RC. 179

GEOLOGICAL SURVEY CIRCULAR 179

GEOLOGIC CONSTRUCTION-MATERIAL RESOURCES IN OSBORNE COUNTY, KANSAS

By Charles P. Walters and Larson Y. Drake

PREPARED IN COOPERATION WITH

STATE HIGHWAY COMMISSION

OF KANSAS

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

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GEOLOGIC CONSTRUCTION-MATERIAL RESOURCES IN OSBORNE COUNTY, KANSAS

INTRODUCTION

Purpose of the investigation

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

The primary objective of the investigation was that of accumulating all field and laboratory data pertaining to the geologic materials in Osborne County that would be of use in the construction of dams, highways, railways, airports, and other engineering structures. Additional geologic data are included in this report but only to the extent of providing information useful in the development of the prospects reported in the inventory, or for the location of other materials required for future engineering needs.

Geography

Area covered by the investigation

Osborne County is in the second tier of Kansas counties south of the Nebraska border and in the sixth tier east of the Colorado border. (See fig. 1.) It comprises 25 townships and covers an area of about 900 sq mi. The county is bounded on the north by Smith County, on the east by Mitchell County, on the south by Russell County, and on the west by Rooks County.

Topography

Good surface drainage has developed over most of Osborne County. Tributary streams in headwater areas occupy poorly defined channels between low rounded interstream areas.

The average altitude for the county is 1,800 ft. The lowest point, 1,455 ft, is on the South Fork Solomon River at the eastern boundary of the county, and the highest point, 2,100 ft, is in the southwestern corner of the county in the vicinity of Natoma.

Drainage

The principal streams in Osborne County are the South and North Forks of the Solomon River. (See pl. 1.) The watershed of the South Fork Solomon River includes most of the county, but the North Fork Solomon River drains the northeastern part, and streams in the southernmost tier of townships drain southward into the Saline River.

The central portion of the county, comprising about half its total area, drains to the South Fork Solomon River by a series of northeast-flowing streams. The larger of them are Medicine, Kill, Covert, Indian, and Twin Creeks.

Paradise Creek, near Natoma, drains south toward the Saline River.

Climate

Osborne County is in an area of continental-type climate in which the summers are relatively long and hot, and the winters short and fairly cold. The mean annual temperature is 54.4° F. The average temperature for the coldest month, January, is 27.6° F and that of the warmest month, July, is 80.2° F. There are 75 cloudy days a year, 95 partly cloudy days, and 195 clear days. The ground is snow covered 30 days of the year. The normal annual precipitation is 21.63 in. The average date of the first killing frost in the fall is October 14, and that of the last killing frost in the spring is April 27. (Flora, 1948.)

Figure 2, a chart showing temperature ranges at Alton, Kans., was compiled from Climatological Data (U. S. Dept. Commerce, 1937-46) for the years 1937 to 1946, inclusive, to provide basic data on temperature in relation to engineering construction. The chart indicates, for the 10-year period, the number of days each month in which the maximum daily temperature fell within certain designated ranges based arbitrarily on temperatures important in various phases of engineering construction.

Days in which the maximum temperature does not exceed 32° F occur only from November to March, inclusive, with the maximum incidence of 7.8 days in January. July is the warmest month of the year, with an average of 21.6 days having a maximum temperature above 90° F. The chart also shows the average difference between the daily maximum and minimum temperatures for each month. The greatest difference in daily temperatures, 30.75° F, is in October; and the least difference, 24.92° F, is in January.

Inasmuch as precipitation also conditions the number of working days in engineering construction, figure 3, a chart showing precipitation ranges at Alton, Kans., is presented to show the effect of this

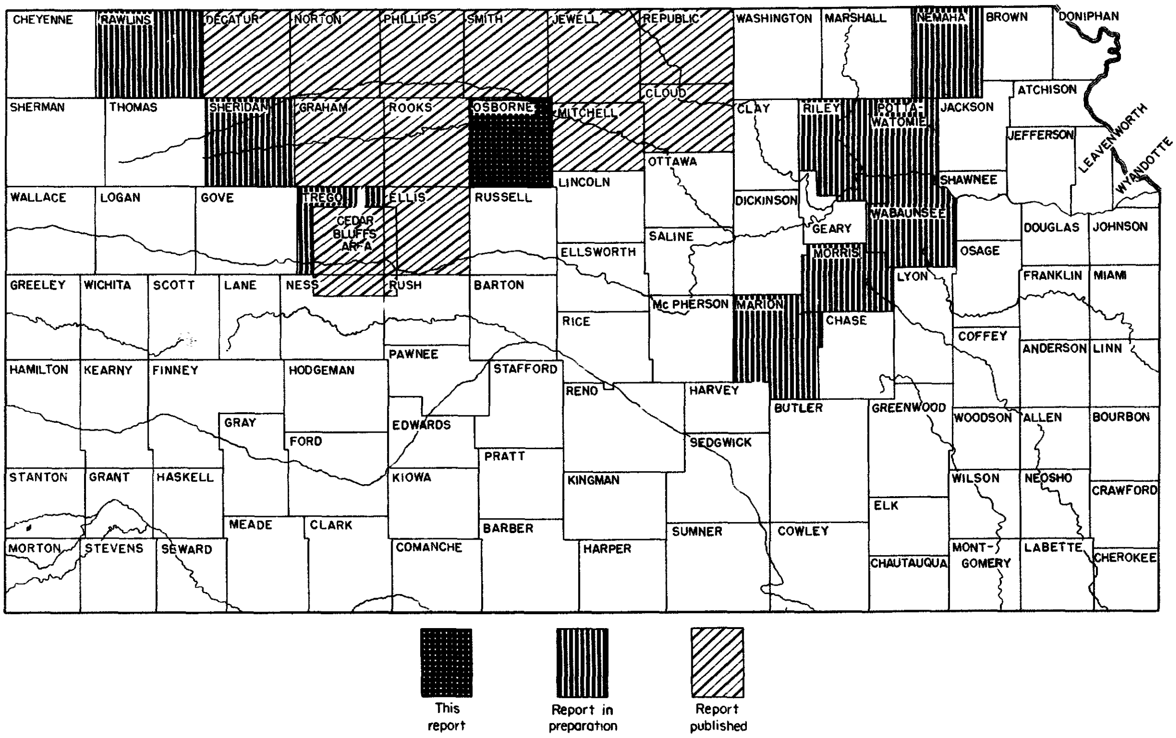
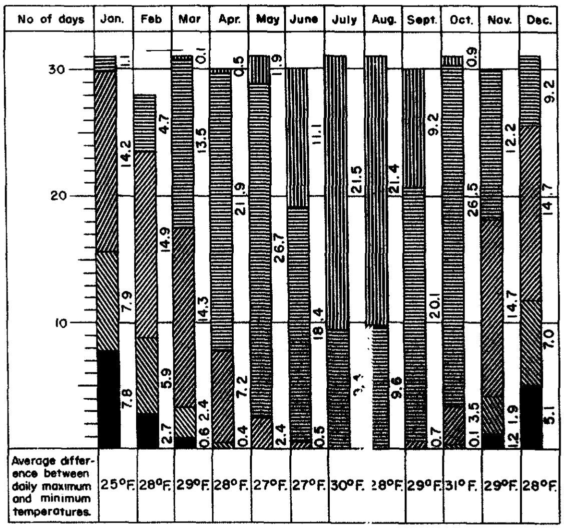


Figure 1.—Index map of Kansas showing areas covered by this report and by other construction materials investigations



EXPLANATION

Days in which maximum temperature was more than 90° F. *(no concrete construction)*

Days in which maximum temperature was between 61°–90° F. *(no interference with any type of construction)*

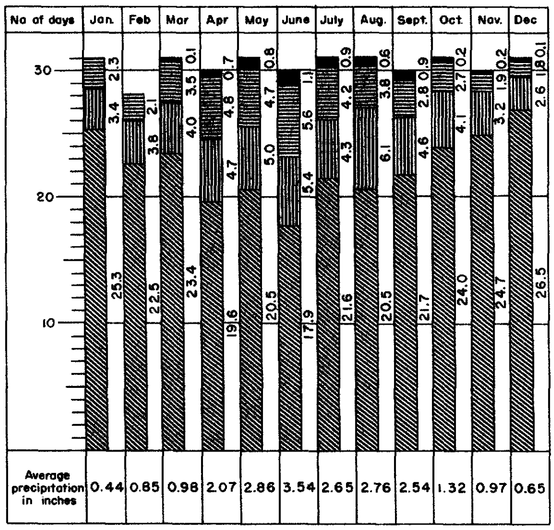
Days in which maximum temperature was between 41°–60° F. *(no interference with concrete construction; no bituminous surfacings laid)*

Days in which maximum temperature was between 32°–40° F. *(concrete construction requires protection)*

Days in which maximum temperature was less than 32° F. *(no concrete construction)*

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

Data for both charts compiled from Climatological Data Kansas Section for years 1937 to 1946, inclusive. Issued by Weather Bureau United States Department of Commerce



EXPLANATION

Days in which precipitation was more than 1 inch *(no construction activity)*

Days in which precipitation was between 0.11 and 1 inch *(no bituminous surfacings laid)*

Days in which precipitation was between a trace and 0.1 inch *(no interference with construction)*

Days in which there was no precipitation *(no interference with construction)*

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

climatic factor. The ranges in precipitation were selected arbitrarily.

As based on a 10-year average (U. S. Dept. Commerce, 1937-46), there are 17.9 days in June, for example, in which no measurable precipitation fell; 5.4 days in which the precipitation ranged from a trace to 0.1 in.; 5.6 days in which 0.11 to 1 in. of rain fell; and one day in which the precipitation was more than 1 in. Continuing rains fall, for the most part, in the late spring and early fall, and other rainfall is usually in the form of showers.

Transportation routes

Osborne County is served by three railways, the Missouri Pacific, Union Pacific, and Atchison, Topeka, and Santa Fe; two transcontinental highways, U S 24 and U S 281; and two Kansas highways, 18 and 181. Kansas 181 is a metaled, all-weather road. The other State and Federal highways are of the blacktop type of construction.

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

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

Investigation procedure

This report is based on field work of the reconnaissance type. The base map (scale: 1 mile to 1 in.) was provided by the State Highway Commission of Kansas. Drainage lines were taken from aerial photographs made available by the Soil Conservation Service of the United States Department of Agriculture. The areal distribution of the stratigraphic units that outcrop in Osborne County was then mapped in the field. Mapped stratigraphic units are those recognized by the United States Geological Survey (Wilmarth, 1938) and the Kansas Geological Survey. (Moore, Frye, and Jewett, 1944.) In this report the principal emphasis is on construction materials. Geologic problems not critically related to construction materials are discussed only briefly.

An effort was made to accumulate all existing data pertaining to construction materials in the county; these are presented in table 1, a summary of materials tests.

Acknowledgments

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

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

General

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

A summary of the data for each mapped unit is presented in figure 4, and the relationships of the stratigraphic units are shown in figure 5, a geologic cross section through the southern part of the county.

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

The locations of pits and quarries are also shown on plate 1. The symbols indicate whether the pit or quarry is, or has been, operated or is a prospect; the type of construction material available at each site; and the quantity of material (in units of 10,000 cu yd) that can be removed under no more than moderate overburden (unconsolidated sediments less than 6 ft thick). Most of these sources are 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 west border of the county, and so on. Within a township the sources are numbered in the same sequence as are the sections of the township.

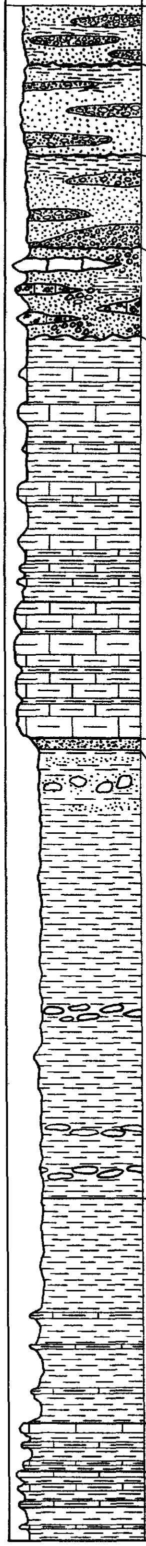
Greenhorn limestone

Areal distribution

The Greenhorn limestone of Late Cretaceous age (see fig. 4) is present under the entire area of the county but crops out only along the southern boundary and, to a limited extent, along the banks of the North and South Forks of the Solomon River at the eastern edge of the county. (See pl. 1.) Near the Russell County line it forms a conspicuous hillside bench marked by numerous old quarry workings.

General description

The Greenhorn limestone, the oldest geologic formation cropping out in Osborne County, was deposited in marine water. The contact of Greenhorn limestone with the overlying Fairport chalky shale member of the Carlile shale is gradational and difficult to determine. The Greenhorn is composed of alternating thin beds of hard chalky limestone less than a foot thick, and generally thicker beds of gray to buff shale.



Outcrop thickness (feet)	System	Series	Formations and members		Generalized description	Construction materials
25	Quaternary	Recent	Alluvium		Clay and silt interbedded with lenses of local gravel and granitic gravelly sand; stream deposited; underlies floodplain and occurs in stream channel.	Aggregate Road metal
40	Quaternary	Pleistocene(?) and Recent(?)	Terrace deposits		Tan and light-brown silt, clayey near surface; beds of sand and lenses of gravel in lower part; stream deposited; underlies flat terraces in valleys of larger streams.	Aggregate Mineral filler Fill material Road metal
40	Quaternary	Pleistocene and Recent(?)	Sanborn formation		Gray or brown silt; clayey near surface; lenses of limestone gravel throughout, with granitic gravel in lower part; stands in vertical banks; develops rolling topography.	Aggregate Mineral filler Road metal Fill material
40	Tertiary	Pliocene	Ogallala formation		Gray sand and silt; gray mortar bed lenses; hard nodular limestone locally; a few thin zones of quartzite.	Aggregate Road metal
115	Cretaceous	Upper Cretaceous	Niobrara formation	Smoky Hill chalk member	Gray and tan chalky shales interbedded with thin buff chalky limestones; outcrops not numerous.	Road metal Structural stone Calcareous binder Fill material
	Cretaceous	Upper Cretaceous	Niobrara formation	Fort Hays limestone member	Thick beds of massive, cream-colored chalky limestone separated by thin partings of gray to tan shale; shattered zone at top; marine; fossiliferous; forms prominent escarpment.	
2	Cretaceous	Upper Cretaceous	Carlile shale	Codell sandstone member	Fine-grained, yellow-brown, quartz sandstone and siltstone; marine.	Fill material
200	Cretaceous	Upper Cretaceous	Carlile shale	Blue Hill shale member	Dark blue-gray to black, thin-bedded, noncalcareous clay shale; silty zones near top; zones of septarian concretions and selenite crystals; marine; fossils in middle and lower portions; erosion produces badland topography.	
100	Cretaceous	Upper Cretaceous	Carlile shale	Fairport chalky shale member	As usually exposed, is similar to underlying Pfeifer shale member of Greenhorn limestone; marine, fossiliferous; weak outcrop expression.	
19	Cretaceous	Upper Cretaceous	Greenhorn limestone	Pfeifer shale member	"Fencepost" bed at top; alternating layers of gray to tan chalky shales and thin layers of tan-gray chalky limestones; marine; fossiliferous; forms hillside bench.	Road metal Structural stone Fill material
15	Cretaceous	Upper Cretaceous	Greenhorn limestone	Jetmore chalk member	"Shell-rock" bed at top; gray to tan chalky shales and thin layers of chalky limestone; fossiliferous; forms hillside bench.	
15	Cretaceous	Upper Cretaceous	Greenhorn limestone	Hartland shale member	Thick gray to tan silty shales; thin gray chalky limestones; fossiliferous.	

Figure 4.--Outcropping stratigraphic units in Osborne County, Kansas and their construction materials.

In roadcut exposures the alternating beds of limestone and shale are most conspicuous, but closer inspection reveals that some of the beds of limestone grade laterally into discoidal calcareous concretions 6 to 18 in. across. Similar concretions occur within the shale. The shale beds are sometimes marked by thin bentonitic zones which weather to reddish-brown streaks.

The Greenhorn limestone is composed of four members which are, in ascending order, the Lincoln limestone, Hartland shale, Jetmore chalk, and Pfeifer shale. (See fig. 4.) Each member will be described separately, but all are shown on plate 1 as a single map unit (Kg).

1. Lincoln limestone member

The Lincoln forms no conspicuous outcrops in Osborne County, but is present under thin cover in the bottoms of stream valleys along the southern boundary of the county. It may be seen in fairly good outcrops in Russell County, and consists of beds of chalky shale alternating with thin beds of brown crystalline limestone which has an oily odor.

2. Hartland shale member

The Hartland forms much of the slope below the "Shell-rock" and "Fencepost" ledges which mark the conspicuous outcrops of the Greenhorn limestone in the southeastern part of the county. It is characterized by beds of dark-gray shale which weather buff or brown, a few thin beds of limestone, and some thin beds of bentonite.

3. Jetmore chalk member

The Jetmore forms the best-developed hillside bench in the outcrop area of the Greenhorn limestone, and is characterized by thin layers of chalky shale interbedded with beds of hard chalky limestone, and an abundance of marine fossils, mostly clams. The top of the member is marked by a bed of limestone about a foot thick, called the "Shell-rock," which contains abundant clam shells.

4. Pfeifer shale member

The Pfeifer contains the well-known "Fencepost" or "Post-rock" limestone bed. It is a hard, tan-gray or orange-gray, chalky, limestone about 0.5 ft thick. It has a characteristic red-brown iron stain in its middle part. At numerous places in the outcrop area, old quarries are marked by shallow pits and piles of overburden. However, only one active quarrying operation in the "Fencepost" limestone was observed in the county in 1949.

A good exposure of the upper members of the Greenhorn limestone may be observed at the point where United States Highway No. 281 crosses into Russell County. This is in the SW¼SW¼ sec. 32, T. 10 S., R. 12 W. The uppermost bed of limestone at this location can be traced into the "Fencepost" quarries east of the highway, and a continuous section is present down into the Hartland shale member, although the lower part is best exposed in Russell County. The overlying Fairport chalky shale member of the Carlile shale is about 7 ft thick in this place, and is very similar to the Pfeifer shale member of the Greenhorn limestone.

Representative measured section

The following section of the Pfeifer shale, Jetmore chalk, and Hartland shale members of the Greenhorn limestone was measured in a road cut along U. S. No. 281 in the SW¼SW¼ sec. 32, T. 10 S., R. 12 W.:

	Feet
Carlile shale:	
Fairport chalky shale member	7.0
Greenhorn limestone:	
Pfeifer shale member:	
Limestone, hard; buff to cream, iron stains in middle part; fossiliferous; "Fencepost" bed	.5
Shale, silty, calcareous; gray, weathers gray and tan; thin seams of bentonite 0.05 and 0.8 ft from base	1.4
Limestone, chalky; buff; thin and lenticular or concretionary; fossiliferous	.2
Shale, calcareous, thin-bedded; gray, weathers gray and tan	1.2
Limestone-concretion zone, buff to white; irregular in shape, discoidal, 4 in. to 2 ft in diameter; fossiliferous	0.5
Shale, blocky to thin-bedded; gray, weathers to tan and gray bands; contains fish scales	1.0
Bentonite, gray-white; weathers red brown	.05
Shale, silty, blocky; gray, weathers buff; clams and fish scales	.6
Bentonite, tan to pink with white bands at top and bottom; abundant small crystals of calcite; known as the "sugar sand"	.4
Shale, calcareous, thin-bedded; light brown, weathers buff	.2
Limestone, massive, blocky, hard; gray, weathers buff to tan; tends to be lenticular	.5
Shale, calcareous, thin-bedded; gray, weathers buff; highly fossiliferous; lenticular limestone masses, gray, streaked with iron oxide, hard, fossiliferous at 0.6, 1.4, 2.1, 2.8, 3.8, and 4.7 ft from base	5.8
Limestone, massive, blocky, hard; gray, weathers cream; fossiliferous	.2
Shale, gray; weathers to tan and gray bands; limestone concretions, buff, discoidal, fossiliferous at base and 1.6, 2.5, 3.1, and 3.9 ft above base	4.8
Shale, thin-bedded; gray, weathers to gray and tan bands; very fossiliferous	1.7

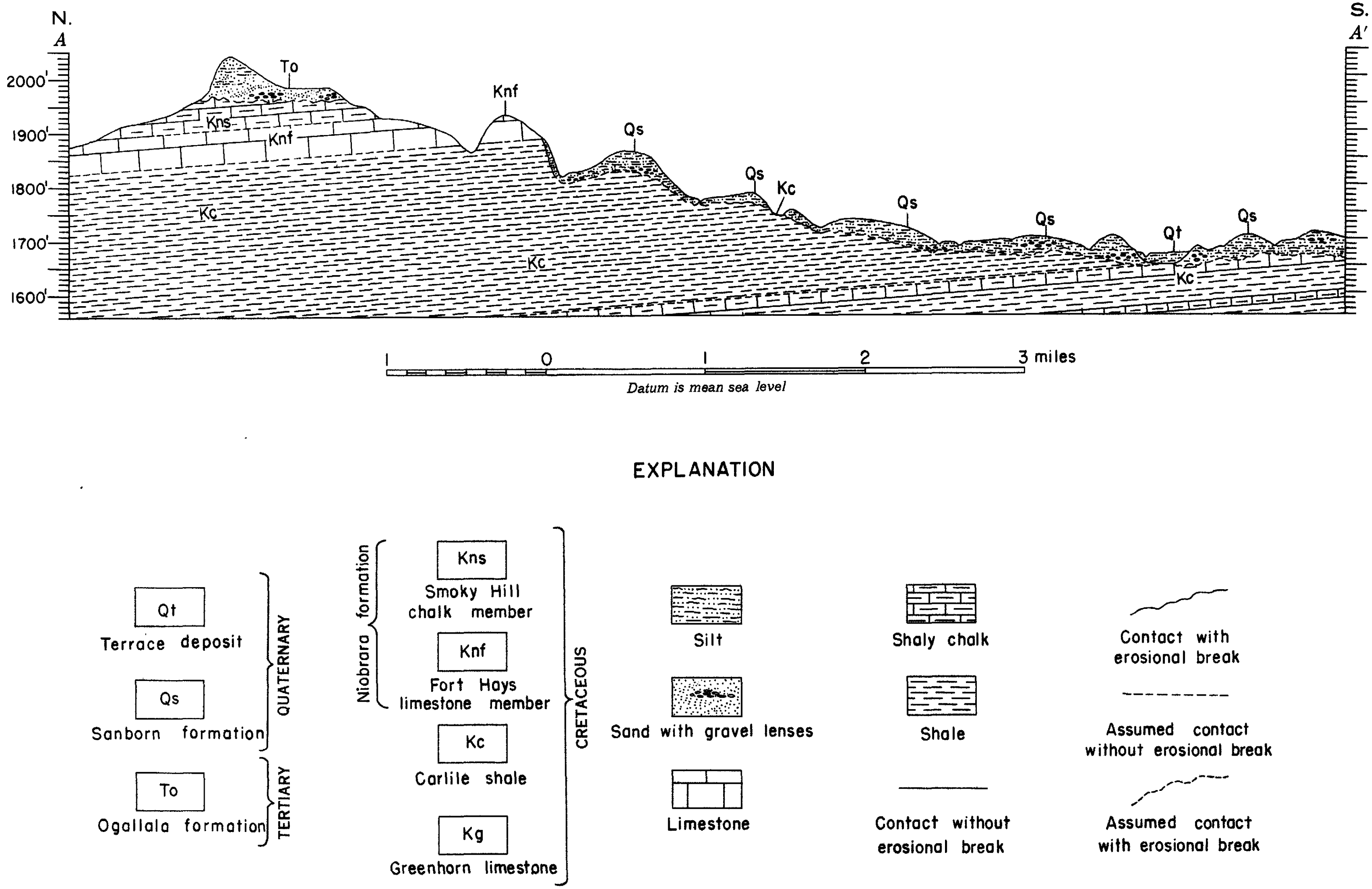


Figure 5. --Geologic cross section along line A-B (line between secs. 21 and 22, T. 9 S., R. 13 W. and secs. 27 and 28, T. 10 S., R. 13 W.)

	Feet
Greenhorn limestone--Continued	
Jetmore chalk member	
"Shell-rock" limestone bed, massive to faintly bedded, hard; gray, weathers buff; fossiliferous	1.2
Shale, chalky, thin-bedded to platy; gray to tan, weathers buff to gray; fossiliferous	1.5
Shale, lower half fossiliferous and dense, buff to gray, weathers cream; upper half thin-bedded, lenses of discoidal, fossiliferous, calcareous concretions	1.5
Limestone, gray; iron-oxide stains on surface and in fractures; fossiliferous	.4
Shale, chalky, hard, compact, weathers to thin plates; gray, weathers white; very fossiliferous	1.0
Limestone, upper half hard, gray, and fossiliferous; lower half chalky and cream to buff	.5
Shale, silty, thin-bedded to very thin-bedded; gray, weathers to gray and pink bands; fossiliferous	.8
Bentonite, white; weathers reddish brown	.05
Limestone, massive, hard, gray; irregular fracture; iron-stained zone near center	.4
Shale, silty, calcareous; thin-bedded; banded tan and gray; iron stains, fossiliferous	0.9
Limestone, gray; weathers buff to brown; iron stain through center, tends to fracture along the stain; fossiliferous	.2
Shale, silty, very thin bedded; banded gray, buff, pink; weathers buff; fossiliferous	1.0
Limestone, gray; weathers white; iron-oxide nodules; irregular in thickness	.2
Shale, calcareous, very thin bedded; gray to buff, weathers tan; fish teeth and scales	.9
Limestone, chalky, blocky; gray, weathers buff; brown iron streak near center	.5
Shale, chalky, very thin bedded to blocky; gray, weathers white; fossiliferous	2.5
Limestone, chalky, blocky; gray, weathers white with tan iron-oxide streak in center; fossiliferous	0.4
Hartland shale member	
Shale, calcareous; gray, weathers white to buff with a few tan zones; fossiliferous	15.0
Total thickness exposed (base covered)	48.0

Thickness

The entire Greenhorn limestone is present at depth under Osborne County and its average thickness is 80 ft. Outcrops are usually of the uppermost 20 or 30 ft of the formation.

Construction materials

Construction materials from the Greenhorn limestone in Osborne County are: road metal, structural stone, and fill material.

Carlile shale

Areal distribution

The Carlile shale of Late Cretaceous age crops out over one-tenth of Osborne County. (See pl. 1.) It forms especially conspicuous bluffs in those places where it is capped by the Fort Hays limestone member of the Niobrara formation.

General description

The Carlile shale is divided into three members which are, in ascending order, the Fairport chalky shale, Blue Hill shale, and Codell sandstone. (See fig. 4.) The three members are shown as a single stratigraphic unit, the Carlile shale, on plate 1.

1. Fairport chalky shale member

The Fairport member lies just above the Greenhorn limestone and the thin beds of limestone in its basal part are very similar to the "Fencepost" bed. Higher in the member the beds of limestone are thinner and farther apart, and some of them are pink or orange. Thin seams of bentonite are common, and pyrite is present in the gray unweathered shale. Fine-crystalline gypsum fills cracks in the shale and appears to have been deposited by ground water. There are a few beds of silty shale in the upper part of the member. Fossils are present throughout; these are mostly marine shellfish, but there are also occasional teeth of sharks and marine reptiles. The Fairport is about 100 ft thick.

2. Blue Hill shale member

The Blue Hill is largely a clay shale but becomes increasingly silty toward the top. It is dark blue gray or black when unweathered, and weathers greenish gray to brown. It contains zones of lime concretions at intervals throughout and contains, in its lower two-thirds, flattened yellow to brown concretions (septarian) associated with fossils of marine shellfish. The silty upper part of the member contains large spherical concretions of lime and is less fossiliferous than the lower part. Crystals of gypsum, some as large as 4 in. across, in many places give a glassy sparkle to exposures of the Blue Hill. Its thickness is about 200 ft.

3. Codell sandstone member

The Codell sandstone member is composed of clean, fine to medium, well-sorted sand. It is soft, very poorly cemented, and is usually brown to tan in weathered outcrops. Fossils present are the teeth of sharks and marine reptiles and a few bones. The member ranges in thickness from 6 in. in the north tier of townships to 5 ft or more near the Russell County line, such as in the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 32, T. 10 S., R. 15 W.

Representative measured sections

1. The following section of the lower part of the Fairport chalky shale member of the Carlile shale is exposed in a small tributary valley of the South Fork Solomon River in the NW¼ sec. 25, T. 7 S., R. 11 W.:

	Feet
Sanborn formation: Tan silt	4.0
Carlile shale:	
Fairport chalky shale member:	
Shale, gray; weathers buff to tan; very fossiliferous	15.0
Limestone, crystalline, soft, buff to orange	.4
Shale, badly weathered; appears to have been bentonitic; dark gray, weathers buff	15.0
Limestone, lenticular to irregular; buff to orange	.3
Shale, calcareous, silty in streaks, thin-bedded; gray, weathers to light gray and tan bands; fossiliferous	2.5
Limestone, pink to orange	.3
Shale, silty in part, thin-bedded, gray; weathers light gray with tan streaks; fossiliferous	5.5
Limestone, granular, hard, gray to brown; weathers buff to pink	.2
Shale, silty, calcareous, very thin bedded; gray, weathers light gray to buff; fossiliferous	8.0
Limestone, gray; weathers light gray to buff; thin seam of bentonite at top	.5
Bentonite, white; weathers brown	.3
Shale, calcareous, silty, very thin bedded; gray, weathers light gray; lenticular calcareous concretions 1.2, 2.8, and 3.5 ft from base; fossiliferous	5.5
Total thickness present (underlain by the Pfeifer shale member of the Greenhorn limestone)	53.5

2. The upper part of the Blue Hill member of the Carlile shale is well exposed under the Fort Hays in the SW¼SW¼ sec. 10 T. 6 S., R. 13 W.:

	Feet
Niobrara formation:	
Fort Hays limestone member	25.±
Carlile shale:	
Codell sandstone member:	
Sandstone, fine-grained, silty, loose to friable, massive, noncalcareous; greenish gray, weathers brown	1.0
Blue Hill shale member:	
Shale, thin-bedded, noncalcareous, gray; weathers buff; limonite streaks	1.2
Carlile shale--Continued	
Blue Hill shale member--Continued	
Shale, thin-bedded to blocky, irregular silty and sandy zones; dark gray to tan, weathers gray to tan; contains sandstone lenses about a foot thick (in places well cemented) and spherical concretions 2 to 5 ft in diameter of granular calcium carbonate in concentric shells	6.6
Shale, noncalcareous, dark-gray; weathers blue gray; limonite streaks	5.0
Shale, thin-bedded to very thin bedded; dark gray, weathers blue gray; silty zone near top; numerous septarian concretions 1 to 2 ft in diameter; gypsum crystals	13.0
Shale, sandy, gray; contains septarian concretions 1 to 2 ft in diameter	2.0
Shale, thin-bedded to very thin bedded; silty zone near top; dark gray, weathers blue gray	16.0
Shale, thin-bedded to very thin bedded; dark blue gray, weathers blue gray; contains mudstone concretions having coarsely granular exterior	10.0
Shale, clayey, noncalcareous; thin-bedded to very thin bedded; dark blue gray, weathers blue gray; occasional mudstone concretions	8.0
Total thickness exposed (base covered)	62.8

3. The middle part of the Blue Hill member of the Carlile shale is exposed in the center of sec. 25, T. 8 S., R. 12 W. as follows:

	Feet
Carlile shale:	
Blue Hill shale member:	
Upper part includes a 2.6 ft Codell sandstone zone; generally duplicates section 2 above	63.0
Middle part:	
Shale, dark-gray; weathers blue gray with iron-oxide stains in fractures; splintery; scattered fractures; concretions of irregular flattened shape	5.0
Shale, thin-bedded to very thin bedded; dark gray, weathers blue gray; fossiliferous concretions, large, yellowish and flattened; pyrite nodules in basal part	16.0

	Feet
Carlile shale--Continued	
Blue Hill shale member--Continued	
Middle part--Continued	
Shale, thin-bedded to very thin-bedded; dark gray, weathers blue gray; large, fossiliferous concretions, yellow to tan at surface; iron-oxide nodules	9.0
Shale, thin-bedded to platy; dark gray, weathers bluish gray and brown	18.0
Shale, silty, well-bedded; blocky fracture; dark gray, weathers brown; scattered concretions including disc-shaped septarians; fossiliferous	5.0
Total thickness exposed (base covered)	53.0

Thickness

The total thickness of the Carlile shale is about 300 ft. It is at or near the surface in nearly half the county.

Construction materials

Fill material is the only construction material available for use from the Carlile shale in Osborne County.

Niobrara formation

General

The Niobrara formation of Late Cretaceous age is composed of two members, the Fort Hays limestone at the base, and the very thick Smoky Hill chalk. (See fig. 4.) In Osborne County, however, only the lower one-fourth of the latter is present. The two members are mapped separately on plate 1 because the Fort Hays limestone member is far more important as a source of engineering construction materials.

Fort Hays limestone member

Areal distribution.--The Fort Hays limestone member caps the higher hills in nearly all the interstream areas. In the western part of the county, where it is partly covered by younger formations, it forms a prominent escarpment or break in the topography. (See pl. 1.) Nearly all of the permanent streams in the county have cut through the Fort Hays into the underlying Carlile shale.

General description.--The Fort Hays member is a marine limestone, chalky, gray to buff, and in massive beds having a maximum thickness of 4.4 ft. Weathered surfaces are gray or white and may be streaked with iron oxide. Nodules of iron oxide are present in some of the limestones. The thick beds of limestone are separated by thin partings of chalky shale and these, coupled with vertical joints spaced at intervals of about 8 ft, cause the beds to break into large blocks. Exposed surfaces are case-hardened by deposition from seepage water.

The upper part of an outcrop of this member is characterized by small fragments of limestone to a depth of 2 or 3 ft. This shattered zone is the result of the mechanical weathering of the rock. The porous and fractured nature of the Fort Hays and its broad outcrop areas make the member a fairly good aquifer, as is indicated by seeps along the outcrops and by the presence of heavier vegetation at the contact between it and the underlying Carlile shale.

Representative measured section.--An old quarry in the SW¼SW¼ sec. 10, T. 6 S., R. 13 W. shows the following section of the Fort Hays member:

	Feet
Soil	0.2
Niobrara formation:	
Fort Hays limestone member:	
Limestone, shattered zone; fragments 1 to 3 in. across, angular, irregular undersides coated with calcium carbonate; moderately hard; white	1.0
Limestone, weathered and broken to blocks 1 to 6 in. thick and 5 to 20 in. across; undersides coated with calcium carbonate, uppersides rounded; hard; buff, weathers white	.6
Shale, calcareous, soft, platy; buff	.1
Limestone, hard, massive; white mottled with buff; contains fossils	.4
Shale, calcareous, soft, platy, buff	.2
Limestone, chalky, massive; buff with iron-oxide stains on fracture planes; contains a few fossil fragments	2.2
Shale, calcareous, soft, platy; buff; iron-oxide stains; fossiliferous	.1
Limestone, chalky, massive, porous, irregular fracture; buff, weathers gray; fossiliferous	2.4
Shale, calcareous; soft, platy; buff; fossiliferous	.1
Limestone, chalky, massive, porous; white, streaked with iron oxide, weathers buff; case-hardened; fossiliferous	1.6
Shale, calcareous, platy; gray, streaked with iron oxide, weathers buff	.2
Shale, chalky, platy to massive; buff, streaked with iron oxide, weathers buff; numerous fossils	.4
Limestone, chalky, massive; porous; buff, weathers cream spotted with iron-oxide stains; case-hardened; abundant fossils	2.8
Limestone, massive to platy; buff with bands of iron-oxide stain; fossiliferous	.6
Limestone, chalky to hard, massive; cream, weathers buff mottled with gray; resistant to weathering	1.6

	Feet
Niobrara formation--Continued	
Fort Hays limestone member--Continued	
Shale, calcareous, platy, gray; weathers buff	.2
Limestone, thick-bedded, cream; weathers white, streaked with iron oxide; fossiliferous	1.0
Shale, calcareous, platy, buff; iron-oxide streaks	0.1
Limestone, porous, massive, cream; weathers white to buff; case-hardened; fossiliferous	2.0
Shale, thin-bedded, gray; weathers buff; limonite nodules; fossiliferous	.1
Limestone, buff; weathers tan; pyrite nodules weathered to iron oxide; large blocks become rounded upon weathering; fossiliferous	3.9
Clay parting	.05
Limestone, massive with coarse texture, chalky; buff to cream, weathers white to tan; weathered surface covered by small pits and iron-oxide nodules; fossils along bedding planes	4.4
Total thickness present (underlain by the Carlile shale)	26.05

Thickness.--The usual exposure of Fort Hays limestone member is from 20 to 30 ft thick. Some of the more prominent escarpments show as much as 40 ft of the limestone, whose total thickness is about 60 ft.

Construction materials.--Construction materials from the Fort Hays limestone member of the Niobrara formation in Osborne County are calcareous binder, road metal, structural stone, and fill material.

Smoky Hill chalk member

Areal distribution.--Occasional outcrops of the Smoky Hill chalk member appear above the prominent escarpment formed by Fort Hays limestone member and in the broad interstream areas of the western half of the county. (See pl. 1.) The most extensive outcrop area is that between Alton and Natoma which extends southwest from Covert. There are less extensive outcrops on the hilltops south of Natoma, and the member is exposed in many places in the interstream area north of Alton. The member is only meagerly represented in the eastern half of the county and its outcrop area does not reach the eastern boundary.

General description.--The Smoky Hill chalk member is composed of beds of cream-colored chalky limestone and buff to tan chalky shale. The limestone is thin-bedded and soft, and makes infrequent outcrops in road cuts, shallow gullies, and plowed fields. Fossils, mostly shellfish, are abundant although they are usually broken. Thin seams of bentonite are present in the beds of shale. The shale beds are about twice as thick as those of limestone.

Occasional small buttes developed in the Smoky Hill chalk member are usually capped by the more resistant rocks of the overlying Ogallala formation. In some places the buttes are capped by the chalk itself which has been made more resistant to erosion by deposits of calcium carbonate that occupy fractures in it. One such butte, in which the calcareous veins are as much as 6 in. thick, is in the SW¼SW¼ sec. 21, T. 8 S., R. 15 W.

Representative measured section.--The valley of an intermittent stream in the NW¼NW¼ sec. 29, T. 9 S., R. 14 W. shows the following section of the Smoky Hill member:

	Feet
Ogallala formation:	2.0
Niobrara formation:	
Smoky Hill chalk member:	
Limestone and shale in alternating beds about 0.5 ft thick; shale is gray, weathers buff, and is very thin bedded; limonite is gray, weathers white, and is platy	8.0
Shale, gray; weathers buff; orange bentonitic seams	1.1
Shale, chalky, hard, gray; weathers white to cream	.1
Shale, calcareous, soft, platy to very thin bedded, cream; bentonite seam near base; abundant fossils	11.0
Limestone, blocky; crudely bedded; gray, weathers white to cream	3.0
Shale, thin-bedded, gray; weathers cream to brown; fossiliferous	3.3
Shale, chalky, hard, massive to blocky, gray; weathers white to cream	.5
Shale, thin-bedded, gray; weathers buff to tan; bentonite seam near middle	1.6
Shale, chalky, firm to hard, gray; weathers cream; fossiliferous	1.8
Shale, thin-bedded, gray; weathers buff to brown; bentonite seam near base; fossiliferous	5.0
Shale, splintery to very thin bedded, gray; weathers buff to cream; hard calcareous beds and soft clay beds; abundant fossils	2.8
Shale, calcareous, very thin bedded, gray; weathers buff to cream; fossiliferous	1.4
Shale, chalky, blocky, hard, gray; weathers cream	.7
Shale, thin-bedded, soft, gray; weathers buff to tan; seam of bentonite near middle	1.8
Shale, blocky, chalky, firm to hard, gray; weathers cream; occasional fossils	.7
Shale, thin-bedded, soft, gray; weathers buff to tan; bentonite seam 1 in. thick	1.0
Shale, chalky, massive to well-bedded, gray; weathers cream; fossiliferous	1.2

	Feet
Niobrara formation--Continued	
Smoky Hill chalk member--Continued	
Shale, calcareous, soft, very thin bedded, gray; weathers buff to tan; fossiliferous	1.5
Total thickness exposed (base covered). .	46.5

Thickness.--Individual outcrops of the Smoky Hill chalk member generally range from 5 to 10 ft thick, although some outcrops are as much as 40 ft thick. The maximum thickness, largely covered, is reported to be 115 ft in sec. 7, T. 9 S., R. 15 W. (Landes, 1930, p. 16.)

Construction materials.--Construction materials from the Smoky Hill chalk member in Osborne County are calcareous binder, road metal, and fill material.

Ogallala formation

Areal distribution

The Ogallala formation of Pliocene age (see fig. 4) crops out near the southwest corner of Osborne County. The easternmost and best exposures are in secs. 22 and 27, T. 9 S., R. 13 W. (See pl. 1.) All of the outcrops are in the interstream areas and are of greatest extent in T. 9 S., R. 15 W. and T. 9 S., R. 14 W. The formation is most conspicuously exposed along the shoulders of tablelike hills and is buried beneath the Sanborn formation back from the shoulders. Because the basal beds of the Ogallala formation closely resemble weathered chalk of the Smoky Hill chalk member of the Niobrara formation, and may grade into it, there are places where it is difficult to distinguish between the two. If a deposit of lime-encrusted pebbles is apparently a foot or more thick, it has been mapped as Ogallala formation on plate 1.

General description

The Ogallala formation consists of layers of sand, silt, some silicified sandstone, and "mortar bed," all of nonmarine origin. The "mortar beds" are lenses of lime-cemented sand and gravel. They are usually harder than the other sediments with which they are interbedded and thus form conspicuous ledgelike outcrops on many hillsides. The pebbles of limestone in them were derived from the underlying Smoky Hill chalk member of the Niobrara formation and cemented together by additional lime deposited by percolating subsurface water.

Some lenses of sand and gravel have been cemented by opaline silica to form a very hard, durable rock called quartzite. However, quartzite is not common in Osborne County and only a few small deposits of it were found, all of which are less than a foot thick. Small fragments of opal are scattered over the outcrops, and close examination of the quartzite reveals small veins filled with opal.

The Ogallala formation is best exposed in the SW¼SW¼ sec. 22, T. 9 S., R. 13 W., where more than 40 ft of interbedded sand, silty sand, and "mortar bed" form a prominent butte. This butte is an erosional remnant of the formation and indicates that at one time it covered the entire county at a comparable level.

Representative measured section

The following section of the Ogallala formation was measured at the previously mentioned erosional remnant in the SW¼SW¼ sec. 22, T. 9 S., R. 13 W.:

	Feet
Ogallala formation:	
"Mortar bed," weathered and broken; composed of sand, and fragments of opal and limestone cemented by calcium carbonate; greenish gray, weathers gray; supports desert vegetation	6.0
"Mortar bed," hard "cap rock" for buttes; coarse sand firmly cemented by lime and silica; gray to greenish gray; some opal in veins	6.0
Sandstone, medium- to coarse-grained, poorly sorted, friable and soft; light gray; a few nodules of silica	8.0
"Mortar beds" composed of lime-cemented medium-grained sand, light-gray, 1 to 2 ft thick, alternating with less well cemented beds of sand	10.0
Sandstone, fine- to medium-grained, poorly sorted, friable to loose; light greenish-gray	16.0
Quartzite, fine to medium-grained, cemented by silica; hard	.5
"Mortar bed" composed of recemented and partly silicified limestone pebbles..............................	2.0
Total thickness present (underlain by the Smoky Hill chalk member of the Niobrara formation)	48.5

Thickness

Except for the 48.5 ft of the Ogallala formation exposed in the measured section cited above, most of its outcrops are from a foot to 4 ft thick and are of the basal part of the formation.

Construction materials

In Osborne County, the construction materials available from the Ogallala formation are road metal and aggregate for concrete.

Sanborn formation

Areal distribution

The Sanborn formation of Pleistocene and Recent(?) age crops out in all parts of Osborne County. (See pl. 1 and fig. 4.) Recent erosion has removed the formation from hillsides and stream banks, but many interstream areas throughout the county have been sufficiently protected from erosion by the Fort Hays limestone member of the Niobrara formation that considerable quantities of the formation remain. The areas of long, gentle slopes underlain by the Fairport chalky shale member of the Carlile shale are also covered by extensive deposits of Sanborn formation. The more rolling slopes formed by the Blue Hill shale member of the Carlile shale are less extensively covered in their interstream areas. Remnants of the Sanborn formation are present on every bench formed by resistant rocks.

General description

The Sanborn formation is composed of materials deposited by streams, slopewash, wind, and through the action of gravity. Frye and Fent (1947, pp. 41-51) have divided the formation into members. It was not feasible to attempt the mapping of these members in the field work on which this report is based. To do so would have required a greatly 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.

Silt is present nearly everywhere in the formation, but especially in the interstream areas. Soil development is deep except in sloping areas subject to considerable erosion. The color of the silt below the "A" horizon may be light gray, tan, or, in some of the older deposits, orange. Orange silts near Covert are separated from the overlying tan or gray silts by an old soil profile, which may be observed as a dark bank running across cultivated fields.

Deposits of volcanic ash were reported by residents of Osborne County and may very likely be present. A careful search should reveal them. Samples of the reported deposits were studied and found to contain fine angular fragments of quartz, but no shards of volcanic glass.

Unsorted sand is mixed with the silt of the Sanborn formation. The sand is composed of rounded coarse-grained fragments of quartz and feldspar, and very likely was derived from the Ogallala formation.

Lenses composed of limestone pebbles are present in the basal part of the Sanborn formation in many places. The pebbles were derived from the Fort Hays limestone member of the Niobrara formation and in some of the deposits, even though they are only crudely stratified, most of the silt has been washed out. The lenses range from 2 to 10 ft in thickness and are characteristic of that part of the Sanborn formation which covers the Blue Hill shale member of the Carlile shale a short distance in front of the escarpment formed by the Fort Hays.

Other deposits of gravel are found in two distinctive positions: a residual position on interstream areas between small intermittent streams and associated with the streams themselves; and in stream valleys where the deposits are fairly well sorted. The deposits on the interstream areas are older, and lie beneath or within the older deposits of silt.

All of the pebbles, except those nearest the base of the escarpment formed by the Fort Hays limestone member of the Niobrara formation, are well rounded and most of them are harder than the unweathered rock from which they were derived. The pebbles are usually flat, and range from 0.25 to 3 in. in diameter.

The lower part of the Sanborn formation in the outcrop areas of the Blue Hill shale member of the Carlile shale contains fragments of concretions eroded from the shale.

A different kind of gravel caps some of the hills in the northern tier of townships. It is a poorly sorted quartz-feldspar sand and gravel associated with an ancient high-level stage of the North Fork Solomon River. The gravel deposits stand well above the present river level and were formed more recently than any of the deposits of limestone gravel.

A characteristic gently rolling surface has developed in the Sanborn formation except for a few gullies and slump areas. In some places the Blue Hill shale member of the Carlile shale has been eroded into a badland type of topography in which remnants of an older, nearly level surface are capped by silt and gravel of the Sanborn.

Representative measured section

The following section is exposed in a road cut in the NE¼NE¼ sec. 24, T. 7 S., R. 14 W.:

	Feet
Soil, light-brown, crumbly, porous	1.0
Sanborn formation:	
Silt, calcareous, crumbly; light tan, weathers cream	3.0
Silt, calcareous; massive; buff; a few small yellowish-white calcareous concretions	6.0
Silt, clay, and sand, well-sorted and stratified; buff; at a higher level than terrace deposits; lowermost foot in fine, well-sorted sand; contains some lime nodules	3.5
Silt, stratified and cross-bedded; buff; a few limestone pebbles	9.0
Sand, medium-grained, variable composition but largely quartz; well-sorted, clean; grains rounded; a few pebbly zones; sampled by augering	8.0
Stratified clay, silt, sand, and pebbles; fragments of Blue Hill shale concretions; sampled by augering	1.0
Coarse gravel, largely limestone fragments, well-rounded; sampled by augering	.5
Total thickness exposed (base covered)	31.0

Thickness

The Sanborn formation ranges in thickness from a foot, where it may be indistinguishable from residual soils, to an estimated 40 ft.

Construction materials

Construction materials available from the Sanborn formation in Osborn County are mineral filler, road metal, aggregate for concrete, and fill material.

Terrace deposits

Areal distribution

Terrace deposits of Quaternary age are characteristic of the valleys of the major streams in the county. (See pl. 1 and fig. 4.) Narrow extensions of these terraces extend a few miles up the valleys of the larger tributary streams. The terrace deposits are broad in the valley of the South Fork Solomon River and are more than a mile wide near Osborne. Terrace deposits are relatively few in the southern half of the county. The presence of older terraces at higher levels is indicated by this investigation, but, inasmuch as their originally flat surfaces have been rounded by erosion or buried under deposits of the Sanborn formation, these are mapped as part of the Sanborn formation. There is a minor development of a lower and younger terrace of limited areal extent in the meanders of the principal streams.

General description

The terrace deposits are composed of clay, silt, sand, and pebbles deposited by the North and South Fork Solomon River and their tributaries during late Pleistocene(?) and Recent time. Lenses of gravel and sand are generally in the lower portion of a deposit and grade upward into well-stratified fine sand and silt. The upper 3 to 5 ft is silt which shows little evidence of stratification and might have been deposited by wind. The silt is gray to buff, and the fine sand is light gray. The thicker terrace sediments tend to be darker in color, with tan to gray silts predominant. Layers of dark-gray clay may represent buried soil horizons.

The lower layers of gravel and sand are well sorted and show both bedding and cross bedding. They are composed largely of fragments of quartz, feldspar, and granite but also contain some fragments of chert or opal and a few pieces of shale from the Blue Hill shale member of the Carlile shale. Most of this material appears to have been eroded from the Ogallala formation and carried into this area by the two forks of the Solomon River.

Representative measured section

The following section of a terrace deposit may be observed in a road cut near the South Fork Solomon River in the NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 14, T. 7 S., R. 13 W.:

	Feet
Soil: unstratified silt	3.0
Terrace deposit:	
Soil, clayey; stratified; gray to gray brown	5.0
Silt, fine sandy, free from clay; loose; buff	7.0
Total thickness exposed (base covered)	12.0

Thickness

The maximum height of the terrace above the South Fork Solomon River is about 37 ft and the average height is about 30 ft. The lowermost 10 ft is generally sand and gravel. Other terraces in the county are no more than 10 or 15 ft above stream level.

Construction materials

From the terrace deposits in Osborne County the following construction materials can be had: mineral filler, aggregate for concrete, road metal, and fill material.

Alluvium

Areal distribution

Alluvium (see fig. 4) is defined in this report as material deposited by present-day streams. Its areal extent is limited in Osborne County. (See pl. 1.) Along the major streams it is largely confined to the stream channel, and small areas of flood plain which occupy the inside curve of some meanders. Intermittent and other minor streams have deposited small amounts of alluvial gravel and sand, but these are so small that they cannot be shown on plate 1.

General description

Alluvium consists of stream-deposited clay, silt, sand, and pebbles. The narrow flood plains are covered with layers of clay and silt, although buried gravel and sand bars are fairly numerous. The South Fork Solomon River and its tributaries are eroding the Carlile shale at several places, and for this reason their alluvium contains a moderately high percentage of clay lumps. Alluvium in the smaller streams reflects the material which the stream is eroding. A small intermittent stream in the SW$\frac{1}{4}$ sec. 4, T. 8 S., R. 13 W. has cut its valley into the Fort Hays limestone member of the Niobrara formation and the Blue Hill shale member of the Carlile shale. It has deposited at least 6 ft of alluvium which consists of silt and flat pebbles of limestone. The pebbles, derived from the Fort Hays, range from $\frac{1}{2}$ to 3 in. in diameter, and are subangular. The silt came largely from the upper part of the Blue Hill shale member.

Representative measured section

The relief of the alluvium is so low that a representative section was not measured. Typically the alluvium exposed along the South Fork Solomon River, such as that in the NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 17, T. 7 S., R. 13 W., consists of about 8 ft of gray to brownish-gray clay, silt, and fine sand, and occasional small lenses of gravel.

Thickness

The maximum thickness of the alluvial deposits is estimated to be about 25 ft.

Construction materials

Construction materials from the alluvium are aggregate for concrete and road metal.

INVENTORY OF CONSTRUCTION MATERIALS

General

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

Whenever available, laboratory test data have been introduced into the report to aid the reader in his evaluation of the materials. The information given in table 1 is based on standard testing procedures of the State Highway Commission of Kansas (1945, pp. 16, 333-334, 335-336) and the American Association of State Highway Officials (1947, pp. 198-204, 235-241, 249-254, 257-258). It is expected that prospects listed in this report will be proved by subsequent augering, drilling, or test pitting, and that the materials themselves will be subjected to laboratory testing prior to production for specific uses.

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

Aggregate for concrete

Engineering and geologic characteristics

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

Stratigraphic sources and performance characteristics

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

1. Alluvium.--The alluvial deposits were not sampled by the field party although they are the most promising source of aggregate in the county. These deposits would have to be pumped directly from the stream bed, and there was no facility available to obtain samples. The alluvial deposits of the North and South Forks of the Solomon River have been used locally in concrete and serve satisfactorily in small structures. They contain pebbles of limestone and soft shale, and some of them are contaminated by a high percentage of silt and clay.

2. Terrace deposits.--Sand and gravel are present in the terrace deposits under a thick overburden of silt. Samples of sand and gravel from this source were obtained by augering but were not tested because of the excessively thick overburden. The sand is siliceous, well sorted, and clean. Intensive search may reveal terrace deposits from which most of the silty upper part has been removed by erosion.

3. Sanborn formation.--Two samples of fine aggregate (fa 1 and fa 2) and one of mixed aggregate (ma 1) were obtained from the Sanborn formation. The sand and gravel of this formation are composed predominantly of particles of granite, quartz, and feldspar, with some chert and limestone.

Additional supplies of sand and gravel from this source may be discovered by careful search of the formation where it outcrops along the margins of river valleys. Ancient high-level river deposits have been mapped on plate 1 as part of the Sanborn formation where they lie above the highest terrace and at the base of a valley wall.

4. Ogallala formation.--Two samples of fine aggregate (fa 4 and fa 5) were obtained from this formation. The beds are not extensive and the deposits are not in commercial quantity. Although other beds of gravelly sand undoubtedly occur in the Ogallala formation, they are probably not adequate sources of aggregate.

Road metal

Engineering and geologic characteristics

Road metal (known also as surfacing material, crushed stone, and aggregate), is defined in this report as any material that may be applied to a road to improve the performance characteristics of that road. Many materials fulfill this requirement, and the list of such materials will differ from one area to another. The following materials are available in Osborne County for use as road metal:

1. Aggregate for concrete.

2. Crushed rock.--The indurated rocks available in Osborne County for use as road metal are nearly all limestone. A small quantity of "mortar bed" in the Ogallala formation is available and, locally, calcareous concretions from the Blue Hill shale member of the Carlile shale have been crushed for this use. The materials included here under crushed rock are listed in table 1 and mapped on plate 1 under the more specific designation of limestone and "mortar bed" because, in addition to their use as road metal, they may be used as structural stone and riprap.

3. Limestone gravel.--The Sanborn formation contains widespread deposits of pebbles derived from the Fort Hays limestone member of the Niobrara formation. These pebbles are harder than the original limestone, rounded, and intermixed with silt.

Stratigraphic sources and performance characteristics

1. Sources of aggregate for concrete.--The materials listed in the section on aggregate for concrete have not been widely used in Osborne County as road metal because of the availability of other, more widespread materials of acceptable quality.

2. Crushed rock.--(a) Ogallala formation. Material from the Ogallala has not been widely used as road metal because of the limited thickness and area of outcrop of the formation. On the hilltops north of Natoma, however, there is sufficient nodular limestone that it might be economically produced for use as road metal. Beds 2 or 3 ft thick crop out at the heads of numerous draws in this region.

(b) Smoky Hill chalk member of the Niobrara formation. Traffic-bound macadam, constructed of the Smoky Hill, was observed on a county road near the northwest corner of the county. The performance of this road appears to be inferior to that of roads constructed of limestone from the Fort Hays limestone member of the Niobrara formation, especially in wet weather. Township roads in the outcrop area of the Smoky Hill, where soils are thin, have been bladed to grade to produce a kind of traffic-bound macadam. So long as the percentage of clay in the Smoky Hill is high, with good drainage these roads give satisfactory all-weather performance.

(c) Fort Hays limestone member of the Niobrara formation. The Fort Hays has been used as crushed rock on a number of light-traffic roads in Osborne County. Generally the shattered zone in the upper part of an outcrop is removed with a blade and transferred directly to the road. Little or no crushing is required and the rock is moved directly into place, wetted down, rolled, and bladed to grade to form a traffic-bound macadam. This use of the rock is made chiefly in areas near the outcrop of the Fort Hays limestone member. Quarrying and crushing any of the beds in the member is feasible throughout the county at any of the outcrops mapped on plate 1.

The crushed limestone makes a satisfactory wet-weather road, although it has a tendency to dust during dry weather.

(d) Pfeifer shale member of the Greenhorn limestone. The "Fencepost" limestone bed and other beds of chalky limestone in the Pfeifer shale member have been used locally as road metal and are satisfactory in this use. The thinness of the beds and their restricted outcrop area limit the quantity of rock that can be produced.

(e) Jetmore chalk member of the Greenhorn limestone. The Jetmore chalk member has not been widely used as road metal in Osborne County because of its restricted outcrop area, but is satisfactory for use on light-traffic roads or as base-course material.

Mineral filler

Engineering and geologic characteristics

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

Stratigraphic sources and performance characteristics

The following stratigraphic units are actual or potential sources of mineral filler:

1. Terrace deposits.--Terrace sediments along the South Fork Solomon River contain extensive deposits of silt and very fine sand which have a coefficient of cementation sufficiently low that they can be used as mineral filler.

A sample (mf 1) of fine sandy silt from the NE¼NE¼ sec. 26, T. 7 S., R. 11 W. shows 48 percent passing the no. 200 sieve and a coefficient of cementation of 20. This material is 15 ft thick above the water table, stratified, and crossbedded. It is similar to terrace deposits throughout the valley of the South Fork Solomon River. Another sample from a terrace south of Osborne (mf 2) is gray sandy loam. Sieve analysis indicates that 70 percent passes the no. 200 sieve, and the coefficient of cementation is 38. The material is acceptable for use as mineral filler under sections 108 and 109 of the 1949 Standard Specifications of the State Highway Commission.

2. Sanborn formation.--A sample of silt (mf 3) from the Sanborn formation shows by analysis that 70.8 percent passes the no. 200 sieve. The coefficient of cementation is 40. The deposit is rather extensive. In most places, however, the Sanborn formation contains so much clay that its coefficient of cementation is too high.

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 in. or more in width and that the specific gravity be 2 or higher.

Stratigraphic sources and performance characteristics

1. Niobrara formation.--None of the limestones of the Niobrara formation are suitable for use as riprap. A few instances of the use of the Fort Hays limestone member for riprap were noted in which blocks were used to face the earthen dams of farm ponds. All evidence indicates that this limestone will disintegrate in a short time if it is exposed to continued immersion in water.

2. Greenhorn limestone.--Both the "Fencepost" limestone bed of the Pfeifer shale member and the "Shell-rock" limestone of the Jetmore chalk member have been cut into blocks and used as riprap. Both appear to perform with fair satisfaction, although some of the blocks have weathered enough in 10 yr to develop numerous fractures. Failure of the reservoir dam at Osborne was not due to disintegration of the riprap, which was rock from the Greenhorn limestone.

Structural stone

Engineering and geologic characteristics

Structural stone, as defined in this report, is any hard, dense rock material that can be quarried and produced to desired size and shape. Materials fulfilling these requirements occur in the Jetmore chalk and Pfeifer shale members of the Greenhorn limestone, and in the Fort Hays limestone member of the Niobrara formation.

Stratigraphic sources and performance characteristics

1. Smoky Hill chalk member of the Niobrara formation.--The chalky limestone which occurs in the Smoky Hill member is not suited for use as structural stone because it slakes too rapidly. One farmhouse was observed which had been constructed partly of chalk from the Smoky Hill. Many of the blocks have completely disintegrated.

2. Fort Hays limestone member of the Niobrara formation.--Blocks of the Fort Hays limestone member are used extensively throughout Osborne County in the construction of dwellings and farm buildings. The limestone is soft and chalky but hardens after being cut. Structures 50 yr old still stand in Osborne, but occasional blocks have disintegrated at or near ground level where moisture has been excessive. The test characteristics are given for one sample of Fort Hays. (See 1s 7 and 1s 10 in table 1.)

3. Pfeifer shale member of the Greenhorn limestone.--The "Fencepost" limestone bed has been widely used as structural stone in Osborne County, although most of the rock was quarried in other counties. The older buildings in Osborne were built more than 50 yr ago and the "Fencepost" limestone used in the foundations of some still appears to be sound. It has also been used for carved trim and the amount of weathering of the cut surfaces is negligible. The Osborne County courthouse is an example of the constructional use of this stone. However, it is to be noted that its foundation was constructed of a much older limestone brought in from eastern Kansas.

4. Jetmore chalk member of the Greenhorn limestone.--The "Shell-rock" and other limestone beds of the Jetmore have been quarried extensively in neighboring counties, but only to a minor extent in Osborne County. The stone is used both for fenceposts and for the construction of buildings. It may or may not exhibit a brown iron-oxide streak, but is generally of greater thickness than the "Fencepost" limestone.

Calcareous binder

Engineering and geologic characteristics

To be classified as calcareous binder the material must be composed essentially of calcium carbonate and must be 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. Smoky Hill chalk member of the Niobrara formation.--Chalk of the Smoky Hill member has been accepted by the State Highway Commission of Kansas as material suitable for use as calcareous binder. It contains beds of chalky limestone similar to those of the Fort Hays limestone member.

2. Fort Hays limestone member of the Niobrara formation.--Limestone of the Fort Hays member has been accepted by the State Highway Commission of Kansas as material suitable for use as calcareous binder. This member contains massive beds of chalky limestone that are soft, easily pulverized, and free from deleterious substances. The material can be obtained in almost unlimited quantities from any of the outcrop areas of the Fort Hays shown on plate 1.

Subgrade and embankment material

Engineering and geologic characteristics

The following definition of subgrade and embankment material is adapted from the specifications compiled for the American Association of State Highway Officials (1937, pp. 37-38). Suitable geologic materials for this kind of construction are: fine, granular, unconsolidated sediments, including soil, of which 50 percent or more pass through a no. 200 sieve; coarse, granular, unconsolidated sediments and broken or crushed consolidated rocks, of which at least 65 percent by weight is retained on a no. 200 sieve; and broken or crushed rock.

Stratigraphic sources and performance characteristics

All of the materials listed above are available in Osborne County for the construction of subgrades and embankments. The geologic formations in which these materials occur are:

1. Fine, granular, unconsolidated sediments.--The Sanborn formation and terrace deposits contain large quantities of silt or clayey silt. The extensive outcrops of these formations are mapped on plate 1 and indicate the availability of the material in most of the county.

2. Coarse, granular, unconsolidated sediments.--A small quantity of sand and gravel is available for use in the construction of subgrades and embankments. Some sand and gravel is present in the basal part of the Sanborn formation, and at a few scattered localities higher in the formation. Sand and gravel also occurs in the lower terrace beds. Some sand and gravel has been produced from alluvium of the major streams, though largely for concrete construction. It is possible that the extensive deposits of limestone gravel within the Sanborn formation will prove acceptable for this use.

3. Broken or crushed rock.--The formations of Cretaceous age are the only extensive sources of broken or crushed rock in Osborne County. Very local use may be made of a nodular limestone which is present to a limited extent in the Ogallala formation.

(a) Greenhorn limestone. Only the Jetmore chalk and Pfeifer shale members are commercial sources of crushed stone. The bearing strength of material from these sources is probably adequate.

(b) Carlile shale. Except for the Codell sandstone member and the silty zones immediately below it, and the lower part of the Fairport chalky shale member, the Carlile shale is composed predominantly of clay.

(c) Niobrara formation. Broken or crushed rock from the Fort Hays limestone and Smoky Hill chalk members appear to be acceptable for use in the construction of subgrades and embankments if drainage is good.

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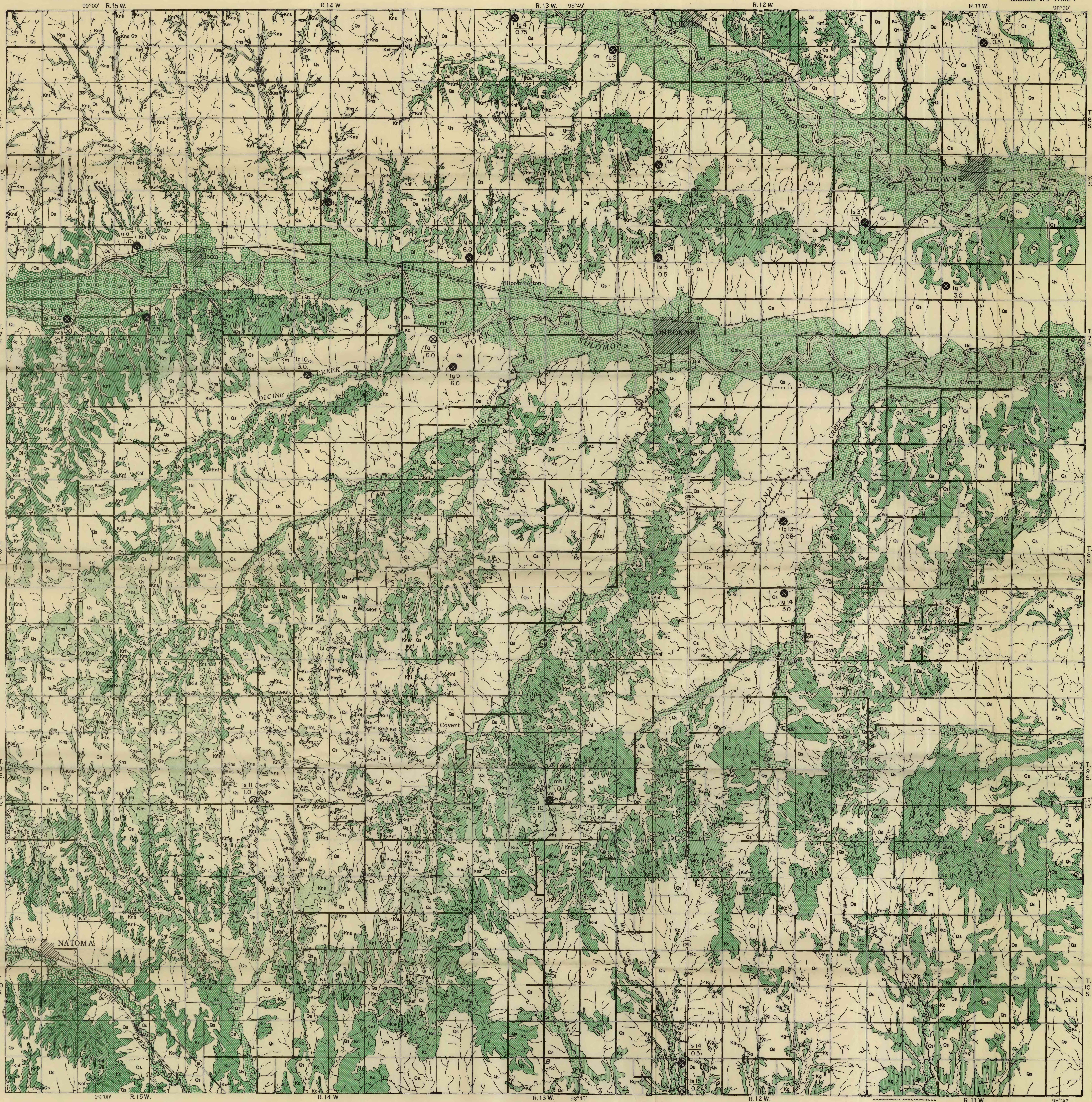
INT.-DUP. SEC., WASH., D.C. 25719

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



EXPLANATION

QUATERNARY	Recent	**Qal** Alluvium. Predominantly silt; lenses of sand and gravel. Source or potential source of: aggregate, road metal
	Pleistocene(?) and Recent	**Qt** Terrace deposits. Silt; lenses of sand and gravelly sand in lower part. Source or potential source of: aggregate, mineral filler, road metal, fill material
	Pleistocene and Recent(?)	**Qs** Sanborn formation. Brown, tan and gray silt; lenses of limestone gravel and sand in lower part. Source or potential source of: mineral filler, aggregate, road metal, fill material
TERTIARY	Pliocene	**To** Ogallala formation. Fine to medium sand, locally cemented by lime to form mortar bed or silica to form quartzite; pebble zone near base. Source or potential source of: road metal, aggregate
CRETACEOUS	Upper Cretaceous	**Kns / Knf** Niobrara formation. Kns; Smoky Hill chalk member: Interbedded calcareous, soft tan and gray shales and thin, light gray to tan, chalky limestones. Source or potential source of: calcareous binder, road metal, fill material. Knf; Fort Hays limestone member: Thick beds of chalky limestone; massive, blocky, soft; light gray to tan. Source or potential source of: calcareous binder, road metal, structural stone, fill material
		Kc Carlile shale. Upper part, dark-blue thin-bedded shale with sandy zone near top, contains zones of concretions; lower part, interbedded fossiliferous, orange-gray chalky limestones and shales. Source or potential source of: fill material
		Kg Greenhorn limestone. Thin, hard limestones separated by calcareous shales; tan and gray; fossiliferous. Source or potential source of: road metal, structural stone, fill material

Geologic contact

Operated pit or quarry

Prospect pit or quarry

ls
Limestone

fa
Fine aggregate

ma
Mixed aggregate

mf
Mineral filler

lg
Limestone gravel

mb
Mortar bed

ls 7
3.5

Letters and number above line indicate materials listed in table 1 and their sample number; number below line indicates quantity of material available in units of 10,000 cubic yards

Township corner

10½°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1951

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 OSBORNE COUNTY, KANSAS

1 0 5 Miles

1952

Geology by Charles P. Walters and Larsen Y. Drake, 1949

Table I. Summary of material tests

(Blank spaces indicate data not available)

Classification of the material	Number on plate I	Location					Estimated quantity of material (cubic yards)	Average thickness		Accessibility	Geologic formation or member	Authority for test data[1]	Date of test	Sieve analysis						Description of the material[2]											Laboratory test data												Remarks
		1/4 fraction	1/4 section	Section	Township (S)	Range (W)		Material (feet)	Overburden (feet)					Percent on 3/4 inch	Percent on 3/8 inch	Percent on No. 4	Percent on No. 16	Percent on No. 100	Percent passed No. 200 (wash)	Fraction	Quartz	Feldspars	Gypsum and anhydrite	Magnetite	Limestone fragments	Shale fragments	Sand aggregates	Basic igneous rocks	Acid igneous rocks	Caliche	Weight per cubic foot (dry)	Specific gravity (dry)	Gradation factor	Compressive strength ratio 1 day	Compressive strength ratio 3 days	Los Angeles percent loss	Soundness (25 cycles)	Toughness	Cementation	Absorption	Color[3]	Laboratory No.	
Fine aggregate	fa 1	SE	SE	9	6	12	31,500			Good	Alluvium	SHCK	4-49	0	0	0	2	70	23.3	Fine siliceous sand.											103.0	2.53	1.16	0.64	0.77						dk st	62421	Acceptable under Secs. 108 and 109, 1945 SHCK Std. Specs.
	fa 2	NE	NE	11	6	13	15,000	20	8	Good	Sanborn	USGS SHCK	7-49	0	2	5	17	92	5.4	Siliceous sand with a small amout of clay intermixed.											105.9	2.58	2.39	1.44	1.36							63874	
	fa 3		SW	31	6	14	1,000			Good	Sanborn	USGS SHCK	6-47	2	7	11	32	98	1.4	Sand, gravel, and clay resulting from the disintegration of siliceous and calcareous rocks.														3.30								54986 55124	Sample 54986 contained 19.9% mud balls and was rejected for use under Sec. 108, 1945 SHCK Std. Specs.
	fa 4		NE	23	7	13	10,000			Fair	Alluvium	SHCK	4-42	0	0	0	0	78	12.9	Naturally disintegrated sand consisting of siliceous particles.											99.0	2.54	1.33	0.67	0.71						lt st	44804	Acceptable under Sec. 69, 1939 SHCK Std. Specs. if brought to required grading.
	fa 5		NW	8	7	14	4,000			Good	Terrace	SHCK	2-35	0	3	7		99	0.8	Clean siliceous sand containing a small portion of hard limestone pebbles.													3.33	1.46	1.49						cl	24892	Acceptable for use as aggregate for concrete if brought to proper grading stated in Sec. 55, 1934 SHCK Std. Specs.
	fa 6	W 1/2	SE	12	7	14	10,000			Fair	Dune sand	SHCK	4-42	0	0	0	0	71	13.6	Naturally disintegrated sand consisting of siliceous and calcareous particles.											93.0	2.51	0.94	0.63	0.65						st	44805	Acceptable under Sec. 69, 1939 SHCK Std. Specs. if brought to required grading.
	fa 7	NE	NE	24	7	14	60,000	8	6	Good	Sanborn	USGS SHCK	9-49	0	1	2	7	84	1.08	C F	 55	 15	 25	 Tr	95 5	Tr Tr	Tr 	 Tr	 Tr		102.2	2.55	1.86	0.96	1.14						cl	64219	Overburden is silt, 6 feet thick, which is acceptable for use as mineral filler (see sample mf 3).
	fa 8	NW	SE	17	7	15	100,000	12	0	Fair	Dune sand	USGS SHCK	7-49	0	0	0	0	87	5.4	Very fine, well sorted, brown sand.											98.9	2.59	1.30	0.63	0.66						v dk st	63872	
	fa 9		SW	31	8	14	700			Good	Alluvium	USGS SHCK	6-47	2	7	11	32	98	1.4	Sand-gravel resulting from the disintegration of siliceous and calcareous rocks.													3.30									55124	
	fa 10	SW	SW	22	9	13	5,000	8	10	Good	Ogallala	USGS SHCK								C F	 70	 Tr							 Tr	 30												63867	Material crumbles under water therefore no test was performed.
Mixed aggregate	ma 1	SE	SE	6	6	12	9,000			Good	Alluvium	SHCK	4-42	0	5	11	38	98	19	Naturally disintegrated sand-gravel consisting of siliceous and calcareous particles.											110.0	2.58	3.84	1.13	1.07	32.0	0.84				cl	44807	Acceptable under Sec. 65, 1937 SHCK Std. Specs. if produced to comply with sieve analysis requirements.
	ma 2	SE	SE	10	6	12	3,000			Good	Sanborn	SHCK	4-42	1	7	16	46	98	2.4	Naturally disintegrated sand-gravel consisting of siliceous and calcareous particles.											110.0	2.58	3.67	1.18	1.05	30.4	0.83				lt st	44800	
	ma 3		SW	31	6	14				Good	Sanborn	SHCK	6-47	5	15	21	46	99	0.32	Naturally disintegrated sand-gravel consisting of siliceous and calcareous particles.													3.89									55130	
	ma 4	NW	NE	19	7	11	11,500			Good	Terrace	SHCK	4-49	0	1	3	17	97	2.5	Naturally disintegrated sand-gravel consisting of siliceous and calcareous particles.											108.7	2.60	2.53	1.17	1.01	34.2	0.87				cl	62420	Acceptable under Secs. 108, 109, 110, and 112, 1945 SHCK Std. Specs. if produced to comply with sieve analysis requirements.
	ma 5		NW	18	7	13	9,000			Good	Terrace	SHCK	4-42	1	5	11	35	98	1.8	Sand-gravel consisting of siliceous and calcareous particles.											107.0	2.58	3.38	1.17	1.07	30.8	0.88				lt st	44806	Acceptable under Secs. 65, 69, 71, and 75, 1937 SHCK Std. Specs. if produced to comply with sieve analysis requirements.
	ma 6		NW	8	7	14	5,000			Good	Alluvium	SHCK	1-48	2	5	10	45	99	0.50	Naturally disintegrated sand-gravel consisting of siliceous and calcareous particles.													3.60									58071	Does not comply with Sec. 106, 1945 SHCK Std. Specs.
	ma 7	NW	SE	3	7	15	10,000	9	5	Good	Sanborn	USGS SHCK	7-49	0	3	7	25	97	2.07	C F	5 60	Tr 5	 10	 Tr	85 20	5 Tr		 Tr	Tr Tr		110.0	2.60	2.93	1.51	1.29						cl	63875	
Mineral filler	mf 1	NE	NE	26	7	11	15,000			Good	Terrace	USGS SHCK	9-49	0	0	0	0	27	48.0	Gray silt.											90.5	2.63							20			64777	
	mf 2	NW	SW	20	7	12	700			Good	Terrace	USGS SHCK	5-47	0	0	0	1	63	30	Gray sandy loam.											90.5	2.64	30.2						38			54985	Acceptable for use as mineral filler under Secs. 108 and 109, 1945 SHCK Std. Specs.
	mf 3	NE	NE	24	7	14	10,000	6	2	Good	Sanborn	USGS SHCK	9-49	0	0	0	0	7	70.8	Yellow silty clay.											89.4	2.59							40			64220	
Vol. ash	va 1		NW	24	10	15	10,000			Good	Sanborn	SHCK	3-42	0	0	1	2	24	67	Light gray volcanic ash.											72.0											44695 44696	Acceptable under Sec. 69, Art. 69.3, 1937 SHCK Std. Specs.
Limestone gravel	lg 1	SW	SW	3	6	11	5,000	10	2	Good	Sanborn	SHCK	6-48	0	2	17	48	65	32.5	Fragments of local limestones in a matrix of clayey silt.													2.84			39.8	0.85					59203	Acceptable under Sec. 116, 1945 SHCK Std. Specs. if produced to comply with sieve analysis and plasticity requirements.
	lg 2	W 1/2	NE	15	6	12	1,300			Good	Alluvium	SHCK	6-47	0	14	51	96	99															5.40									55131	
	lg 3	SW	NW	30	6	12	20,000	8	2	Good	Terrace	USGS SHCK	7-49	1	9	31	57	68	30.82	Limestone gravel in a matrix of clayey silt.													3.41			33.4	0.71					63869 64214	
	lg 4	SW	NW	4	6	13	7,500	15	2	Good	Sanborn	USGS SHCK	9-49	2	9	24	42	56	42.3	Limestone gravel in a matrix of clayey silt.													2.67			32.0	0.67					63870 64215	
	lg 5	N 1/2	SE	14	6	13	7,000			Good	Sanborn	SHCK	4-47							White and yellowish gray limestone gravel.																39.4	0.68					54397	Acceptable under Supplemental Spec. 45-111, SHCK, if produced to comply with sieve analysis requirements.
	lg 6	SE	NE	33	6	14	5,000	15	2	Good	Sanborn	USGS SHCK	9-49	1	12	33	66	84	14.55	Fragments of local limestone in a matrix of clayey silt.													4.01			36.4	0.54					63871 64216	
	lg 7	NW	SW	9	7	11	30,000	6	2	Good	Sanborn	USGS SHCK	9-49	3	19	40	68	76	21.80	Limestone gravel in a matrix of clayey silt.													4.10			34.8	0.76					64222	
	lg 8	SE	SE	6	7	13	60,000	6	6	Good	Sanborn	USGS SHCK	10-49	1	9	30	59	69	29.4	Fragments of local limestone in a matrix of clayey silt.													3.47			35.1	0.66					64221	
	lg 9	SE	SW	19	7	13	60,000	9	2	Good	Sanborn	USGS SHCK	9-49	1	12	29	51	70	26.7	Fragments of limestone and calcareous concretions in a matrix of clayey silt.													3.25			27.0	0.81					64224	
	lg 10	NE	NW	28	7	14	30,000	9	2	Good	Sanborn	SHCK	8-46	2	17	37	61	77	18.6	Mixture of calcareous gravel and binder.											92.4	2.32	3.86			33.8	0.61					64223	
	lg-11	NW	SE	3	7	15	10,000			Good	Sanborn	USGS SHCK	9-49							Limestone gravel resulting from the natural disintegration of calcareous rocks.																38.8	0.66					64218	
	lg 12	SW	SE	17	7	15	25,000	6	2	Good	Sanborn	SHCK	7-49	2	4	19	53	73	24.19	Fragments of local limestone in a matrix of clayey silt.											97.5	2.29	3.83			36.6	0.70					51723 63873	
	lg 13	NW	NE	15	8	12	800	8	2	Good	Sanborn	USGS SHCK	5-47							Large fragments of local limestone in a silty matrix.																44.8	0.60					54987	Does not comply with soundness requirements of Secs. 108 and 109, 1945 SHCK Std. Specs.
	lg 14	NW	NE	27	8	12	30,000			Good	Sanborn	SHCK	4-42						20.9	Limestone gravel in a clayey matrix.																			75			44801	Acceptable under Sec. 74, 1937 SHCK Std. Specs.
	lg 15		SW	13	8	13	30,000			Good	Sanborn	USGS SHCK	7-48																								0.71					59578	Does not comply with soundness requirement of Supplemental Spec. 45-341, SHCK Std. Specs.
	lg 16		SW	14	8	13				Good	Sanborn	SHCK	5-40	1	15	38	63	77	20.5	A mixture of clay, calcareous binder, and limestone pebbles.																			100			39783	Acceptable under Sec. 74, 1937 SHCK Std. Specs.
	lg 17		SW	12	9	13	9,000			Good	Sanborn	SHCK	7-40 4-42						25.2	Mixture of calcareous, siliceous, and silty clay materials.																			100			44803	Acceptable under Sec. 74, 1937 SHCK Std. Specs.
	lg 18		SE	35	10	13				Good	Sanborn	SHCK	10-38 4-42						19.5	Mixture of calcareous, siliceous, and silty clay materials.																			100			44802	Acceptable under Sec. 74, 1937 SHCK Std. Specs.
	lg 19		SE	21	10	15	20,000			Good	Sanborn	SHCK	6-37 8-46	3	11	33	64	75	22.4	Light gray limestone gravel.											98.3	2.28	3.80			53.9	0.58					51722	
Limestone	ls 1		NE	3	6	12	2,500	20	1	Good	Fort Hays	SHCK	4-33							Soft white limestone.												1.83				13.1% Wear	Not Sound	3		15.55		21277	Not acceptable as coarse mineral aggregate in bituminous mat construction.
	ls 2	NE	NE	10	6	12	2,500	20	1	Fair	Fort Hays	SHCK	4-33							Soft white limestone.											115.0	1.84				10.25% Wear	Sound	3		15.07		21278	Acceptable for use as mineral aggregate in bituminous mat construction.
	ls 3	SE	SE	36	6	12	15,000	30	1	Good	Fort Hays	SHCK	5-34							Soft, white to cream, thick-bedded, chalky limestone.											110.0	1.76				14.1% Wear	Not Sound	3		16.0		23321	Not satisfactory for use in bituminous-mat or portland-cement construction; satisfactory, if pulverized, for use as mineral filler.
	ls 4	SW	SW	30	6	13	5,000	20	1	Good	Fort Hays	SHCK	5-34							Soft white limestone.											118.0	1.89				17.8% Wear	Not Sound	3		13.8		23323	Not satisfactory for use in bituminous-mat or portland-cement construction; satisfactory, if pulverized, for use as mineral filler.
	ls 5	SW	SW	6	7	12	5,000	20	1	Good	Fort Hays	SHCK	5-34							Massive beds of soft yellow limestone.											104.0	1.67				13.5% Wear	Not Sound			19.1		23322	Not satisfactory for use in bituminous-mat or portland-cement construction; satisfactory, if pulverized, for use as mineral filler.
	ls 6	SW	SE	6	7	13	5,000	20	1	Good	Fort Hays	SHCK	5-34							Light yellow limestone.												1.74				10.8% Wear	Not Sound	3		16.7		23324	Unsound, so not acceptable for use in concrete construction.
	ls 7	NE	SE	15	7	15	35,000	35	1	Good	Fort Hays	USGS SHCK	7-49							Massive beds of soft chalky limestone.												1.81				50.4	0.48			17.21		63876	
	ls 8		SW	7	8	12	5,000	20	1	Good	Fort Hays	SHCK	6-34							Soft white limestone.											119.0	1.91				18.0% Wear	Not Sound	4		13.4		23320	Unsound, so not acceptable for use in concrete construction.
	ls 9		SW	7	8	12	5,000	20	1	Good	Fort Hays	SHCK	6-34							White limestone.											145.0	2.32				8.2% Wear		7		5.0		23320	Satisfactory for use as mineral aggregate in bituminous-mat and portland-cement construction.
	ls 10	E 1/2	SE	19	9	12	10,000	20	1	Good	Fort Hays	SHCK	4-46							Soft, white, chalky limestone.												1.76				64.8	0.22			18.24		50554	Acceptable for use under Type LM-4 of Sec. 116, 1945 SHCK Std. Specs.
	ls 11	SE	SE	19	9	14	10,000	10	1	Good	Smoky Hill	USGS SHCK	10-49							Tan, platy, shaly chalk.												1.83				56.8	0.19			15.65		64773	
	ls 12			7	10	12		20	1	Good	Fort Hays	SHCK	5-36							Light yellow limestone.												2.09				9.5% Wear	OK	6		8.5		28267	Acceptable as aggregate under Sec. 58, 1934 SHCK Std. Specs.
	ls 13			26	10	12					Pfeifer	SHCK	8-41							Light yellow limestone.																	Sound					42987	Acceptable for use as riprap under Sec. 91, 1937 SHCK Std. Specs.
	ls 14	NE	NE	31	10	12	5,000	1	5	Good	Pfeifer	USGS SHCK	10-49							Massive tan limestone marked by red-brown streak in middle zone.												2.14				43.4	0.86			7.8		64771	"Fencepost" limestone bed.
	ls 15	SE	SE	31	10	12	2,000	1	5	Good	Jetmore	USGS SHCK	10-49							Massive gray limestone which contains an abundance of fossil shells.												2.18				43.6	0.94			7.06		64774	"Shell-rock" limestone bed.
Mtr. bed	mb 1	SW	SW	22	9	13	1,000	6	2		Ogallala	USGS SHCK	10-49							Mortar bed; friable to firmly cemented, well-sorted sand.																						64772	Material crumbles under water so no tests were performed.

1. SHCK, State Highway Commission of Kansas. SHCK and USGS, sieve analysis and laboratory tests by State Highway Commission; 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. Color: cl, clear; lt st, light straw; st, straw; dk st, dark straw; v dk st, very dark straw.