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GEOLOGIC CONSTRUCTION-MATERIAL RESOURCES IN MITCHELL COUNTY, KANSAS

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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 construction materials. A field party composed of personnel from the two cooperating agencies was sent into Mitchell County, Kans., in the summer of 1948 to investigate sources of engineering construction materials. This report of the Mitchell County investigation is a part of the general inventory and a contribution to the geologic mapping and investigation of mineral resources being made in connection with studies of the Missouri River basin. 1/

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

Geography

Area Covered by the Investigation

Mitchell County is in the second tier of Kansas counties south of the Nebraska border and in the seventh tier west of the Missouri border. (See fig. 1.) It comprises 20 townships and covers an area of about 720 square miles. The county is bounded on the north by Jewell and Cloud Counties, on the east by Cloud and Ottawa Counties, on the south by Lincoln County, and on the west by Osborne County.

Topography

The average altitude of Mitchell County is 1,500 feet. The lowest point, about 1,310 feet, is on the Solomon River at the east boundary and the highest point, about 1,885 feet, is a short distance southeast of Tipton in the area known as the Blue Hills.

The two most conspicuous topographic features in the county are the valley of the Solomon River and the Blue Hills. The valleys of the North and South Forks of the Solomon River, which join in the vicinity of Cawker City to form the Solomon River, are incised about 50 feet below the general level; in the eastern part of the county, the valley of the Solomon River has been incised to a depth of about 150 feet. In the valley is an extensive terrace which, in the vicinity of Glen Elder, is only slightly more than a mile wide but increases in width to almost 4 miles at the eastern boundary of the county.

The Blue Hills in the southwestern part of Mitchell County stand conspicuously above the general level. The hills are buttes and mesas capped by the Fort Hays limestone member of the Niobrara formation. (See pl. 1 and fig. 4.) Their steep slopes have been cut into the Carlile shale. The highest of the hills project almost 300 feet above the surrounding upland plain.

Most of the area of Mitchell County is occupied by a rolling upland plain only moderately dissected by the tributaries of the Solomon River in the central and northern parts of the county and by those of Salt Creek in the southern part. The walls of the valleys through which the smaller streams flow are gently sloping for the most part; a shoulder formed by the Greenhorn limestone (see pl. 1 and fig. 4) marks the top of many of the valley walls. Interstream areas are flat to rounded.

Drainage

Surface drainage in Mitchell County is controlled by the Solomon River and its tributaries. (See pl. 1.) The longest tributaries, Walnut and Clay Creeks, head in the Blue Hills and flow northward. Salt Creek is the largest stream in the southern part of the county. It is another tributary of the Solomon River, which it joins in the northern part of Saline County.

Climate

Mitchell County is in an area of continental-type climate in which the summers are relatively long and hot and the winters short and

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

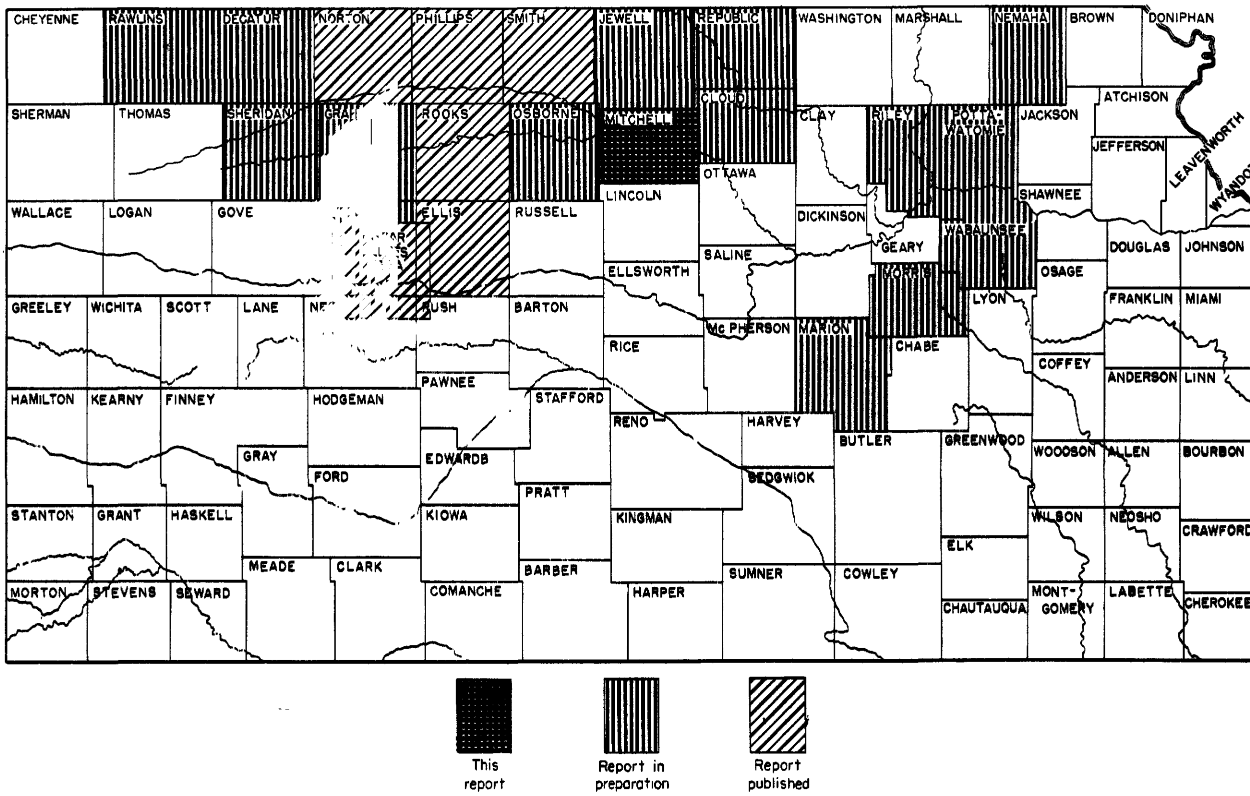
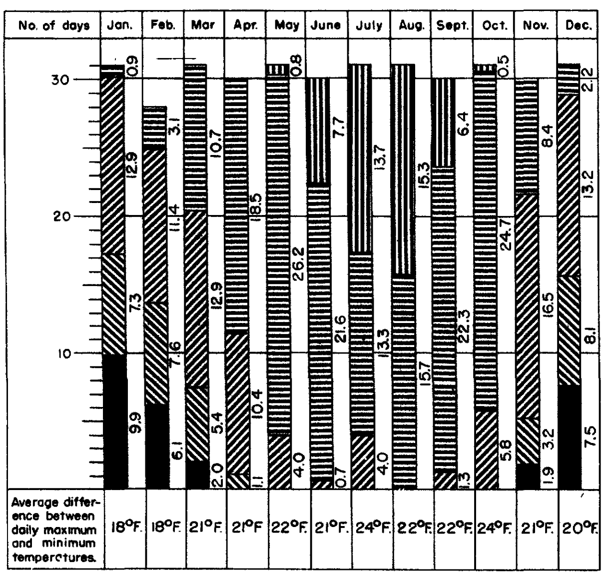


Figure I.—Index map of Kansas showing areas covered by this report and by other construction materials investigations



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)*

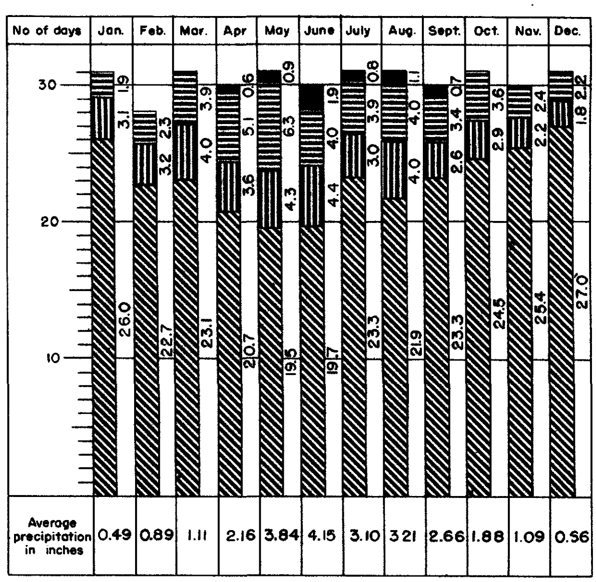
Days in which maximum temperature was between 41°-60° F. *(no interference with concrete construction; no bituminous surfacings laid)*

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 Concordia, 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 Beloit, Kansas

fairly cold. The mean annual temperature is about 54 ° F. and ranges from a low of about 28° F. in January to a high of about 80° F. in July. (These figures were interpolated from data from nearby stations inasmuch as the weather station at Beloit does not maintain records on temperature.) On the average, there are 75 cloudy days a year, 110 partly cloudy days, and 180 clear days. The ground is covered with snow on the average of 28 days of the year. The average annual precipitation is 24.17 inches. 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. 2/

Figure 2, a chart showing temperature ranges at Concordia, Kans. (about 30 miles northeast of Beloit), was compiled from Climatological Data 3/ 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 to 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 9.9 days in January. August is the warmest month in the year and on the average of 15.3 days maximum temperatures exceeds 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, 24° F., is in July; and the least difference, 18° F., is in January and February.

Inasmuch as precipitation also conditions the number of working days in engineering construction, figure 3, a chart showing precipitation ranges at Beloit, Kans., is presented to show the effect of this climatic factor. The ranges in precipitation were selected arbitrarily.

As based on a 10-year average 4/ there were 19.7 days in June, for example, in which no measurable precipitation fell; 4.4 days in which the precipitation ranged from a trace to 0.1 inch; 4 days in which 0.11 to 1 inch of rain fell; and 1.9 days in which the precipitation was more than an inch. Continuing rains fall, for the most part, in the late spring and early fall and other rainfall is generally in the form of showers of short duration.

Transportation Routes

Mitchell County is served by two railways, the Missouri Pacific which extends westward across the northern part of the county, and a branch line of the Union Pacific that starts in Beloit and extends southeastward. It is traversed by U. S. Highway No. 24 and Kansas highway 14. A second Kansas Highway (No. 128) extends north from a point a short distance northwest of Glen Elder. East of Beloit, U. S. Highway No. 24 is constructed of concrete; west of Beloit it is of the black-top type of construction, as is Kansas Highway 14. Kansas Highway 9, entering the county from the east, is a metaled all-weather road as far as its junction with U. S. 24 a mile north of Beloit. That part of Kansas Highway 128 which is included in this county is a metaled all-weather road.

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

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

Investigation Procedure

This report is based on field work of the reconnaissance type. The base map was provided by the State Highway Commission of Kansas (scale: 1 mile to 1 inch). Drainage lines were taken from aerial photographs (scale: 1 mile to 4 inches) made available by the Mitchell County office of the Soil Conservation Service of the United States Department of Agriculture. The areal distribution of the stratigraphic units that crop out in Mitchell County was then mapped in the field. The mapped stratigraphic units are those recognized by the United States Geological Survey 5/ and the Kansas Geological Survey. 6/ The principal emphasis of this report is on construction materials. Geologic problems not critically related to construction materials, therefore, are considered to be of secondary importance.

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

Acknowledgments

Appreciation is expressed to the following for contributing information found useful in the compilation of the geologic map and construction-materials 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 Mitchell County office of the Soil Conservation Service, United States Department of Agriculture; and the county engineer and residents of Mitchell County.

This report, in manuscript form, was reviewed by various members of the State High-

[2] Flora, S. D., The climate of Kansas: Kansas State Board Agr. Rept., vol. 67, no. 285, 320 pp., 1948.

[3] U. S. Dept. Commerce, Weather Bur.: Climatological Data, Kansas section, 1937-46.

[4] Op. cit., Weather Bur., 1937-46.

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

[6] Moore, R. C., Frye, J. C., and Jewett, J. M., Tabular description of outcropping rocks in Kansas: Kansas Geol. Survey Bull. 52, pt. 4, 212 pp., 1944.

way Commission of Kansas and the United States Geological Survey.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

General

This discussion of the stratigraphic units cropping out in Mitchell County emphasizes the areal distribution, general characteristics, thickness, and the construction materials in each geologic formation or member. 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 geologic formation or member is presented in figure 4. The areal distribution of the local stratigraphic units is shown on plate 1, a map showing construction materials and geology of Mitchell County, Kans. Each unit is indicated by an identifying symbol, and its outcrop areas are shown by a distinctive pattern. Plate 1 is printed in four parts for more convenient use in the field; there is an area of overlap 2 miles wide along the contacts between the parts.

The locations of pits and quarries also are shown on plate 1. The Symbols indicate whether the pit or quarry is or has been operated or is a prospect, the type of construction material available at each site, and the quantity of the material (in units of 10,000 cubic yards) that can be removed under no more than moderate overburden (unconsolidated sediments less than 6 feet thick). Most of these sources are listed in table 1. Materials represented on the map by inclined letters have not been tested and are not listed in table 1. All materials sources listed in table 1 are numbered within each materials classification according to the following plan: The numbering starts in the northeastern-most township and continues along the same tier to the west boundary of the county; it is continued in the next tier south starting again with the township in the eastern-most range and proceeding to the west boundary of the county, and so on. Within a township the sources are numbered in the same sequence as are the sections of the township.

Dakota Sandstone

Areal Distribution

The Dakota sandstone of Cretaceous age is the oldest stratigraphic unit that outcrops in Mitchell County. (See pl. 1 and fig. 4.) It underlies the entire county but is concealed by younger, overlying formations except along the Solomon River in the eastern part of the county and Salt Creek in the southeastern part. Its most extensive area of outcrop is that along the north wall of the valley of the Solomon River in secs. 22, 23, 26, and 27, T. 7 S., R. 6 W. Several small isolated outcrops occur just east of this large one. The formation is well exposed at the base of the south wall of the valley of the Solomon River in T. 8 S., R. 6 W., although its outcrop is masked in many places by the younger Sanborn formation. (See fig. 4.) The Dakota sandstone makes a bold outcrop at the base of the south wall of the valley of Salt Creek in T. 9 S., R. 7 W. Only isolated outcrops of it are mapped on the north side of Salt Creek, as in the eastern part of T. 9 S., R. 7 W. and the southwestern part of T. 9 S., R. 6 W. The westernmost exposure of the formation is in the valley of a small stream in the SW¼SE¼ sec. 35, T. 9 S., R. 8 W. Outcrops of this and other formations of Cretaceous age are shown in more extensive areas on a geologic map constructed by Landes 7/ which shows, for the most part, only the bedrock in the area and does not depict the unconsolidated geologic formations that mask it in many places.

General Description

The Dakota sandstone, unlike other formations of Cretaceous age cropping out in this county, was deposited under nonmarine conditions. As exposed in Mitchell County, this formation consists of about 14 feet of sandstone underlain by about 7 feet of shale. (For a typical exposure, see the representative measured section.) The sandstone occurs in massive beds which show cross-bedding indicative of its nonmarine origin, and is fine-grained and soft. Most of the beds are gray orange or red brown and weather gray brown or tan gray. Lenses and concretionary masses of brown iron oxide (iron-stones) are numerous in it.

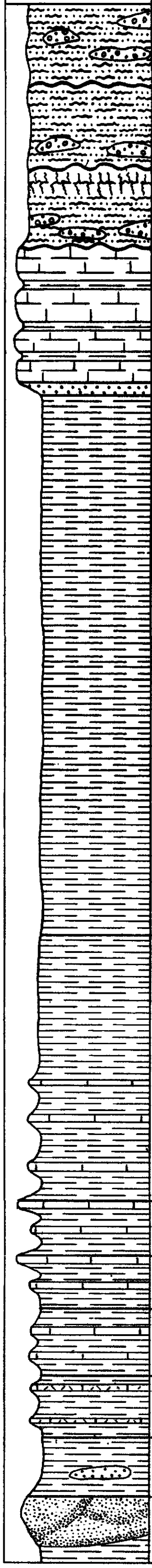
The beds of shale which are exposed beneath the sandstone in some outcrops are usually silty and noncalcareous, although thin clay zones do occur. The shale is varicolored - that is, it exhibits interbedded zones of gray, tan, red brown, gray orange, and blue black. When weathered, these zones develop lighter shades of the same colors. Some layers of shale are thin-bedded, others are blocky, and still others are platy. Iron-oxide stains occur on many of the fracture planes.

Plant fossils are abundant in the Dakota sandstone in outcrops in other parts of Kansas but were not found in the exposures of the formation in this county. In some places the plant remains are so concentrated that they form lenses of low-grade coal (lignite), a fact which confirms the nonmarine origin of this unit.

The beds of sandstone in the Dakota form a conspicuous rounded bench which, in this county, is usually near the base of a valley wall. The average surface slope of an outcrop of this formation is more than 12 percent. 8/ The more firmly the sandstone is cemented by pore-space deposits of calcium carbonate or iron oxide, the more conspicuous the bench it forms. All of the beds examined in Mitchell

[7] Landes, K. K., The geology of Mitchell and Osborne Counties, Kans.: Kansas Geol. Survey Bull. 16, pl. 2, 1930.

[8] Slope data for the outcropping stratigraphic units are interpretations of a reconnaissance soil-conservation survey map published by the Soil Conservation Service, U. S. Department of Agriculture, in cooperation with the Kansas State Agriculture Experiment Station.



Exposed thickness (in feet)	System	Series	Formations and members		Generalized description	Construction materials
30	Quaternary	Pleistocene and 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 Fill material
30			Terrace deposits		Tan and light brown silt; clayey near surface, lenses of gravel in lower part; stream deposited; underlies flat terraces in valleys of larger streams.	Mineral filler Fill material
30			Sanborn formation		Gray or brown silt; clayey near surface, lenses of limestone gravel and granitic gravelly sand in lower part; stands in vertical banks; develops rolling topography.	Aggregate Mineral filler Road metal Fill material
50	Cretaceous	Upper Cretaceous	Niobrara fm.	Fort Hays limestone member	Thick beds of massive, cream-colored chalky limestone separated by thin partings of platy, gray-orange chalky shale; shattered zone below surface; marine; fossiliferous; forms conspicuous escarpment.	Road metal Structural stone Calcareous binder Fill material
2			Carlile shale	Codell sandstone member	Fine-grained, yellow-brown sandstone and siltstone; marine.	Road metal Fill material
200				Blue Hill shale member	Dark blue-gray, very thin-bedded, noncalcareous clay shale; silty zones near top; interbedded zones of septarian concretions and selenite crystals; marine; few fossils; erodes to form badland-type topography.	
100				Fairport chalky shale member	As usually exposed, is similar to underlying Pfeifer shale; marine; fossiliferous; weak outcrop expression.	
18			Greenhorn limestone	Pfeifer shale member	"Fencepost" bed at top; alternating layers of dark gray to orange-gray chalky shales and thin layers of tan-gray chalky limestones; marine; fossiliferous; forms hillside bench.	Road metal Structural stone Riprap Calcareous binder Fill material
18				Jetmore chalk member	"Shell-rock" bed at top; alternating layers of blue-gray and tan-gray chalky shales and limestones; marine; fossiliferous; hillside bench.	
27				Hartland sh. member	Alternating thick beds of calcareous, gray and gray-orange silty shales, thin beds of tan-gray chalky limestones, and thin seams of bentonite; marine; fossiliferous; weak outcrop.	Road metal
22				Lincoln ls. member	Alternating thick layers of thin-bedded, gray to brown shale, thin beds of hard crystalline limestone and thin beds of bentonite; marine; fossiliferous; weak outcrop.	
21			Graneros shale		Interbedded thick layers of noncalcareous, thin-bedded, blue-gray clay shale, thin seams of bentonite, and lenses of red-brown sandstone; marine; nonfossiliferous; weak outcrop.	None
25			Dakota sandstone		Massive, cross-bedded, soft, orange to brown sandstone underlain by noncalcareous, vari-colored silt shale; non-marine; forms conspicuous bench.	Road metal Fill material

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

County are soft and easily pulverized (friable), but, in other parts of the State, local beds in the formation are so firmly cemented by pore-space deposits of silica that they are quartzitic.

Representative Measured Section

This outcrop of the Dakota sandstone was measured in a cut along U. S. Highway 24 in the NE¼NW¼ sec. 27, T. 7 S., R. 6 W.:

	Feet
Soil: Silt, sandy; reddish-brown	1.0±
Dakota sandstone	
Sandstone, massive, soft; red-brown; weathers gray brown	.9
Sandstone, powdery, very fine-grained; gray-orange; weathers light gray orange; intersected by thin veins of calcium carbonate and brown iron oxide	1.2
Sandstone, massive, soft, cross-bedded; red-brown; weathers gray brown; thin parting of silt about a foot below top; ironstone concretionary zone near middle; weathered surface pitted	2.8
Sandstone, soft, cross-bedded; gray-orange becoming tan in basal part; weathers tan gray; numerous interbedded thin partings of silt	1.1
Siltstone, very soft except for interbedded lenses of harder material, cross-bedded; gray, red-brown, gray-orange, and tan; weathers tan; small ironstone concretions scattered throughout	8.2
Shale, silty, noncalcareous; thin-bedded; mottled dark-gray, tan, and gray-orange; weathers tan	0.2
Ironstone lens, very hard; red-brown	0.2
Shale, silty, noncalcareous; thin-bedded; mottled tan and gray-orange; weathers tan	0.3
Shale, silty, noncalcareous; cross-bedded; dark-gray; weathers gray; interbedded thin lenses of yellow silty shale	1.1
Shale, clayey, noncalcareous; platy; blue-black; weathers light blue black; soft, red-brown ironstone concretions scattered throughout	.8
Shale, clayey but contains some silt-size particles, noncalcareous; blue-black; weathers light blue black; ironstone concretions scattered throughout	1.0
Shale, silty, noncalcareous; platy; blue-black; weathers light blue black; iron stains on fracture planes	2.0
Total thickness exposed (base covered)	20.9

Thickness

The greatest thickness of the Dakota sandstone exposed at the surface in this county is about 25 feet, and most of the outcrops are from 10 to 15 feet thick. Only the uppermost part of the formation is exposed locally and its total thickness is probably in excess of 200 feet.

Construction materials.--Materials from the Dakota sandstone in Mitchell County are used as road metal and fill material.

Graneros Shale

Areal Distribution

The Graneros shale and the overlying formations of Cretaceous age (see fig. 4) cropping out in Mitchell County are of marine origin. The Graneros shale crops out only in the east-central and south-central parts of the county. (See pl. 1.) Individual outcrops are generally concealed beneath the younger Sanborn formation and are thus of limited areal extent. The most extensive exposure is that along the south wall of the valley of Salt Creek in the southern part of T. 9 S., R. 7 W. and the eastern part of the next township west. The formation is here exposed immediately above an extensive outcrop of the Dakota sandstone. Very small isolated outcrops occur in some of the valleys of streams tributary to Salt Creek and, in the eastern part of the county, in valleys of streams tributary to the Solomon River.

General Description

The Graneros is predominantly a noncalcareous clay shale but includes some thin silty zones and other slightly calcareous zones. The shale is soft and thin-bedded. The beds are usually gray or blue gray and weather light gray or tan. Some of the fractures in the shale are filled with thin veins of calcium carbonate (calcite). Numerous small crystals and occasional veins of a variety of gypsum (selenite) are scattered throughout the shale. Many of the fracture planes are stained with brown iron oxide. This shale is generally nonfossiliferous.

Included in the formation are interbedded layers and thin seams of white to cream-colored bentonite. The weathered surface of the bentonite is orange-colored or reddish brown. Although most of the bentonitic layers are no more than 0.2 foot thick, a bed a foot thick is remarkably persistent in the uppermost part of the formation. Bentonite is altered volcanic ash, and its volume is greatly increased when it becomes saturated with water.

The Graneros shale also includes interbedded thin layers and lenses of sandstone. The sandstone is thinbedded and is usually slightly calcareous. Its color is red brown because of the presence of iron oxide which, together with calcium carbonate, was deposited in the pore-spaces between the sand grains and serves as the cementing substance.

This formation, because of its softness, makes only a very weak outcrop. It is largely masked by the slopewash and gravity-moved sediments (colluvium) mapped on plate 1 as part of the Sanborn formation. The surface slope developed in an outcrop of the Graneros shale is usually more than 12 percent.

Representative Measured Section

The entire thickness of the Graneros shale is exposed in a road cut in the $SE\frac{1}{4}SE\frac{1}{4}$ sec. 24, T. 8 S., R. 6 W. as follows:

	Feet
Overlain by the Lincoln limestone member of the Greenhorn limestone	
Graneros shale:	
Shale, clayey, somewhat calcareous; brown and gray; weathers light gray; numerous crystals of selenite	0.9
Bentonite; cream-colored; weathers orange and red	1.0
Shale, clayey, noncalcareous; soft; very thin-bedded; dark blue-gray; weathers light gray; numerous small crystals of selenite throughout and fractures filled with thin veins of the same material; thin lenses of iron-stained sandstone in upper part; interbedded thin seams of bentonite throughout	10.1
Sandstone, slightly calcareous; thin-bedded; red-brown; weathers brown, occasional thin veins of calcite	0.5
Shale, clayey, noncalcareous; soft; thin-bedded; blue-gray; weathers light blue gray; small crystals of selenite scattered throughout; fractures filled with thin veins of brown iron oxide; several thin lenses of iron-stained sandstone in upper part	6.1
Shale, silty, noncalcareous; soft; thin-bedded; red-brown; weathers tan	0.6
Shale, clayey but with some silt-size particles, noncalcareous; soft; thin-bedded; gray; weathers light gray	2.25
Total thickness (underlain by the Dakota sandstone)	21.45

Thickness

The outcrop of the Graneros shale cited as the representative measured section is the thickest exposure of this formation found in Mitchell County. In most outcrops, a thickness of 10 feet or less of the formation is exposed at the surface.

Construction Materials

So far as is known, materials of the Graneros shale have not been used in engineering construction.

Greenhorn Limestone

Areal Distribution

The second Cretaceous formation of marine origin, the Greenhorn limestone, crops out extensively in the eastern part of Mitchell County but, for the most part, is buried beneath younger formations farther west. (See pl. 1. and fig. 4.) This formation forms the greater part of the walls of the valleys of the Solomon River and its tributaries in the vicinity of Beloit. It is conspicuously displayed, also, throughout much of the watershed of Salt Creek. The Greenhorn limestone caps most of the interstream areas in eastern Mitchell County but is concealed beneath the Sanborn formation except along the edges of the deeper valleys. Although thin and usually discontinuous outcrops are mapped on plate 1 along the Solomon River as far west as Cawker City, the Greenhorn limestone is concealed beneath a younger Cretaceous formation, the Carlile shale, in the western part of the county.

General Description

The Greenhorn limestone is shown on plate 1 as a single map unit (Kg) but the description of this formation will be based upon the members of which it is composed. These are, in upward order: the Lincoln limestone member, Hartlant shale member, Jetmore chalk member, and Pfeifer shale member.

1. Lincoln limestone member of the Greenhorn limestone.--The Lincoln member is composed of alternating thick beds of shale, thin layers of limestone, and thin seams of bentonite. The greater part of its thickness, therefore, is shale. The shale is silty for the most part and heavily impregnated with calcium carbonate. It is soft and thin to very thin-bedded, although a few thin layers of platy shale appear in the upper part of the member. The unweathered shale shows zones of tan gray, gray orange, gray brown, brown, and dark gray; the weathered rock is light gray or tan gray. Thin fracture fillings of calcite and selenite occur in some of the beds. Iron-oxide stains are common along fracture planes and concretions of the same material are present in limited numbers.

Whereas most of the limestones of the Greenhorn limestone are soft and chalky, those in the Lincoln member are hard and crystalline. The beds of limestone range from 0.1 to 0.6 foot in thickness with one 0.6-foot-thick bed near the base and one 0.6-foot-thick bed near the top of the member. The beds are generally massive but some near the top have platy structure. The rock is usually some shade of brown and weathers tan gray. A strong odor of oil can be detected in freshly broken blocks.

The seams of bentonite interbedded with the shales and limestones range from 0.05 to 0.3 foot in thickness. This material shows a blocky structure and is white or light gray when fresh but weathers gray orange or red brown.

Unlike the underlying Graneros shale, the Lincoln limestone member of the Greenhorn limestone is generally fossiliferous. Clams, fish scales, and shark teeth are most abundant, and coiled shellfish (cephalopods) are present in limited numbers. Although most of the beds of limestone contain fossils, only the shales in the upper part of the member are fossiliferous.

Landes [9] states that the Lincoln limestone is at least 22 to 24 feet thick; this is confirmed by a complete section of the member (see representative measured section) which shows a total thickness of 22 feet. Outcrops of the Lincoln limestone member are few. The bed of limestone 0.6-foot thick near the top of the member forms an identifiable bench on some hillsides.

2. Hartland shale member of the Greenhorn limestone. --The Hartland shale member, as the Lincoln limestone member below it, is composed of thick beds of shale, thin layers of limestone, and thin seams of bentonite. However, the shales of the Hartland are more chalky than those of the Lincoln. Limestones of the Hartland are generally chalky rather than crystalline. The beds of shale in this member are composed predominantly of chalky silt but some thin zones of clay are also present. The shale is generally soft and is platy to thin-bedded. Alternating zones of light gray, gray orange, and, less commonly, red brown are conspicuous on unweathered surfaces; weathered exposures are usually tan gray but may show zones of light gray and gray orange. Very thin partings of calcium carbonate occur in some parts of the member, and iron-stained zones are found at various levels.

The beds of limestone in the Hartland shale member range from 0.1 foot to 2.2 feet in thickness. Although most of the limestone is soft and chalky, some of it is hard and crystalline and has much the same appearance as the limestone of the Lincoln member. The beds are generally thin-bedded to blocky but are somewhat massive in the upper part. The limestones are generally gray or tan gray, occasionally red brown, and almost all of them weather tan gray. The beds of limestone characteristically are broken by very thin partings of chalky shale. Iron-stained zones occur in some of the thicker limestones.

The interbedded seams of bentonite range from 0.05 to 0.65 foot in thickness. This material, white or light-gray where unweathered, is present as orange or red-brown streaks on weathered outcrops. It is generally blocky but some seams are finely granular.

Clam shells, fish scales, and shark teeth are numerous or abundant in some zones of this member. The Hartland shale member develops a poor outcrop expression. Most of its exposures are low on the walls of the deeper valleys in the eastern part of the county.

The maximum thickness exposed in Mitchell County is 27 feet but a typical outcrop shows only 10 or 12 feet of the total thickness.

3. Jetmore chalk member of the Greenhorn limestone. --The Jetmore chalk member is composed of alternating beds of shale and limestone; most of the limestones range from 0.2 to 0.4 foot in thickness and the shales from 0.8 to 1 foot in thickness. The proportionate thickness of the limestones, therefore, is greater in the Jetmore than it is in the underlying Hartland shale and Lincoln limestone members.

The beds of shale are silty and highly calcareous. They tend to be thin-bedded in the lower part of the member and platy in the upper part. The lower beds are generally blue gray and weather light blue gray; whereas the upper beds are generally gray orange and weather tan gray. Thin seams of calcite are scattered throughout the shale zones, and iron-oxide stains are common.

The top of the Jetmore chalk member is defined as the top of the "shell-rock" bed. The name "shell-rock" refers to the great abundance of clam shells that the bed contains. This is a massive bed of limestone and is usually slightly more than a foot thick. The beds of limestone lower in the member are less thick and chalky. They are tan gray in the upper part and blue gray in the lower part. Iron-oxide stains and ferruginous concretions are typical of the limestones.

Fossils, especially clams, are numerous to abundant in the beds of limestone but are less numerous in the beds of shale. The coiled shells of cephalopods are occasional fossils in the Jetmore chalk member.

The greatest thickness of the Jetmore chalk member measured in Mitchell County is 18 feet and many of its exposures are from 12 to 15 feet thick. Outcrops of the Jetmore are easily identified by the close-spaced beds of chalk it contains and by the shell-rock bed which makes a prominent shoulder on many of the valley walls. One or more of the lower limestones may form a less well developed bench below the shell-rock shoulder. The Jetmore outcrops at many places in the general area of outcrop of the Greenhorn limestone.

4. Pfeifer shale member of the Greenhorn limestone. --The Pfeifer shale member is composed of alternating beds of chalky shale, which average 0.5 foot in thickness; chalky limestones, which average 0.2 foot in thickness; and occasional thin seams of bentonite about 0.1 foot in thickness. The beds of shale are platy and tan gray or orange gray in the upper part of the member, and are thin-bedded and dark gray in the lower part. Most of the upper beds weather gray orange and the lower ones weather light gray.

The top of the member is defined as the top of the "Fencepost" bed. This is a massive layer of tan-gray limestone characterized by a red-brown band of iron oxide extending through the middle part of the limestone. The bed is 0.6 foot thick. Its name indicates the use that was made of this lime-

[9] Op. cit., p. 29.

stone in earlier years; at the present time it is used as building stone.

The other beds of limestone in the Pfeifer shale member are chalky soft massive and light gray or tan gray. Many of them are marked by thin red-brown streaks of iron oxide.

Several thin seams of bentonite are interbedded with the shales of this member. Despite their thinness, each one of them can be traced over a wide area. The weathered bentonite is white, but, as exposed in the face of an outcrop, it is a streak of gray orange or red brown.

Another persistent bed included in this member is the one known as the "sugar sand." It is 0.2 foot thick and occurs about 5 feet below the base of the "Fencepost" bed. It is composed of small grains of calcite and is gray orange.

Fossilized clam shells are abundant in the beds of limestone but are not so numerous in the beds of shale.

The total thickness of the Pfeifer shale member in Mitchell County is 18 feet. Most of that thickness is exposed in many of the outcrops of the member. This shale has a strong outcrop expression and is readily identified by the "Fencepost" bed, which forms a conspicuous angular shoulder at the top of the walls of many valleys; the shoulder is marked by crescent-shaped quarries which were opened wherever the over-burden was thin.

<u>Representative Measured Sections</u>

1. The section of the lower part of the Pfeifer shale member exhibits the full thicknesses of the Hartland shale and Lincoln limestone members. It was measured in a road cut in the SE¼SE¼ sec. 24, T. 8 S., R. 6 W., as follows:

	Feet
Soil:	1±
Greenhorn limestone:	
Jetmore chalk member (0.4 foot present)	
Limestone, chalky; red-brown to tan-gray; weathers light red brown; concretions of iron oxide in middle part; thin seams of calcite. Clam shells, fish scales, shark teeth, and occasional shellfish	.4
Hartland shale member (27.18 feet thick)	
Bentonite; tan-gray	.2
Shale, silty, calcareous; thin-bedded; tan-gray; weathers light gray; iron-oxide stains on fracture surfaces. Clams, fish scales, and shark teeth	2.4
Shale, silty, calcareous; thin-bedded; red-brown; weathers tan gray; iron-oxide stains on bedding planes. Fish scales and some clam-shell fragments	2.65
Limestone, chalky; soft; tan-gray; weathers light gray	1.5
Shale, silty, calcareous; thin-bedded; mottled tan-gray and gray-orange; weathers tan gray	.85
Bentonite, red-brown and gray-orange	.65
Limestone, chalky; soft; light-gray; weathers tan gray; iron stains on fracture surfaces	.3
Shale, silty, calcareous; thin-bedded; mottled gray-orange and red-brown; weathers light gray; iron stains on bedding planes. Clam-shell fragments, fish scales, and shark teeth	2.1
Limestone, chalky; tan-gray; weathers light tan gray; occasional thin calcite seams and iron stains. Clam-shell fragments, fish scales, and shark teeth	0.3
Shale, silty, calcareous; thin-bedded; red-brown; weathers gray orange; iron-stained. Clam-shell fragments and fish scales	.45
Shale, clayey, calcareous; blocky; gray-orange; weathers gray	.35
Shale, very silty, calcareous; massive; mottled tan and red-brown; weathers light gray; iron stains on fracture surfaces. Clam-shell fragments and fish scales	1.3
Bentonite; orange	.2
Limestone; thin-bedded with shale partings; gray-orange; weathers gray. Clams and fish scales	2.2
Limestone, thin-bedded; light-gray; weathers tan gray; occasional small concretions of iron oxide	0.2
Shale, silty, calcareous; platy; mottled light-gray and red-brown; weathers tan gray; occasional seams of calcite. Clam shells, fish scales, and shark teeth	1.4
Bentonite; orange	.03
Shale, silty, calcareous; platy; mottled light-gray and reddish-brown; weathers tan gray; occasional thin seams of calcite. Clam shells, fish scales and teeth	.8
Bentonite; orange	.1
Shale, silty, calcareous; platy; mottled light-gray and red-brown; weathers tan gray; occasional seams of calcite. Clam shells, fish scales and teeth	3.3
Bentonite; orange	0.2
Shale, silty, calcareous; platy; mottled gray-orange and gray; weathers tan gray. Clam shells, fish scales and teeth	.3

	Feet
Bentonite; mottled gray-orange and brown.	.2
Shale, silty, calcareous; platy; brown; weathers tan gray. Clam shells, fish scales and teeth . .	1.0
Bentonite; orange; thin lenses of iron oxide	.15
Shale, silty, calcareous; brown; weathers tan gray. Clam shells, fish scales and teeth	.6
Limestone; thin-bedded; crystalline; beds separated by very thin shale partings; gray; weathers tan gray. Clam shells, fish scales and teeth	.5
Shale, silty, calcareous; platy; mottled gray-orange and light-gray; weathers tan gray; occasional very thin beds of gray crystalline limestone. Clam shells, fish scales and teeth. . .	1.3
Bentonite; orange	.05
Limestone, chalky; blocky; gray-orange; weathers gray. Clam shells, fish scales and teeth . .	.1
Bentonite; orange	.1
Shale, silty, calcareous; platy; occasional very thin partings of limestone; brown to reddish-brown; weathers tan gray. Clam shells, fish scales and teeth . .	1.4
Lincoln limestone member (22.03 feet thick) Limestone, crystalline; thin-bedded; thin partings of silty shale; red-brown; weathers tan gray. Clam shells, fish scales and teeth	1.0
Limestone, crystalline; tan-gray; weathers gray. Clam shells, fish scales and teeth	.3
Shale, silty, calcareous; platy; brown; weathers gray. Clam shells and fish scales	.2
Bentonite; orange	0.05
Limestone, chalky; thin-bedded; light-gray; weathers tan gray. Fish scales	.15
Shale, silty, calcareous; platy; brown to black; weathers gray; occasional thin limestone seams	.3
Shale, silty, calcareous; platy; brown to dark-brown; weathers tan gray; occasional thin seams of calcite	.2
Bentonite; gray-orange	.2
Limestone, chalky; platy; very soft; dark-gray and red-brown; weathers tan gray; occasional irregular carbonaceous seams. Clam shells, fish scales, and shark teeth	.4
Shale, silty, calcareous; thin-bedded; dark-gray and gray-brown; weathers gray. Fish scales and shark teeth	.3
Bentonite; red-brown	0.3
Limestone, chalky; gray-brown; weathers tan gray. Fish scales abundant	.05
Shale, silty, calcareous; thin-bedded; gray-brown; weathers light gray. Fish scales.	.08
Limestone, crystalline; platy; hard; red-brown; weathers tan gray. Fish scales and shark teeth	.1
Shale, silty, calcareous; thin-bedded; reddish-brown; weathers tan gray; iron-oxide concretions in middle part . . .	.4
Shale, clayey, calcareous; very thin-bedded; gray-brown to black; weathers tan gray; irregular thin lenses of hard, crystalline gray-brown lime-stone. Fish scales.	4.0
Bentonite; mottled cream and red-brown	.3
Shale, clayey, calcareous; thin-bedded; dark-gray; weathers light gray; iron-oxide streaks throughout; small crystals of selenite along bedding planes . .	4.9
Shale, very silty, calcareous; thin-bedded; red-brown; weathers tan gray; thin seams of bentonite; crystals of selenite along fractures	5.1
Shale, silty, calcareous; thin-bedded; tan-gray; thin cal-careous partings	1.4
Limestone, crystalline; gray-orange; weathers light gray. Clam shells.	.6
Shale, silty, calcareous; thin-bedded; gray-orange; weathers light gray; thin calcareous layers	.8
Limestone, crystalline; dark-gray; weathers light gray. Abundant shark teeth.	.2
Shale, silty, calcareous; thin-bedded; gray-brown; weathers gray; interbedded very thin layers of crystalline lime-stone	0.7

Underlain by the Graneros shale. — 2 Complete sections of the upper two members of the Greenhorn limestone, the Pfeifer shale member and Jetmore chalk member, were measured in a road cut in the NW¼NE¼sec. 10, T. 7 S., R. 8 W.:

	Feet
Greenhorn limestone:	
Pfeifer shale member (18.18 feet thick)	
"Fencepost" limestone bed; massive; light-gray with red-brown streak through middle; weathers tan gray. Occasional clam shells and rare shells of cephalopods	0.6
Shale, silty, calcareous; platy; tan; weathers dark gray. Clam shells	.3

	Feet
Shale, silty, calcareous; platy; mottled light-gray and gray-orange; weathers gray. A few clam shells	0.2
Shale, silty, calcareous; platy; gray-orange; weathers light gray orange. A few clam shells	.2
Bentonite; mottled-gray and gray-orange	.1
Shale, silty, calcareous; platy; mottled gray-orange and light-gray; weathers light gray. Occasional clam shells . .	.6
Limestone, soft; light-gray streaked with gray-orange; weathers gray; lenticular. Occasional clam shells	.2
Shale, silty, calcareous; platy; mottled gray-orange and light-gray; weathers light gray orange. Occasional clam shells	1.4
Limestone, hard; tan-gray; weathers tan. A few clam shells	0.2
Shale, silty, calcareous; platy; gray-orange with streaks of light-gray; weathers light gray orange.	.9
Bentonite; gray-flecked with gray-orange	.01
Shale, silty, calcareous; somewhat blocky; light-gray with streaks of gray-orange; weathers light gray orange. Fish scales	.6
Granular calcite; "sugar sand" bed; mottled-cream and yellow	.25
Shale, silty, calcareous; platy; light-gray; weathers light orange. Fish scales and a few clam shells	.2
Limestone, hard; red-brown with light-gray band at top and base. Clam shells	.3
Shale, silty, calcareous; platy; gray-orange; weathers gray. A few clam shells	0.1
Bentonite; mottled-white and red-brown	.1
Shale, silty, calcareous; platy; gray-orange; weathers light gray orange. Fish scales and a few clam shells	.6
Limestone, hard; gray-orange; weathers light gray; lenticular. Some clam shells	.3
Shale, silty, calcareous; platy; gray-orange; weathers light gray orange. Clam shells . . .	1.4
Limestone, hard; light-gray; weathers tan gray; thin calcite streaks throughout. Clam shells	.3
Shale, silty, calcareous; platy; gray-orange. Clam shells.	.5

	Feet
Limestone, hard; light-gray; weathers tan gray; lenticular; thin seams of calcite throughout. Clam shells	0.3
Shale, silty, calcareous; platy; gray-orange; weathers light gray orange; thin seams of calcite throughout. Clam shells	.5
Limestone, hard; light-gray; thin seams of calcite scattered throughout. Clam shells	.2
Shale, silty, calcareous; platy; gray-orange; abundant seams of calcite. A few clam shells . . .	.5
Limestone, hard; gray; weathers light gray; calcite seams; lenticular. Clam shells	.2
Shale, silty, calcareous; platy; gray-orange; abundant seams of calcite. Clam shells	.6
Limestone, hard; light-gray. Clam shells	.02
Bentonite; mottled-gray and orange	0.02
Shale, silty, calcareous; platy; dark-gray; weathers gray. A few clam shells	.2
Limestone; lenticular; light-gray. Abundant clam shells	.2
Shale, silty, calcareous; platy; dark-gray with streaks of gray-orange; weathers dark gray; seams of calcite. Abundant clam shells	.4
Limestone; lenticular; gray; weathers light gray; seams of calcite. Abundant clam shells	.2
Shale, silty, calcareous; platy; dark-gray mottled with gray-orange; weathers gray. A few clam shells	.3
Limestone; irregular; light-gray. Abundant clam shells	.1
Shale, silty, calcareous; soft; thin-bedded; dark-gray mottled with gray-orange becoming blue black near base; weathers dark gray. A few clam shells	0.3
Limestone; irregular; tan; weathers light gray. A few clam shells	.1
Shale, silty, calcareous; soft; thin-bedded; blue-black; weathers light blue black. A few clam shells	.2
Limestone; irregular; tan; weathers light gray. A few clam shells	.1
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	.7
Limestone, hard; tan-gray; weathers light gray; a few seams of calcite. Abundant clam shells	.2

	Feet
Shale, silty, calcareous; platy; gray-brown. A few clam shells	0.6
Limestone; irregular; gray-orange with irregular red-brown streaks in middle part; weathers light gray orange. A few clam shells	.1
Shale, silty, calcareous; platy; gray-brown. A few clam shells	.5
Limestone, hard; irregular; tan; weathers tan gray; some seams of calcite. Abundant clam shells	.1
Shale, silty, calcareous; platy; gray-brown. A few clam shells	.7
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	.4
Shale, silty, calcareous; platy; mottled tan-gray and gray-orange; weathers light gray orange; calcite seams. Clam shells, fish vertebrae	.9
Jetmore chalk member (18.20 feet thick)	
"Shell-rock" limestone bed; massive; hard; tan-gray. Great abundance of clam shells	1.1
Shale, silty, calcareous; platy; light-gray mottled with some gray-orange; weathers light gray orange. A few clam shells	1.2
Limestone, hard; irregular; light-gray; weathers tan. A few clam shells	.1
Shale, silty, calcareous; platy; light-gray mottled with gray-orange; weathers light gray orange. A few clam shells	.3
Limestone, hard; irregular; tan-gray; numerous seams of calcite. Clam shells	.2
Shale, silty, calcareous; platy; mottled light-gray and gray-orange; weathers light gray orange; numerous seams of calcite. Abundant clam shells	.9
Limestone, hard; gray; weathers tan gray; irregular thin seams of calcite. Abundant clam shells	0.3
Shale, silty, calcareous; platy; gray-orange with blue-black layer near top; weathers light gray orange; abundant irregular seams of calcite. Clam shells	.9
Limestone, hard; light-gray. Abundant clam shells	.3
Shale, silty, calcareous; platy; gray-orange with blue-black zone in middle part; weathers light gray orange; thin seams of calcite. Clam shells	.9
Limestone, hard; massive; gray; weathers light gray; ironstone concretions in middle part. Clam shells	.9
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	.8
Limestone, hard; gray; weathers light gray; ironstone concretions in middle part. Clam shells	0.2
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	.8
Limestone, hard; dark-gray; weathers gray; somewhat crystalline	.2
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	.8
Limestone, hard; dark-gray; weathers gray; irregular thin seams of calcite; iron-oxide stains on weathered surface. Clam shells	.3
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	1.9
Limestone, soft; light gray; iron-oxide concretions in middle part; hard crystals inside concretions; tendency to shatter and split. A few clam shells	0.4
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black; somewhat jointed. A few clam shells	.7
Limestone, hard; gray; weathers tan gray. A few clam shells	.3
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	.7
Limestone; irregular; blue-gray; weathers light blue gray. A few clam shells	.2
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black; somewhat jointed. A few clam shells	1.0
Limestone, hard, light-gray; iron-oxide concretions in middle part. A few clam shells	0.3
Shale, silty, calcareous; thin-bedded, blue-black; weathers light blue black. A few clam shells	1.0
Limestone, hard; mottled gray and gray-orange; weathers tan gray. A few clam shells	.2
Shale, silty, calcareous; thin-bedded; blue-black; weathers light blue black. A few clam shells	.9

	Feet
Limestone, hard; mottled-gray and gray-orange; weathers light gray; iron-oxide conretions and stains in middle part; tends to split near middle. A few clam shells	.4

Underlain by Hartland shale member.

Thickness

The total thickness of the Greenhorn limestone in Mitchell County is about 81 feet and is distributed among the four members as follows: Lincoln limestone member 22 feet; Hartland shale member 27 feet; Jetmore chalk member, 18 feet; and Pfeifer shale member 18 feet. The entire formation does not crop out at any one place in the county but a number of exposures of about half of the formation were noted. Surface slopes developed in outcrops of the Greenhorn limestone range from 2 to 12 percent or more, and are usually from 7 to 12 percent.

Construction Materials

Materials from the Greenhorn limestone in Mitchell County are used as: road metal, structural stone, riprap, calcareous binder, and fill material.

Carlile Shale

Areal Distribution

The Carlile shale, the third Cretaceous formation of marine origin, is exposed in only a few places in the eastern part of the county, but crops out widely in the western part. (See pl. 1 and fig. 4.) The easternmost exposures are those at the top of the valley walls of some of the streams tributary to the Solomon River near Beloit. The outcrops become more numerous and more extensive in the western part of the watershed of the Solomon River. The Carlile is well exposed in the watershed of Salt Creek in the south-central part of the county. However, its outcrops are most extensive and most numerous in the area of the Blue Hills southeast of Tipton. The Carlile shale underlies many of the interstream areas in the western two-thirds of the county but is concealed beneath the younger Sanborn formation and, in the Blue Hills area, beneath the Fort Hays limestone member of the Niobrara formation. The formation dips at a low angle toward the northwest, as do all of the formations of Cretaceous age.

General Description

The Carlile shale is shown on plate 1 as a single map unit (Kc) but the description of this formation will be based on the members of which it is composed. These are, in upward order, the Fairport chalky shale member, Blue Hills shale member, and Codell sandstone member.

1. Fairport chalky shale member of the Carlile shale. --The lower part of the Fairport chalky shale member is very similar to the Pfeifer shale member of the Greenhorn limestone from which it is arbitrarily separated by the "Fencepost" limestone bed. This basal member of the Carlile shale consists of interbedded shales, limestones, and occasional thin seams of bentonite. The shales are chalky and thin-bedded for the most part but are very thin-bedded in some zones and blocky in others. They are tan gray and weather cream. Many of the fracture and bedding planes are stained red brown by iron oxide. The beds of shale are usually slightly more than a foot thick.

The limestones in the Fairport member are chalky and soft. They occur in massive beds, some of which weather platy. Their color is cream in fresh exposures, and buff in weathered exposures. Many of the beds, as those in the Pfeifer shale member of the Greenhorn limestone, are marked by reddish-brown streaks of iron oxide. The limestones in the lower part of the member tend to be nodular and average 0.3 foot in thickness.

Only occasional thin seams of bentonite are included in the Fairport chalky shale member. They are usually from 0.05 to 0.02 foot thick, and appear as red-brown or gray-orange streaks in (the face of) a weathered outcrop.

Clam shells are numerous in both shale and limestone. A section of the Fairport chalky shale member measured by Landes 10/ in the eastern part of Osborne County indicates that it is about 100 feet thick. The only conspicuous outcrops of this member are those of its basal part which are frequently associated with outcrops of the underlying Pfeifer shale member. The upper part of the Fairport chalky shale member is largely masked by the younger Sanborn formation. Surface slopes developed in the basal part of this member are generally from 7 to 12 percent or more; those of the upper part generally range from 2 to 5 percent.

2. Blue Hill shale member of the Carlile shale. --The Blue Hill is a noncalcareous clay shale (although some silty zones are included in its upper part) and is black or dark blue gray. The silty zones contain numerous lime-cemented concretions some of which are as much as 8 feet in diameter. The clay shales, which predominate in the member, are very thin bedded; the silt shales, however, tend to be platy. Iron-oxide stains are found along many of the fracture surfaces.

Several zones of spheroidal concretions (septaria), averaging from 1 to 3 feet in diameter, are included in the clayey middle and lower parts of the Blue Hill shale member. They are formed by the intersection of radiating veins and concretric shells of calcium carbonate. Frequently they develop around the coiled shell of a cephalopod.

Numerous zones of selenite crystals are included in the Blue Hill member and, upon weathering and erosion of their shale matrix,

[10] Op. cit., pp. 21-23.

reflect sunlight in a manner that gives a hillside a sparkling appearance. The crystals average about 2 inches long but may be as much as 5 or 6 inches long.

The total thickness of the Blue Hill shale member is about 200 feet and the greater part of that thickness is exposed on the sides of the Blue Hills. This member has a bold outcrop expression and, in some of the more extensive outcrop areas, small streams have eroded the soft clay shale to produce a badland-type of topography. The surface slopes of outcrops are steepest (more than 12 percent) in the area of the Blue Hills and usually range from 7 to 12 percent elsewhere in the county.

3. Codell sandstone member of the Carlile shale. --The Codell sandstone member, although generally very thin, can almost always be identified at the contact of the Carlile shale and the overlying Fort Hays limestone member of the Niobrara formation. The thickness of the Codell varies (greatly) within short distances. Landes 11/ reports that it is 42 inches thick at the north end of the Blue Hills; in other places in the county, however, it is less than a foot and its average is probably about 2 feet. The Codell is a fine-grained sandstone or siltstone and contains a moderately high percentage of clay. It is usually yellow brown, but some exposures more heavily stained with iron oxide are red brown.

Representative Measured Sections

1. The outcrop of the basal part of the Fairport chalky shale member was measured in a road cut in the NW$\frac{1}{4}$SW$\frac{1}{4}$sec. 21, T. 7 S., R. 7 W. as follows:

	Feet
Sanborn formation: Gray-brown silt; abundant lime nodules in lower part	7$\pm$
Fairport chalky shale member of the Carlile shale:	
Limestone, chalky, soft; massive; weathers platy; tan-gray with light-brown streak near middle; weathers buff; case-hardened. Clam shells	.3
Bentonite; flaky; mottled orange tan and buff	0.3
Shale, clayey silt, highly calcareous; thin- to very thin-bedded; tan; weathers cream; iron-oxide stains along bedding and fracture planes. Fragments of clam shells	1.5
Limestone, semicrystalline; soft; massive; light tan-gray with light-brown streak through middle part; weathers buff; nodular. Clam shells	.2
Shale, silty, calcareous; thin-bedded to blocky in middle part; tan-gray; weathers cream; iron-oxide stains along fracture planes. Clam shells fairly abundant	1.4
Limestone, chalky, soft; massive; cream, weathers buff; nodular. Fragments of clam shells	.2
Shale, silty, calcareous; thin-bedded; tan-gray; weathers cream. Fragments of clam shells	0.6
Total thickness present (underlain by Pfeifer shale member of the Greenhorn limestone)	4.5

2. The following section is representative of the Codell sandstone and Blue Hill shale mem bers of the Carlile shale. It was measured in a cut bank along a tributary of Carr Creek in the NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 34, T. 8 S., R. 10 W.:

	Feet
Fort Hays limestone member of the Niobrara formation:	35$\pm$
Carlile shale:	
Codell sandstone member (0.5 foot thick)	
Sandstone, fine-grained; gray and reddish-brown; weathers reddish brown	.5
Blue Hill shale member (23$\pm$ feet exposed)	
Shale, clayey but some interbedded silty zones; noncalcareous; thin-bedded to very thin-bedded; dark blue-gray; weathers light blue gray; numerous calcareous concretions; veins of calcium carbonate in some fractures; fracture surfaces commonly iron-stained	23$\pm$
Base covered.	

Thickness

The total thickness of the Carlile shale is about 302 feet. The average thicknesses of its members are: Fairport chalky shale member, 100 feet; Blue Hill shale member, 200 feet; and Codell sandstone member, 2 feet. The thickest and most conspicuous outcrops are those of thr Blue Hill.

Construction Materials

Construction materials from the Carlile shale in Mitchell County are road metal and fill material.

Niobrara Formation

Areal Distribution

The uppermost formation of Cretaceous age exposed in Mitchell County, the Niobrara,

11 Op. cit., p. 19.

consists of two members, the Fort Hays limestone member (the lower member) and the Smoky Hill chalk member (the upper member). (See fig. 4.) However, only the Fort Hays crops out in this county, and only in the area of the Blue Hills where it forms the cap rock of the mesa- and butte-like hills. (See pl. 1.) It may underlie some of the higher interstream areas in the westernmost part of the county but, if so, is concealed beneath the younger Sanborn formation.

General Description

The Fort Hays limestone member of the Niobrara formation consists of thick layers of chalky limestone separated by thin partings of chalky shale. The beds of limestone are massive although some of them become platy when weathered. The rock is usually cream-colored and weathers to some shade of gray. Shells of clams and oysters are found in it but not in the abundance that they occur in the underlying formations of Cretaceous age. The beds of limestone average 2.5 feet in thickness.

The partings of shale are only about 0.1 foot thick. The shale has a tendency to be platy, is always chalky, and its color is usually gray orange.

The uppermost 3 or 4 feet of the Fort Hays limestone member typically weather mechanically to produce a "shattered" zone. The shattered fragments of limestone are 5 or 6 inches long, angular, and irregularly disc shaped.

Outcrops of the Fort Hays limestone member form bold escarpments generally from 35 to 40 feet high. The total thickness of the member is estimated, on the basis of a topographic map published by the United States Geological Survey, to be about 50 feet.

Representative Measured Section

The following section of the Fort Hays limestone member of the Niobrara formation is the upper part of that which was cited for the Codell sandstone and Blue Hill shale members of the Carlile shale. It is thus exposed in the bank of a tributary to Carr Creek in the NW¼SE¼ sec. 34, T. 8, S., R. 10 W.:

	Feet
Soil	3±
Fort Hays limestone member of the Niobrara formation:	
Limestone, chalky; "shattered" zone; cream; weathers gray. Fossil clams and oysters	2.6
Limestone, chalky; massive; cream; weathers gray	2.6
Shale, silty, calcareous; platy; gray-orange	.1
Limestone: This and the underlying beds of limestone are similar to the limestone bed described above	2.2
Shale: this and the underlying beds of shale are similar to the bed of shale described above	.1
Limestone	2.4
Shale	.1
Limestone	2.3
Shale	.1
Limestone	1.8
Shale	.1
Limestone	1.4
Shale	.3
Limestone	3.3
Shale	.1
Limestone	1.6
Shale	.2
Limestone	1.4
Shale	0.1
Limestone	1.9
Shale	.1
Interbedded thick layers of limestone and thin partings of shale	11.3
Total thickness present (underlain by the Carlile shale)	36.1

Thickness

As stated above, the total thickness of the Fort Hays limestone member is estimated to be about 50 feet.

Construction materials.--Construction materials from the Fort Hays limestone member of the Niobrara formation are: Road metal, structural stone, calcareous binder, and fill material.

Sanborn Formation

Areal Distribution

In Mitchell County, the most extensive outcrops are those of the Sanborn formation of Pleistocene and Recent(?) age. (See pl. 1 and fig. 4.) It occurs topographically as: 1 an upland phase, a mantle of silt capping the interstream areas, and 2 a valley phase in which it is a discontinuous deposit of silt along the margins of the valleys of the larger streams and their tributaries masking the lower part of the valley wall. The upland phase is well displayed in every part of the county; the valley phase is especially conspicuous along the north side of the valley of the Solomon River east of Beloit and along the north side of the lower part of the valley of Salt Creek. The valley phase is never so extensive along the south side of a valley as it is along the north side. Because of the similarity of their lithologic characteristics, the two phases of the Sanborn formation are mapped on plate 1 as a single unit (Qs).

General Description

The Sanborn formation is composed of materials deposited by wind (loess), streams, slopewash, and through the action of gravity (colluvium). Although the formation is subdivided into members in Nebraska and in some parts of Kansas, this practice was not followed in Mitchell County inasmuch as the materials characteristics of the two or more members recognized in the county are essentially similar. The treatment of the Sanborn formation as an undivided unit seems adequate to serve the purpose of this inventory of construction materials.

Although brown in some places, gray is the prevailing color in the Sanborn formation. The "A" horizon of the soil profile is darker than the underlying horizons and is brown, dark brown, or black. Buried soil zones occur in a few places in the county.

The Sanborn formation is composed predominantly of silt-size particles. The weathering of the silt in the upper part of the formation has broken the particles down to clay size; thus the upper part of the formation is a clayey silt and the lower part is largely composed of silt. Leaching of calcium carbonate from the upper horizons of the soil profile, through the action of downward-percolating subsurface water, causes this part of the formation to be noncalcareous. The calcium carbonate has been re-deposited in the lower horizons of the profile either in a disseminated stain or as calcareous pipes, concretions, and nodules.

A granitic gravelly sand composed predominantly of sand-size particles of quartz and feldspar occurs in the basal part of the formation just above the wall of the valley of the Solomon River. Exposures of the sand are infrequent and of small extent. They are best along the south side of the valley because most of the recent erosive activity of the Solomon River has been directed against the south valley-wall and has removed the valley phase of the Sanborn formation which masks the deposits of gravelly sand along the north side of the valley. The largest deposit is cited in table 1 as sample fa 1.

Where the Sanborn formation rests on the Carlile shale at the base of the escarpment formed by the Fort Hays limestone member of the Niobrara formation, its lower part is a limestone gravel. The gravel-size particles are fragments of the Fort Hays. That they show little rounding indicates that they have not been transported very far from the bed of limestone from which they were derived. The deposits of limestone gravel contain a heavy intermixture of silt-size particles.

The upland phase of the Sanborn formation was deposited by wind, for the most part, and is therefore classified as loess. The valley phase may represent the dissected remnant of an old high-level stream terrace, but it also includes some material deposited by slopewash, some deposited by the wind, and colluvium moved down the valley wall through the action of mantle creep.

A phenomenon known as "catstep" erosion is displayed on the steeper slopes of the Sanborn formation. The catsteps are slump blocks that moved down the slope by gravity when saturated with water. The blocks are formed by scarps from 1 foot to 3 feet high, and the blocks are usually from 15 to 20 feet wide.

Surface slopes in the valley phase of the formation range from 2 to 5 percent for the most part. Those in the upland phases are as great as 2 percent in broad interstream areas and range from 2 to 5 percent in narrow interstream areas.

Representative Measured Section

The Sanborn formation, as usually exposed in this county, is so homogeneous that no section of it was measured. In almost all places it is a gray or gray-brown silt, clayey and noncalcareous in its upper part, and heavily impregnated with secondary calcium carbonate in its lower part.

Thickness

The thickness of the Sanborn formation ranges from a feather edge to a maximum of approximately 30 feet on the crests of some of the interstream areas.

Construction Materials

Construction materials from the Sanborn formation in Mitchell County are: Aggregate for concrete, road metal, mineral filler, and fill material.

Terrace Deposits

Areal Distribution

Terrace deposits of Quaternary age are conspicuous in the valleys of the principal streams in Mitchell County. (See pl. 1 and fig. 4.) Narrow extensions of the terraces extend into the valleys of the larger tributary streams. The most extensive terrace is that of the Solomon River which ranges in width from about a mile, in the western part of the county, to almost 4 miles in the eastern part. The terrace in the valley of Salt Creek is also prominant but its average width is only 0.75 mile. The terraces along smaller streams average less than 0.5 mile wide. The surface slope of a terrace deposit is less than 2 percent.

General Description

The terrace sediments are composed predominantly of tan to light-brown silt-size particles intermixed with clay in the upper part of a deposit and interbedded with lenses of gravel in the lower part. Most of the clay-size fraction is probably derived through the weathering of silt in the process of soil development. A dark brown or black "A" hori- velopment. A dark brown or black "A" horizon is always present at the top of a deposit and one or more buried "A" horizons may occur within the deposit. The particles of gravel usually wellrounded, are interbedded as lenses in the lower part of a deposit and are fragments of the Dakota sandstone, Greenhorn limestone, and Fort Hays limestone member of the Niobrara formation.

Crude columnar structure is exhibited in most of the cut banks eroded into this formation. The faces of the cuts stand nearly vertically. Whereas the upper part of a deposit is noncalcareous, the lime leached from it has been redeposited in the lower part in the form of nodules and pipe-like concretions, and as a disseminated impregnation.

Representative Measured Section

This section of a terrace deposit was measured in a road cut on the south side of the Solomon River in the SE¼SW¼ sec. 32, T. 7 S., R. 6 W.:

	Feet
Soil: Silty clay; black	1.7
Terrace deposit:	
Silt, somewhat clayey, noncalcareous; dark-brown	1.3
Silt; blocky; light-brown; abundant thin streaks of calcium carbonate and some small pipe-like concretions of the same material; stands in vertical bank and exhibits crude columnar structure . .	4.3
Silt; somewhat blocky; tan; small lens of local gravel in middle part; numerous small nodules of calcium carbonate; stands in vertical bank and exhibits crude columnar structure	4±
Total thickness exposed (base covered)	9.6±

Thickness

The terrace along the Solomon River stands from 25 to 30 feet above the level of the river. The heights of other terraces in the county are 20 feet or less above stream level. In the absence of test-hole data, it was impossible to determine the full thickness of the terrace deposits.

Construction Materials

Construction materials from terrace deposits in Mitchell County are mineral filler and fill material.

Alluvium

Areal Distribution

The deposits formed by streams in their present gradational cycles are mapped as alluvium. (See pl. 1 and fig. 4.) They constitute the most recent geologic formation in the county and are being laid down by present-day streams. Alluvium is defined in this report as the material which underlies the present floodplain of a stream. The floodplain is the area adjacent to the stream channel that is covered by water during normal flood stage; its surface slope is less than 2 percent. The terrace deposits are composed of alluvium laid down by these same streams flowing at higher levels in earlier geologic time.

Alluvium is mapped only along the Solomon River. Deposits of it are also present in the valleys of Salt Creek and some of the larger tributary streams but could not be shown because the map is on too small a scale. The alluvium in the valley of the Solomon River averages 0.3 mile in width.

General Description

The alluvium of the Solomon River is composed of clay and silt and interbedded lenses of local gravel and gravelly sand. Gravel bars are quite numerous in the channel of the Solomon River, as in the channels of other streams in the county. The particles of gravel are fragments of the Cretaceous formations which crop out in the watershed of the stream. They include waterworn fragments of the Fort Hays limestone member of the Niobrara formation, concretions and clay balls eroded from the Carlile shale, the limestones in the Greenhorn limestone, and the Dakota sandstone that is along the Solomon River in the eastern part of the county and along Salt Creek in the south-central part.

Representative Measured Section

The alluvium shows so little relief that a representative section could not be measured.

Thickness

The alluvial deposits are undoubtedly thickest along the Solomon River and are estimated to be about 30 feet thick. Similar deposits along other streams are thought to be no more than 20 feet thick.

Construction Materials

Construction materials from alluvium in Mitchell County are: Aggregate for concrete, road metal, and fill material.

INVENTORY OF CONSTRUCTION MATERIALS

General

The objectives of this inventory of construction materials in Mitchell 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 American Association of State Highway Officials 12/ and the State Highway Commission of Kansas. 13/ It is expected that prospects listed in this report will be proved by subsequent augering, drilling, or test pitting and that the materials themselves will be subjected to laboratory testing prior to production for specific uses.

Although numerous prospect pits and quarries were located in the field, no attempt was made to complete an exhaustive survey of all possible sources. If the construction materials that are available in Mitchell County can be related to the geologic formations mapped on plate 1, then the use of that map will aid the field man in his search for the materials needed in a construction project. It will eliminate the non-productive areas from the search and, at the same time, will indicate the areas in which the needed materials are most likely to occur.

Aggregate For Concrete

Engineering and Geologic Characteristics

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

The materials reported in this and other classifications are exposed at the surface or are under unconsolidated overburden sufficiently thin that they may be economically developed. Because of the added expense in the removal of the overburden, deposits of sand and gravel overlain by thick or consolidated beds usually are not included, nor are relatively inaccessible deposits.

Stratigraphic Sources and Performance Characteristics

Two of the geologic formations mapped on plate 1 are actual or potential sources of aggregate for concrete. They are the Sanborn formation and alluvium.

1. Sanborn formation. -- One sample of fine aggregate (fa 1) was obtained from the Sanborn formation. (See table 1.) The material is a fine-grained sand composed largely of quartz, subordinately of particles of feldspar, and occasional particles of opal and chalcedony. Opal and chalcedony are not present in injurious amounts. The material contains only a moderate amount of wash, it is clear in the colorimeter test, but its compressive strength ratio after 3 days is 0.83. The deposit from which this material was sampled is in the basal part of the Sanborn formation just above the south wall of the valley of the Solomon River. Other similar deposits are undoubtedly along the south side of the river.

2. Alluvium. -- Five samples (ma 1, ma 2, ma 3, ma 4, and ma 5) were collected from the alluvium of the Solomon River by the State Highway Commission in a State-wide sampling program carried out in 1932. The samples were obtained from gravel bars in the stream bed. The gravel-size particles are fragments of limestones cropping out in the watershed of the Solomon River; the sand-size particles are predominantly fragments of quartz and feldspar. The gradation factor of the samples ranges from a minimum of 3.08 to a maximum of 3.84; the amount of wash ranges from 1 to 3 percent. The colorimeter test shows that there is a small to moderate amount of organic material intermixed with the alluvium. Compressive-strength ratios are all above unity, and the loss through wear is uniformly 3 percent.

The alluvium of the Solomon River is the most important source of aggregate for concrete in the county. The alluvial deposits of other streams are composed predominantly of silt-size particles. Lenses of gravel and sandy gravel are included in the terrace deposits but lie at such depths below the surface that they cannot be developed economically.

Road Metal

Engineering and Geologic Characteristics

Road metal, known also as surfacing material, crushed stone, and aggregate is defined in this report as any material that may be applied to a road to improve the performance characteristics of that road. The following materials are available in Mitchell County for use as road metal.

1. Aggregate for concrete. -- (Table 1).

2. Indurated rocks. -- Indurated rocks available in Mitchell County for use as road metal are (a) chalky limestone, a compact, massive layer of calcareous material ranging from soft to moderately hard; (b) shale, a very thin-bedded to massive layer composed of clay- or silt-size particles, or both; (c) sandstone, a layered rock composed of sand-size particles of quartz cemented by pore-space deposits of calcium carbonate, silica, iron oxide, clay, or varying combinations of

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

13 State Highway Commission of Kansas, Standard specifications for State road and bridge construction, 1945. Gradation factor, p. 16, Sieve analysis, pp. 333-334, Soundness, pp. 335-336.

these. The materials included here under indurated rocks are listed in table 1 and mapped on plate 1 under the more specific designation of limestone, shale, and sandstone, because in addition to their use as road metal two of them, limestone and sandstone, may be used as structural stone and riprap.

3. Limestone gravel. --A deposit composed of subangular to rounded gravel-size fragments of limestone in a matrix of silt-size particles is here classified as limestone gravel.

Stratigraphic Sources and Performance Characteristics

1. Sources of aggregate for concrete. The materials listed in the section on aggregate for concrete have been used in Mitchell County as road metal on light-traffic roads or as base-course material in roads of the concrete or black-top type of construction. Their sources and performance characteristics have been discussed under Aggregate for concrete.

2. Indurated rocks.

(a) Dakota sandstone. --Three samples of the Dakota sandstone (ss 1, ss 2, and ss 3) were collected and submitted to the Road Materials Laboratory of the State Highway Commission for testing. However, two of them (ss 1 and ss 2) slaked so quickly under water that no tests were performed. The one sample on which tests were completed (ss 3) shows an abrasion loss of 96.2 percent and a soundness ratio of 0.77. So far as is known, all of the sandstone ledges in the Dakota exposed in this county are composed of poorly cemented sand grains and are therefore easily pulverized. Similar rock has been quarried in other counties in Kansas and, because it usually pulverizes during the quarrying operation, it has been used as loose road metal on light-traffic roads and as base-course material. Large quantities of this material are present in the areas mapped on plate 1.

(b) Greenhorn limestone. --A combined sample (sh 2) of the Lincoln limestone and Hartland shale members of the Greenhorn limestone was submitted to the testing laboratory as material potentially useful in road stabilization. Although the results of the test shown in table 1 do not include the plasticity index of the material, that index is probably moderately high because of the content of clay in these two members of the Greenhorn limestone.

Three samples of the Jetmore chalk member were submitted for testing. --Two (ls 4 and ls 5) were collected from the "shell-rock" bed and the third (ls 1) was collected from the interbedded limestones and shales below the "shell-rock" bed. Successful use of this and similar material in the construction of a light type of traffic-bound macadam has been observed on many roads in north-central Kansas.

From the Pfeifer shale member of the Greenhorn limestone one sample (ls 2) of the "Fencepost" limestone bed and another (sh 1) of the interbedded shales and limestones below the "Fencepost" bed were submitted for laboratory testing. The test data shown in table 1 indicate that the "Fencepost" limestone bed is acceptable for use in the construction of roads of the traffic-bound macadam type; however, because the bed is so thin, a sufficient quantity of rock for this use probably could not be produced. The interbedded shales and limestones below the "Fencepost" bed are used in north-central Kansas in the construction of stabilized roads. This member of the Greenhorn limestone crops out extensively in the areas mapped as Kg on plate 1.

(c) Carlile shale. --One sample (sh 3) of the Fairport chalky shale member was submitted to the Road Materials Laboratory but no tests were performed on it because it slakes quickly when immersed in water. The basal part of this member is similar lithologically to the Pfeifer shale member of the Greenhorn limestone, and is probably acceptable for the same use in road stabilization.

(d) Niobrara formation. --The Fort Hays limestone member (see ls 3 in table 1) is utilized throughout north-central Kansas as a source of rock for the construction of traffic-bound macadam. The "shattered" zone in this member can be removed with a blade but the massive ledges must be quarried. Roads constructed of this material give good performance in wet weather but have a tendency to "dust" seriously in prolonged dry weather.

3. Sanborn formation. --Numerous samples (see table 1) of limestone gravel were collected from the Sanborn formation. Where used as a road metal, the particles of silt size serve as a binder for the gravel-size particles of local limestone. This material is used extensively as metal on light-traffic roads in north-central Kansas.

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 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 (oral communication) that material will qualify for mineral filler only if laboratory tests indicate a low coefficient of cementation.

Stratigraphic Sources and Performance Characteristics

Two stratigraphic units were sampled as possible sources of material to be used as mineral filler; these are: the Sanborn formation and terrace deposits.

1. Sanborn formation. --One sample (mf 4) of the Sanborn formation was tested for use as mineral filler. The test data show that

its cementation factor is excessive, undoubtedly because of a too-heavy intermixture of clay. The deeper zones in the formation contain much less clay and would be productive of acceptable mineral filler in those places where erosion has removed the surficial zone of clayey silt.

2. Terrace deposits. --Of the three samples of potential mineral filler obtained from terrace deposits (see table 1), only one (mf 3) had a coefficient of cementation within acceptable limits. This sample was obtained by augering and does not include the upper, weathered part of a deposit in which the percentage of clay is highest. Presumably, if the upper horizons of the soil profile were stripped away from the Sanborn formation and terrace deposits, the material exposed would contain only a negligible percent of clay-size particles and thus would have a coefficient of cementation within acceptable limits.

Riprap

Engineering and Geologic characteristics. -- Riprap, as defined in this report, is any material suitable for protecting earthen fills from erosion. To be acceptable for this use the material must be relatively sound and free from cracks and other structural defects or impurities that would cause it to disintegrate through abrasion, slaking, or freeze-and-thaw. It is desirable that the material be in blocks having approximately rectangular faces 7 inches or more in width and that the specific gravity be 2 or higher.

Stratigraphic sources and performance characteristics. -- Three of the geologic formations cropping out in Mitchell County are actual or potential sources of rock for use as riprap: (1) Dakota sandstone, (2) Greenhorn limestone, and (3) the Niobrara formation (Fort Hays limestone member).

1. Dakota sandstone. The sandstone of the Dakota firmly cemented by pore-space deposits of silica (quartzite) or calcium carbonate (quartzose sandstone) is acceptable, on the basis of field observation in other counties, for use as riprap. However, no ledges so cemented were found in Mitchell County. An intensive search of the area of outcrop of the Dakota sandstone mapped on plate 1 would possibly reveal one or more such ledges not discovered in this investigation.

2. Greenhorn limestone. Use of the "shell-rock" limestone bed of the Jetmore chalk member and the "Fencepost" limestone bed of the Pfeifer shale member as riprap has been observed on a number of small dams in north-central Kansas. Although the test data shown in table 1 indicate that neither of these is highly desirable in this use, field observation reveals that they perform acceptably when used to protect small structures.

3. Niobrara formation. Blocks of the Fort Hays limestone member have been used as riprap on several small dams in north-central Kansas. Inspection reveals that this rock is not acceptable for this use inasmuch as it disintegrates within a short time. Its low specific gravity and soundness ratio and its high absorption percentage (see ls 3 in table 1) are adequate reasons to explain the failure of the rock.

Structural Stone

Engineering and geologic characteristics. -- Structural stone, as defined in this report, is any hard, dense, rock material that can be qurraied and produced to desired size and shape. Materials fulfilling these requirements occur in the Greenhorn limestone and the Niobrara formation in Mitchell County.

Stratigraphic sources and performance characteristics. -- 1. Greenhorn limestone. Two limestone beds in the Greenhorn limestone are used in this and adjacent areas as structural stone. The shell-rock limestone bed at the top of the Jetmore chalk member has been used to a limited extent as structural stone. Although acceptable for this use, its appearance is not altogether pleasing. The "Fencepost" limestone bed, which marks the top of the Pfeifer shale member, is the source of most of the structural stone used in Mitchell County. The stone has adequate bearing strength, withstands weathering well, and has a very pleasing appearance. Many farm homes and other farm buildings, city residences, business houses, and municipal buildings have been constructed of it.

2. Niobrara formation. Limited use of stone from the Fort Hays limestone member in the construction of farm buildings was observed in this county. Although the rock is easily produced to desired size and shape, it weathers fairly rapidly and, where used close to the ground and thus subject to excessive moisture, it disintegrates rapidly through slaking and the process of freeze-and-thaw.

Calcareous Binder

Engineering and geologic characteristics. — To be classified as calcareous binder the material must be composed essentially of calcium carbonate and must be soft and easily pulverized. Two of the geologic formations mapped on plate 1 are sources or potential sources of calcareous binder: (1) Greenhorn limestone and (2) the Niobrara formation.

Stratigraphic sources and performance characteristics. -- 1. Greenhorn limestone. The interbedded chalky limestones and chalky shales of the Jetmore chalk and Pfeifer shale members of the Greenhorn limestone appear to be acceptable for use as calcareous binder. The rock is highly calcareous and, for the most part, is soft and relatively easy to pulverize.

2. Niobrara formation. The Fort Hays limestone member has been accepted by the State Highway Commission of Kansas as a potential source of material suitable for use as calcareous binder. The beds of chalky

limestone are soft, easily pulverized, and free from deleterious substances. However, this source of calcareous binder is available only in the Blue Hills area in the southwest part of the county, whereas far greater quantities of binder may be obtained from the much more extensive outcrops of the Jetmore chalk and Pfeifer shale members of the Greenhorn limestone. (See pl. 1.)

Subgrade and Embankment Material

Engineering and geologic characteristics. -- This definition of subgrade and embankment material is adapted from the specifications compiled for the American Association of State Highway Officials. 14/ Suitable geologic materials shown as "fill material" in fig. 4 and in sections on outcropping stratigraphic units) for this kind of construction are (1) Fine-granular unconsolidated sediments, including soil, of which 50 percent or more pass through a No. 200 sieve; (2) 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; (3) broken or crushed rock.

Stratigraphic sources and performance characteristics. -- All of the materials listed above are available in Mitchell County for the construction of subgrades and embankments and may be the product of excavation along the alignment of the structure, or they can be obtained from adjacent areas. The geologic formations in which these materials occur are:

1. Fine-granular sediments. The Sanborn formation and terrace deposits contain almost unlimited quantities of silt or clayey silt. The extensive outcrops of these formations are mapped on plate 1 and indicate the almost universal availability of the material over the county.

14 Am. Assoc. State Highway Officials, Highway materials, pt. 1, Specifications, pp. 37 and 38, 1937.

2. Coarse-granular sediments. A very small quantity of sand and gravel is available for use in the construction of subgrades and embankments. The two sources are the basal part of the Sanborn formation and the alluvium of the Solomon River. It is possible that the more extensive deposits of limestone gravel which occur in the basal part of the Sanborn formation might also prove acceptable for this use.

3. Broken or crushed rock. The formations of Cretaceous age are the only potential or actual sources of broken or crushed rock in Mitchell County.

Dakota sandstone. The beds of sandstone in this formation are easily pulverized and might produce material acceptable for some types of subgrades or embankments.

Graneros shale. The bentonitic clay shales of the Graneros exhibit such low bearing strength that it is doubtful that they would be acceptable for use in the construction of a subgrade or embankment.

Greenhorn limestone. The bearing strength of material obtained from the Lincoln limestone and Hartland shale members of this formation probably is low; the strength of the material obtained from the Jetmore chalk and Pfeifer shale members is undoubtedly appreciably higher.

Carlile shale. Except for the Codell sandstone member and the lower part of the Fairport chalky shale member, the Carlile shale is composed predominantly of clay.

Niobrara formation. Broken or crushed rock from the Fort Hays limestone member apparently is acceptable for use in the construction of subgrades or embankments but if the environment in which it is used is one of a high moisture content, its acceptability will be doubtful.

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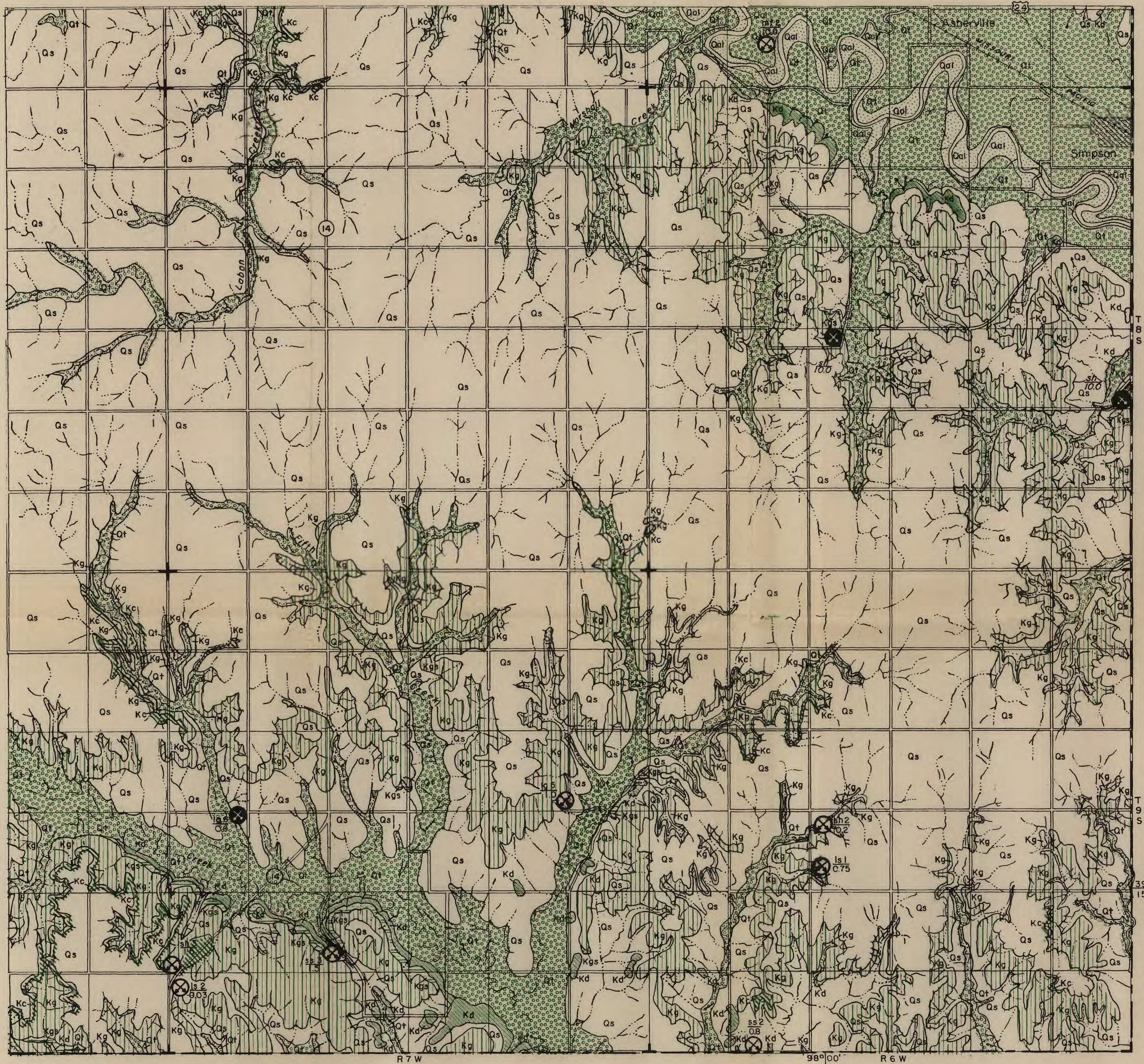
Southeastern Mitchell County



EXPLANATION

Quaternary — Pleistocene and Recent

Qal Alluvium
(Clay and silt interbedded with lenses of local gravel and granitic gravelly sand. Source or potential source of: aggregate, road metal, mineral filler.)

Qt Terrace deposits
(Tan or light brown silt, clayey near surface and lenses of local gravel in lower part. Source or potential source of: mineral filler, fill material.)

Qs Sanborn formation
(Gray or brown silt, clayey near surface and lenses of limestone gravel and granitic gravelly sand in basal part. Source or potential source of: aggregate, road metal, mineral filler, fill material.)

Cretaceous — Upper Cretaceous

Knf Fort Hays limestone member of the Niobrara formation
(Thick beds of massive, cream-colored chalky limestone separated by thin partings of chalky shale; shattered zone below top; forms escarpment. Source or potential source of: road metal, structural stone, fill material, calcareous binder.)

Kc Carlile shale
(Thin zone of red-brown sandstone at top; upper part blue-gray noncalcareous clay shale with zones of septarian concretions and selenite crystals; lower part orange-gray chalky shale interbedded with chalky limestone near base; forms local areas of badland topography. Source or potential source of: road metal, fill material.)

Kg Greenhorn limestone
(Gray, orange-gray, and dark gray shales interbedded with thin layers of tan-gray or brown chalky or crystalline limestone and thin seams of bentonite; includes "Fence-post" and "shell-rock" beds which forms hillside benches. Source or potential source of: road metal, structural stone, riprap, calcareous binder, fill material.)

Kgs Graneros shale
(Thin-bedded blue-gray noncalcareous clay shale with interbedded seams of bentonite and lenses of red-brown sandstone. Not a source of material.)

Kd Dakota sandstone
(Thick layer of massive cross-bedded soft gray-orange to red-brown sandstone underlain by vari-colored noncalcareous silty shale; forms hillside bench. Source or potential source of: road metal, fill material.)

Geologic boundary
fa Fine aggregate
ma Mixed aggregate
lg Limestone gravel
mf Mineral filler
ls Limestone
sh Shale
ss Sandstone
ls Inclined letters indicate materials not listed in Table I.
ls2 Vertical letters indicate materials listed in Table I and their sample number.
1.0 Quantity of material available *(in units of 10,000 cubic yards).*
Operated pit or quarry
Prospect pit or quarry
Township corner
City
Federal *(US)* highway
State highway
Other roads, all classes
Railway
Section line
Stream, permanent
Stream, intermittent

10°
Approximate mean declination, 195[illegible]

Drafted by R. M. Soelter, C. E. Grieshaber and V. L. Stallbaumer.

Base adapted from map prepared by State Highway Commission of Kansas.

Drainage from aerial photographs provided by U. S. Department of Agriculture.

CIRCULAR 106 PLATE I

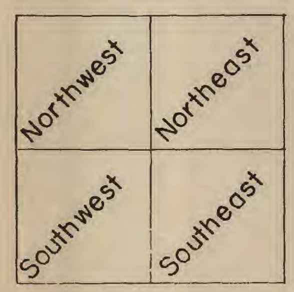
MAP OF MITCHELL COUNTY, KANSAS

Showing Construction Material Sources and Geology

1950

Scale

1 0 1 2 3 4 miles



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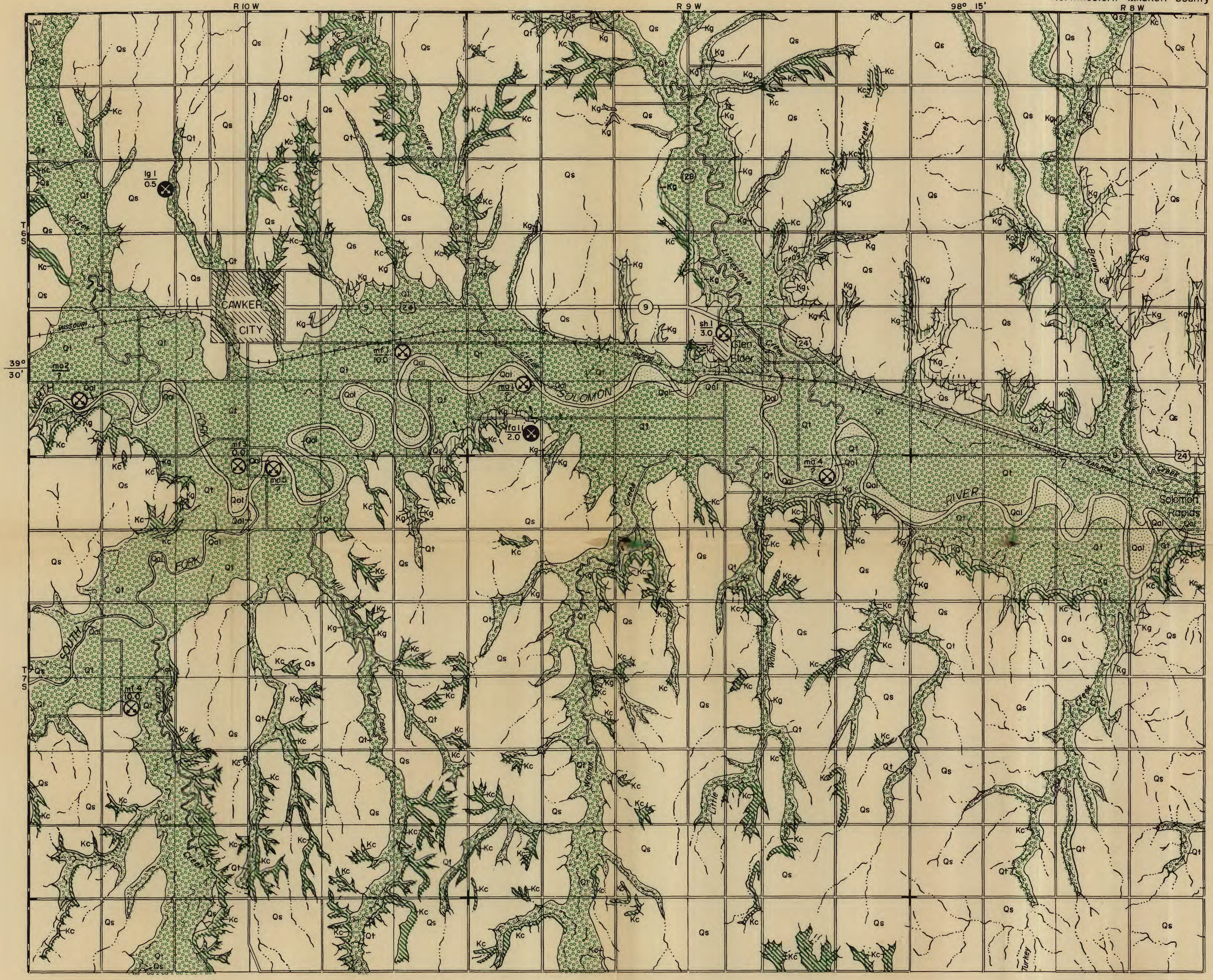
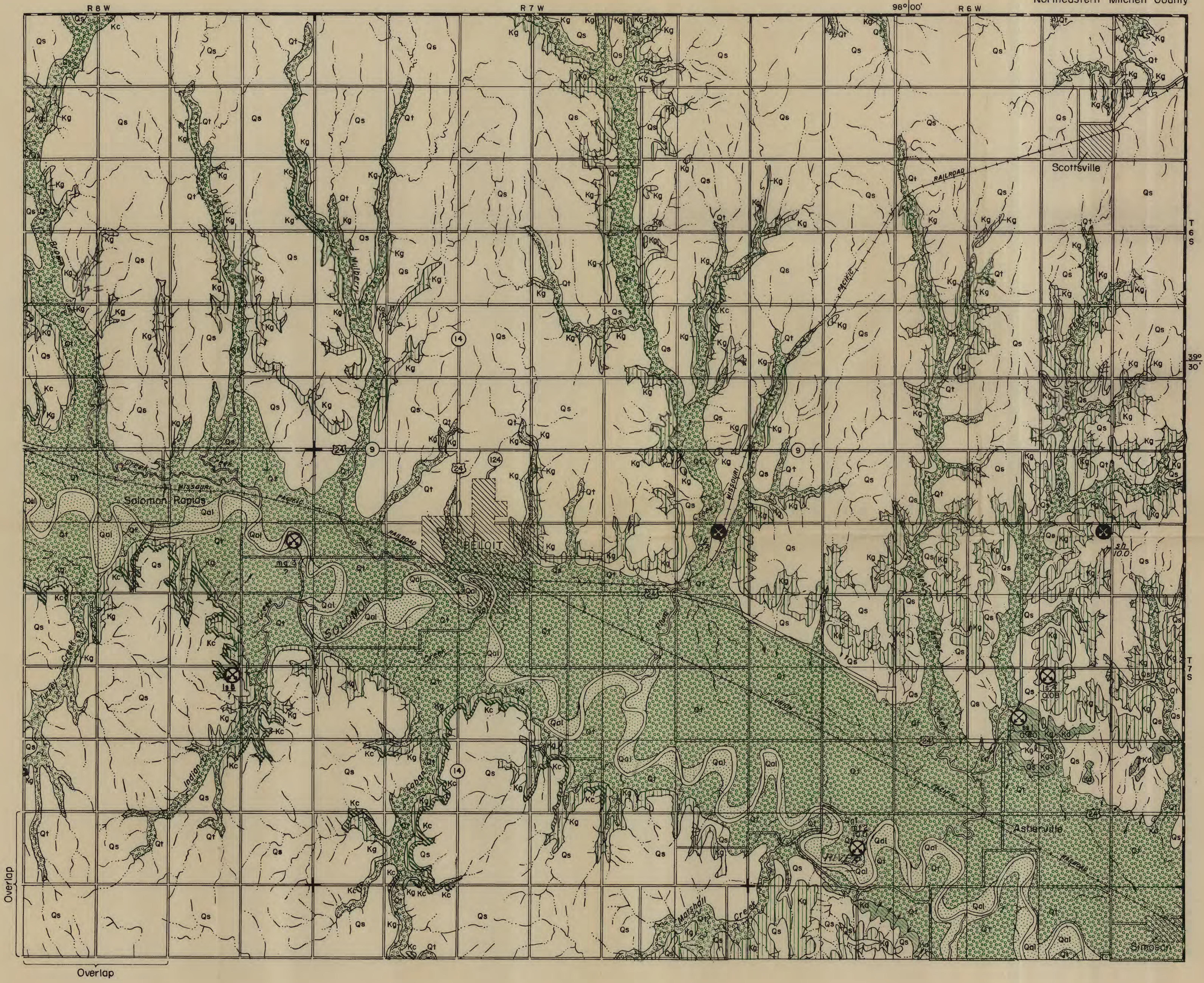
Geology by W. B. Johnson and D. W. Bergman

United States Department of the Interior
Geological Survey
and
State Highway Commission of Kansas
Geological Department

Northwestern Mitchell County



Northeastern Mitchell County




Overlap
Tipton
Hunter
T 8 S
T 9 S
39° 15'
R10W
R9W
98° 15'
R8W
Overlap

Table I. Summary of material reports

(Blank spaces indicate data not available)

Classification of the material	Number on plate I	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 [1]	Authority for test data [2]	Date of test	Sieve analysis: Percent on 3/4 inch	Percent on 3/8 inch	Percent on No. 4	Percent on No 16	Percent on No. 100	Percent passed No. 200 (wash)	Description of the material	Laboratory test data: 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 [3] (25 cycles)	Cementation	Absorption	Color [4]	Laboratory No.	Remarks
Fine agg	fa 1	NE	SE	31	6	9	20,000	11	0-2	Good	Sanborn	USGS	10-48			0	1	93	4.8	Percentage composition: quartz, 90; feldspar, 10; opal and chalcedony, trace.	101.6	2.57	1.96	1.00	0.83					cl	60743	Opal and chalcedony not present in injurious amounts.
Mixed aggregate	ma 1		NE	31	6	9					Alluvium	SHCK	10-32	0	4	23	49	98	1	Clean, siliceous sand-gravel containing some limestone pebbles.			3.84							lt st	20387	Compressive strength: 7 days, 175; 28 days, 125. Wear, 3 percent. Sand bar in Solomon River.
	ma 2		NE	31	6	10					Alluvium	SHCK	10-32	2	4	8	27	98	2	Clean, siliceous sand-gravel containing some hard limestone pebbles.			3.19							m st	20384	Compressive strength: 7 days, 155; 28 days, 125. Wear, 3 percent. Sand bar in North Fork Solomon River.
	ma 3		NE	12	7	8					Alluvium	SHCK	10-32	2	2	7	25	96	3	Clean, siliceous sand-gravel containing some hard limestone pebbles.			3.08							lt st	20391	Compressive strength: 7 days, 138; 28 days, 125. Wear, 3 percent. Sand bar in Solomon River.
	ma 4		NE	2	7	9					Alluvium	SHCK	10-32	0	3	9	50	98	2	Clean, siliceous sand-gravel containing some limestone pebbles.			3.68							st	20388	Compressive strength: 7 days, 172; 28 days, 125. Wear, 3 percent. Sand bar in Solomon River.
	ma 5		NW	3	7	10					Alluvium	SHCK	10-32	0	5	10	27	99	1	Clean, siliceous sand-gravel containing some hard limestone pebbles.			3.21							st	20385	Compressive strength: 7 days, 165; 28 days, 125. Wear, 3 percent. Sand bar in Solomon River.
Mineral filler	mf 1	NW	SW	25	6	10	100,000	12	0-1	Good	Terrace deposit	USGS	10-48				0	3	94	Light-gray, somewhat calcareous, clayey silt.	81.6	2.55						100+			60744	Cementation factor too high.
	mf 2	SE	NW	32	7	6	100,000	11	0-1	Good	Terrace deposit	USGS	10-48			0	1	13	82	Dark-brown to tan, very calcareous silt and clay.	80.4	2.50						100+			60745	Cementation factor too high.
	mf 3	NE	NE	4	7	10	100,000	12	1-3	Good	Terrace deposit	USGS	11-48				0	12	82.4	Gray-tan silt and fine sand; friable; slightly calcareous.	86.8	2.59						30			61037	Sample obtained by use of 4-inch auger.
	mf 4	SE	NW	20	7	10	100,000	11	0-2	Good	Sanborn	USGS	10-48			0	3	15	80.0	Red-brown to gray, somewhat calcified, clayey silt.	83.0	2.51						100+			60740	Cementation factor too high.
Limestone gravel	lg 1	SE	NE	17	6	10	5,000	7	2-6	Good	Sanborn	USGS	10-48	1	4	11	34	86	11.6	Rounded pebbles of local limestone and sand-size quartz grains in silt matrix.			2.95								60739	Used on County Highway 705 from Jewell County line to Cawker City.
	lg 2	SW	SW	33	8	8	5,000	7	2-4	Good	Sanborn	USGS	10-48	19	26	44	72	87	11.5	11 percent of particles larger than 3 inches in diameter; local limestone; silt matrix.			4.94								60737	Used on County Highway 492 between junctions with County Highways 480 and 725.
	lg 3	NE	SW	10	8	10	5,000	7	2-4	Good	Sanborn	USGS	10-48	7	16	43	66	75	22.0	Rounded pebbles of local limestone in silt matrix.			4.12								60741	Used on County Highway 705 from junction with County Highway 480 to Tipton.
	lg 4	SW	SW	29	8	10	15,000	11	0-2	Good	Sanborn	USGS	10-48	1	12	38	65	79	17.6	Rounded pebbles of local limestone in silt matrix.			3.95								60742	
	lg 5	SE	SE	14	9	7	10,000	7	0-2	Poor	Sanborn	USGS	10-48	14	34	54	78	91	8.57	Angular fragments of local limestone in a matrix of silt.			5.12								60736	
	lg 6	NE	NE	19	9	7	6,000				Sanborn	SHCK	5-40	19	35	51	77	99	11.7	A mixture of clay and calcareous binder and limestone pebbles.			5.31								39799	
	lg 7	SW	SE	6	9	9	10,000	7	0-2	Good	Sanborn	USGS	10-48	5	16	34	58	68	30.9	Rounded, fairly small pebbles of local limestone in a matrix of silt.			3.61								60738	
Limestone	ls 1	NW	SW	21	9	6	7,500	9	0-4	Good	Jetmore chalk member	USGS	11-48							Interbedded thin-bedded, silty, chalky shale and thin, massive, buff limestone.		2.46				40.1	0.78		3.23		61031	
	ls 2	NW	NW	31	9	7	300	1	0-2	Good	Pfeifer shale member	USGS	11-48							Massive, somewhat crystalline, buff limestone marked by rust-colored zone in middle of ledge.		2.11				44.0	0.85		8.21		61035	"Fencepost" limestone bed.
	ls 3	SE	SE	11	9	10	10,000	12	0-3	Good	Fort Hays limestone member	USGS	11-48							Massive, cream-colored, chalky limestone.		1.79				61.4	0.34		17.81		61036	Specific gravity low; abrasion loss and absorption high.
	ls 4	NW	NW	23	7	6	800	1	0-4	Good	Jetmore chalk member	USGS	11-48							Massive, fossiliferous, buff limestone.		2.06				55.8	0.84		9.06		61028	"Shell-rock" bed. Abrasion loss high.
	ls 5		NE	23	7	8					Jetmore chalk member	SHCK	10-32							Soft white and yellow limestone containing large fossil shells.	133.0	2.13					OK		7.4		20406	Deval abrasion loss: 12.5 percent.
Sandstone	ss 1	NW	SE	22	7	6	6,000	6	0-1	Good	Dakota sandstone	USGS	11-48							Poorly cemented, light-gray sandstone.											61029	Slakes under water; no tests performed.
	ss 2	SE	SW	32	9	6	8,000	10	0-4	Good	Dakota sandstone	USGS	11-48							Soft, loosely cemented, light-gray sandstone; some iron-cemented, brown streaks.											61032	Slakes under water; no tests performed.
	ss 3	NW	SW	28	9	7	15,000	12	0-6	Good	Dakota sandstone	USGS	11-48							Iron-cemented, cross-bedded, fine-grained, red-brown sandstone; upper part of ledge.		1.83				96.2	0.77		13.17		61033	
Shale	sh 1	SE	NW	27	6	9	30,000	12	2-4	Good	Pfeifer shale member	USGS	11-48							Interbedded thin chalky limestones and thick chalky shales; brown to buff.											61038	Slakes under water; no tests performed. Sample did not include the "Fencepost limestone" bed.
	sh 2	NW	NW	21	9	6	2,000	12	10	Good	Lincoln limestone Hartland shale members	USGS	11-48							Thin-bedded, dark-gray, silty shale with inter-bedded thin seams of bentonite and limestone.		1.94				62.2	0.10		13.13		61030	Abrasion loss high; unsound.
	sh 3	SW	SW	30	9	7	15,000	20	0	Good	Fairport chalky shale member	USGS	11-48							Thick clayey shale interbedded with thin chalky limestone.											61034	Slakes under water; no tests performed.

1. All correlations with geologic formations or members by USGS.
2. SHCK, State Highway Commission of Kansas: sample collection and test data. USGS, U.S. Geological Survey: sample collection and description of material; test data by SHCK.
3. Loss ratio.
4. cl, clear; lt st, light straw; m st, medium straw; st, straw.