. The lenses of ash occur in a zone immediately above the basal sand and gravel phase of the formation. In two localities along the Smoky Hill River (SE¼SW¼ sec. 31, T. 15 S., R. 16 W., and NE¼NE¼ sec. 34, T. 15 S., R. 16 W.) there are lenses of clay that contain high percentages of intermixed volcanic ash.

Riprap

Engineering and geologic characteristics

Riprap is any material suitable for protecting earthen fills from erosion. To be acceptable for this use the stone must be relatively sound and free from cracks and other structural defects or from impurities that would cause it to disintegrate. The stone should be in blocks having approximately rectangular faces 7 inches or more in width. The specific gravity of the rock material should be 2.0 or higher.

Stratigraphic sources and performance characteristics

In the counties adjacent to Ellis County the Ogallala formation includes lenses of quartzite. Field observations indicate that the quartzite is highly desirable as riprap material. In Ellis County, however, no such quartzite lenses were found in the Ogallala. Blocks of limestone quarried from the Fort Hays limestone member have been used as riprap in several north-central Kansas counties. Examination of the dam faces riprapped with the Fort Hays limestone indicates quite conclusively that this material is unsatisfactory for such use, as the soft chalky limestone, when saturated with water, disintegrates rapidly, either through slaking or freeze-and-thaw. No local materials were found that could be considered adequate for use as riprap.

Structural stone

Engineering and geologic characteristics

Structural stone, as defined in this report, is any hard, uniform-textured rock material that can be quarried and cut to desired size and form. The sources of this material in Ellis County are somewhat deficient in one respect or another, as indicated in the

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

descriptions that follow.

Stratigraphic sources and performance characteristics

(1) Greenhorn limestone.—The "Fencepost" limestone bed at the top of the Pfeifer shale member is used extensively as structural stone throughout the area of its outcrop. Many barns, houses, stores, and other business buildings have been constructed of this rock. Use of the "Fencepost" limestone as structural stone in the construction of small bridges was observed in the southeastern part of Ellis County. Field observation indicates that this material is satisfactory for the uses listed above. The stone apparently has relatively high bearing strength and is not adversely affected by weathering. The rock is easily quarried and casehardens after exposure to air. The chalky character of the limestone, however, indicates that it would not be advisable to use the stone in places where it would come in long-continued contact with water. It is probable that in such situations the material would deteriorate through slaking or by freeze-and-thaw.

The "shell rock" limestone bed at the top of the Jetmore chalk member has served as a structural stone in the construction of some buildings in northern Kansas. Although the rock appears to stand up as well as the "Fencepost" limestone it is not used so extensively, as it does not have the pleasing appearance of the "Fencepost."

(2) Fort Hays limestone member of Niobrara formation.—The Fort Hays limestone member has been used in the northern part of the county as a structural stone for dwellings and farm buildings. The stone hardens after being cut, and structures built of it stand up well in the relatively dry climate of western Kansas. Field observations indicate that the Fort Hays limestone should not be used in a place where it is subject to water saturation, such as in the foundations of buildings. In such places the stone deteriorates fairly rapidly by freeze-and-thaw or slaking or through both processes.

Calcareous binder

Engineering and geologic characteristics

Calcareous binder includes a variety of geologic materials. Those materials are composed essentially of calcium carbonate, are soft, and are easily pulverized.

Stratigraphic sources and performance characteristics

(1) Niobrara formation.—Both the Fort Hays limestone and the Smoky Hill chalk members of the Niobrara formation have been accepted by the State Highway Commission of Kansas as calcareous binder. The chalkiness of both materials permits easy pulverization. The material is available throughout the mapped area of its outcrop. (See pl. 1.)

(2) Ogallala formation.—Mortar-bed lenses in the Ogallala formation are possible sources of calcareous binder material. Some lenses probably contain too much intermixed sand and gravel for such use, and other lenses have hardened so much that pulverization probably would be difficult. In view of the widespread availability of the Niobrara formation it is thought that mortar-bed lenses in the Ogallala formation can be disregarded as sources of calcareous binder in Ellis County.

Limestone for portland cement

Engineering and geologic characteristics

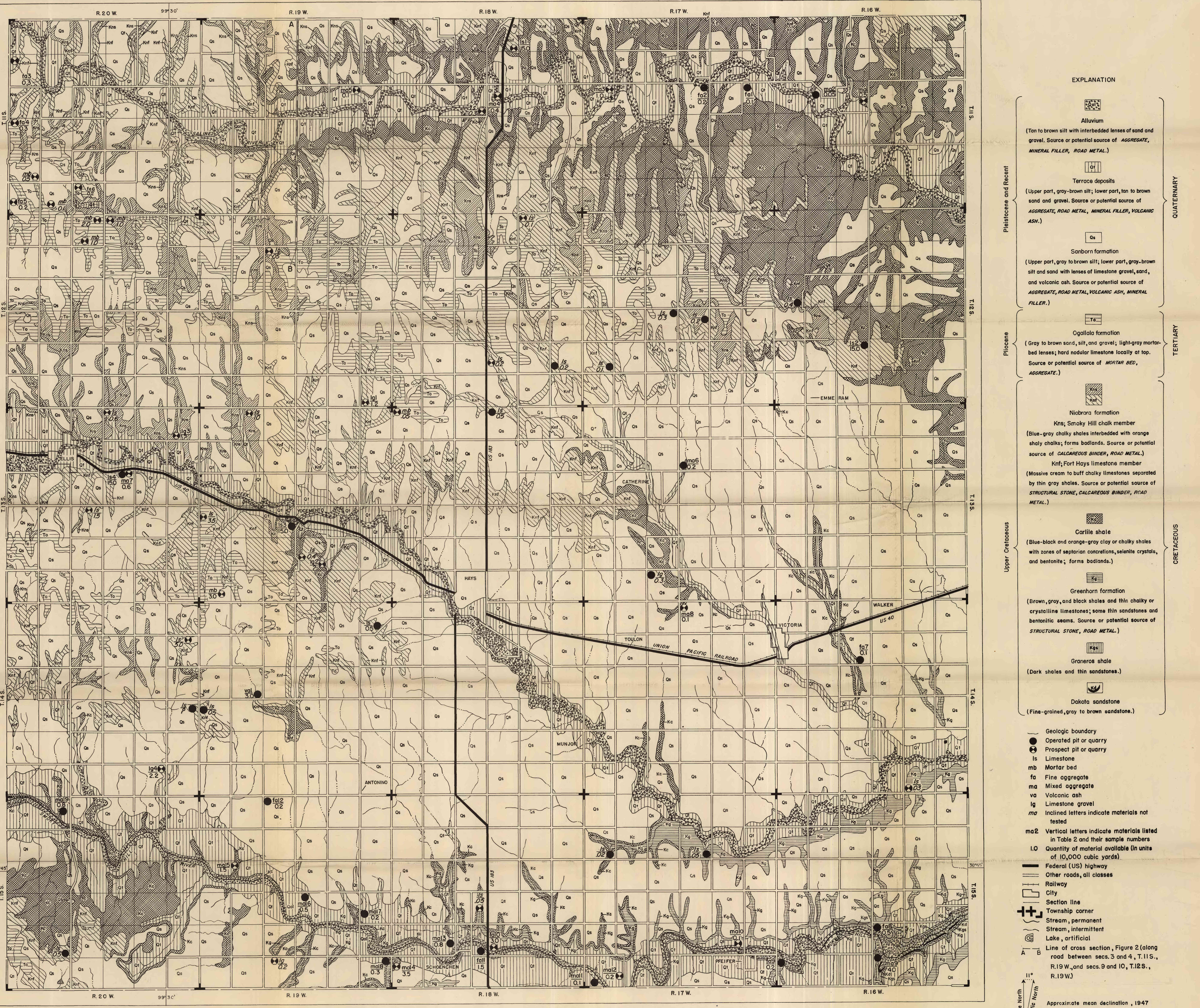
Many limestones are satisfactory for use in portland cement. To be acceptable for this use the limestone should be relatively constant in its composition, should be composed predominantly of calcium carbonate, and should be essentially free from such deleterious materials as flint nodules. The limestone bed should be sufficiently thick and the overburden thin enough so that it can be quarried economically.

Stratigraphic sources and performance characteristics

Landes 10/ reports that the Fort Hays limestone member was once quarried near Yocemento, where a cement plant was in operation. The installation has long been abandoned. In at least one other place in north-central Kansas (north-central Jewell County) the Fort Hays limestone member is quarried for limestone to be used in the manufacture of portland cement.

10/ Landes, K. K., Mineral resources of Kansas counties: Kansas Geol. Survey Mineral Resources Circular 4, p. 32, 1937.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



Base adapted from maps provided by the State Highway Commission of Kansas
Drainage from aerial photographs provided by U. S. Department of Agriculture

MAP SHOWING CONSTRUCTION MATERIALS AND GEOLOGY OF ELLIS CO., KANSAS

1 0 1 2 3 4 MILES

1949

Geology by F. E. Byrne, V. B. Coombs, and C. H. Bearman

Table 1. Summary of material tests

(Blank spaces indicate data not available)

Classification of the material	Number on plate 1	Location: 1/4 fraction	Location: 1/4 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: Percent on 1-2 inch	Percent on 3-8 inch	Percent on No. 4	Percent on No. 16	Percent on No. 100	Percent passed No. 200 (wash)	Laboratory tests: Weight per cubic foot (dry)	Specific gravity (sat.)	Los Angeles percent loss	Soundness[3] (25 cycles)	Remarks
Fine Aggregate	fa 1	NW	NW	13	11	17	1,000	6	4	Good	Sanborn	SHCK USGS	2-47			2	6	99						High percentage of soft limestone fragments.
	fa 2	NE	NE	15	11	17	2,000	6	1-5	Good	Sanborn	SHCK USGS	2-47			2	11	98						10 percent chert in coarse fraction.
	fa 3	SE	SE	7	11	20	3,000	4	1-5	Good	Terrace deposit	SHCK USGS	2-47				3	95						High percentages of soft limestone fragments and silt.
	fa 4	NW	NW	19	11	20	3,000	6	2-8	Good	Ogallala	SHCK USGS	2-47					88						
	fa 5	NW	SW	31	11	20	2,000	6	6	Good	Ogallala	SHCK USGS	2-47					95						
	fa 6	NW	NW	33	11	20	2,000	4	1-5	Good	Sanborn	SHCK USGS	2-47				22	97						
	fa 7	SW	SE	9	14	16	1,000	2	2	Good	Sanborn	SHCK USGS	2-47				8	94						
	fa 8	NW	NW	27	15	16	5,000	5	2	Good	Terrace deposit	SHCK	1-46		1	3	17	94	3	113	2.62	39.7	0.96	10 percent chert in coarse fraction.
	fa 9	SW	NW	31	15	16	2,000	8	2	Good	Terrace deposit	SHCK USGS	2-47			4	10	98						
	fa 10		SW	27	15	18	30,000	5	2	Good	Terrace deposit	SHCK	1-46			1	20	90	9					Cementation: 31; high percentage of clay.
	fa 11		SE	28	15	18	15,000	5	3	Good	Terrace deposit	SHCK	2-47		1	3	17	80	15	111				Cementation: 18; high percentage of clay.
	fa 12	NW	NW	4	15	19	2,000	6	2	Good	Sanborn	SHCK USGS	2-47				26	98						
Mixed Aggregate	ma 1	NE	SE	16	11	16	5,000	6	2	Good	Sanborn	SHCK	1-46		1	12	50	97	3	108	2.6	43.4	0.91	
	ma 2	SE	NW	17	11	16	500	3	2	Good	Sanborn	SHCK USGS	2-47			12	28	98						High percentage of soft limestone fragments.
	ma 3		NW	18	11	17	10,000	8	4	Good	Terrace deposit	SHCK	1-46		4	9	33	96	3	109	2.56	49.6	0.87	
	ma 4	SE	NW	15	11	18	4,000	9	2	Fair	Terrace deposit	SHCK	1-46		4	8	35	92	5	113	2.6	42.1	0.87	
	ma 5	NE	NE	14	11	19	1,000	6	1	Good	Sanborn	SHCK USGS	2-47			7	28	98						
	ma 6	SW	SW	10	13	17	2,000	8	4-5	Good	Terrace deposit	SHCK	1-46			10	30	99						High percentage of soft limestone fragments.
	ma 7		SE	10	13	20	6,000	5	1	Fair	Sanborn	SHCK	1-46		7	17	45	96	3	109	2.6	46	0.72	
	ma 8	NW	NW	3	14	17	1,000	3	2-4	Good	Sanborn	SHCK USGS	2-47			13	30	98						High percentage of soft limestone fragments.
	ma 9	NW	NW	34	15	16	40,000	12	4	Good	Terrace deposit	SHCK	1-46		5	12	45	97	2	110	2.61	42.2	0.93	Lime-coated and limonite stained; 10 percent chert in coarse fraction.
	ma 10	NE	SE	26	15	17	1,000	6	1-3	Good	Terrace deposit	SHCK USGS	2-47	12		20	34	98						10 percent chert in coarse fraction.
	ma 11	SE	SW	31	15	17	1,000	5	3	Good	Terrace deposit	SHCK USGS	2-47			10	50	99						
	ma 12	NW	SW	32	15	17	2,000	6+	2	Good	Terrace deposit	SHCK USGS	2-47	12		21	57	98						10 percent chert in coarse fraction.
	ma 13	NE	SE	29	15	18	8,000	7	3	Good	Terrace deposit	SHCK	1-46		10	16	56	97	1	115	2.62	36.3	0.97	Overlain by 2 feet of volcanic ash and fine sand.
	ma 14		NW	31	15	18	35,000	7	4	Good	Sanborn	SHCK	2-46		2	6	43	98	1	112	2.6	34.5	0.94	
	ma 15		NW	17	15	19	15,000	7	3	Fair	Terrace deposit	SHCK	1-46		6	12	50	98	1	113	2.62	40.2	0.99	
	ma 16	NE	NW	22	15	19	5,000	7	1	Good	Terrace deposit	SHCK USGS	2-47			10	42	99						10 percent chert in coarse fraction.
	ma 17	NW	SW	24	15	19	2,000	8	3	Good	Terrace deposit	SHCK USGS	2-47			9	61	99						Limonite stained; 10 percent chert in coarse fraction.
	ma 18	NE	NE	36	15	19	3,000	8	4	Good	Terrace deposit	SHCK USGS	2-47			14	43	98						
	ma 19	SW	NE	5	15	20	8,000	4	2	Good	Terrace deposit	SHCK	2-46		6	14	65	96	3	113.2	2.61	33.6	0.93	
Limestone Gravel	lg 1		SW	36	12	19	12,000	4	2	Good	Sanborn	SHCK	1-46		15	26	40	82	15			50.0		
	lg 2		SE	27	13	19					Sanborn	SHCK			4	21	58	77	23					Slaking: 16.
	lg 3	SE	SW	1	13	20					Sanborn	SHCK			6	16	34	84	16					Slaking: 30+.
	lg 4		NE	35	14	20	22,000	7	1	Good	Sanborn	SHCK	1-46		10	26		85	10			33.4		
Vol. ash	va 1	SE	SE	17	14	19	30,000	5	4	Good	Sanborn	SHCK	2-46							59.4	2.34			
Limestone	ls 1		SE	3	11	18	150,000	4		Good	Ft. Hays	SHCK	1-46								2.09	66.8	0.44	
	ls 2	NE	NE	28	12	16	150,000	5		Good	Ft. Hays	SHCK	1-42								2.16	6.08		
	ls 3		E 1/2	21	13	19	150,000				Ft. Hays	SHCK	1-46								2.06	70.5	0.52	
	ls 4		SE	10	13	20	150,000			Good	Ft. Hays	SHCK	1-46								2.01	68.2	0.51	

Description of material[2]

Number on plate 1	Fraction	Limestone	Mortar bed	Quartz	Chert	Feldspar	Granite	Quartzite	Shale	Silt and clay	Sandstone	Calcite	Hornblende	Magnetite	Caliche
fa 1	C	60		5		5	10					20			
fa 1	F	10		50		15						15	5	5	
fa 2	C	25		15	10	10	25					15			
fa 2	F			60	5	20						10		5	
fa 3	C	90					5					5			
fa 3	F	15		50		15						10	5	5	
fa 4	C														
fa 4	F			75		20								5	
fa 5	C														
fa 5	F			85		15									
fa 6	C														
fa 6	F			60	10	25						5			
fa 7	C														
fa 7	F		5	60		15						20			
fa 8	C	35		30	10	20						5			
fa 8	F			60	5	20									
fa 9	C			15	5	15	65								
fa 9	F			60	5	15						10	5	5	
fa 12	C														
fa 12	F			65	5	20						5		5	
ma 1	C	25		15		10	20			25		5			
ma 1	F			60		20				5		10		5	
ma 2	C	85					5					10			
ma 2	F	20		50	5	15						10			
ma 5	C	30			5		20		40			5			
ma 5	F			55	5	20			10			10			
ma 6	C	60		20	5	10						5			
ma 6	F	5		55	5	20				5		10			
ma 8	C	70	10		5		5					10			
ma 8	F	10		50	5	20						10		5	
ma 9	C	20		45	10	20						5			
ma 9	F			60	5	20						10		5	
ma 10	C	35		15	10	5	30					5			
ma 10	F	5		55	5	20						10		5	
ma 11	C			20	10	10	25			30		5			
ma 11	F			65		15				10		10			
ma 12	C	15		15	10	5	50					5			
ma 12	F			60	5	20						10		5	
ma 13	C	15		30	5	5	40					5			
ma 13	F			60	5	15	5					10		5	
ma 16	C			30	10	20	35					5			
ma 16	F			65		20	5					5		5	
ma 17	C			30	10	20	40								
ma 17	F			70	5	15	5								
ma 18	C	20		15	5	15	40					5			
ma 18	F			60	5	20	5					10			

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.
3. Loss ratio.