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CONSTRUCTION-MATERIALS IN CLOUD COUNTY, KANSAS

By

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STATE HIGHWAY COMMISSION OF 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 of construction materials. In connection with this work, a field party composed of members of the United States Geological Survey investigated sources of engineering construction materials in Cloud County, Kansas, during the summer of 1948. This report of the investigation is a contribution to the geologic mapping and investigation of mineral resources being made in the Missouri River Basin. 1/ The primary objective of the investigation was to collect all data pertaining to the geologic materials which would be useful in engineering projects.

GEOGRAPHY OF THE AREA

Area covered by the investigation. --Cloud County is in the second tier of Kansas counties south of the Nebraska border and in the eighth tier east of the Colorado border. (See fig. 1.) It comprises 20 townships and covers an area of about 720 square miles. The county is bounded by parallels 39°18' and 39°39' north latitude and meridians 97°22' and 97°56' west longitude.

Topography. --Cloud County lies in the eastern part of the Plains Border division of the Great Plains physiographic province, a submaturely to maturely dissected plateau region. 2/ The land surface in Cloud County has been dissected to a rolling topography of moderate relief.

A conspicuous topographic feature in the northern part of the county is the broad, flat valley of the Republican River, part of which is more than 3 miles wide. The valley of the Solomon River, which crosses the southwestern corner of the county, has a flat floor more than 2 miles wide. These valleys are about 200 feet below the undulating upland and their valley walls are moderately steep. Valleys cut into the unconsolidated sediments in the divide area between the two rivers are shallow with gently sloping walls. Areas between the upland valleys are gently rolling.

The points of lowest elevation in Cloud County, about 1300 feet above sea level, are in the southwestern part along the Solomon River and in the northeastern part along the Republican River. The highest elevations in the county are along the divide between the two rivers, one point in the south-central part being more than 1700 feet above sea level.

Drainage. --Approximately the northern two-thirds of Cloud County lies in the drainage basin of the Republican River. (See pl. 1.) This river rises about 350 miles to the west in Colorado and flows generally toward the east in southern Nebraska, and toward the southeast in Kansas, joining the Smoky Hill River at Junction City to form the Kansas River. The tributary streams in Cloud County which enter the Republican River on the north side rise in Republic County. Buffalo Creek, the largest tributary, rises in Jewell County. This stream and its tributaries drain the northwest part of Cloud County. The tributaries entering the river from the south in Cloud County head in the divide area, between the Republican and Solomon Rivers.

Nearly one-third of Cloud County lies in the drainage basin of the Solomon River which rises about 185 miles to the west in Thomas County, Kansas. This river flows generally toward the east and joins the Smoky Hill River at Solomon, Kansas. The tributaries entering the river from the north in Cloud County drain the southern slope of the divide area between the Republican and Solomon Rivers. Chapman Creek, in the southeast part of the county, is a tributary of the Smoky Hill River.

Climate. --Cloud County lies in an area of continental-type climate in which the summers are long and the winters are short and fairly cold. The average annual precipitation is about 25.24 inches. 3/ The average date of the last killing frost in spring is April 15, and the average date of the first killing frost in fall is October 18. 4/ The average number of cloudy days is about 90 a year, of partly cloudy days about 100 a year, and of clear days about 175 a year. 5/

Temperature and precipitation are factors which are important in various phases of engineering construction such as setting concrete, laying bituminous-mat, grading, and excavation. Figure 2, a chart

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

[2] Frye, J. C., The High Plains surface in Kansas: Kansas Acad. Sci. Trans., vol. 49, no. 1, pp. 76, 81-82, June 1946.

[3] Flora, S. D., The Climate of Kansas: Kansas State Board of Agri. Rept. vol. 67, no. 285, p. 84, June 1948.

[4] Ibid., pp. 223 and 224.

[5] Ibid., pp. 239 and 240.

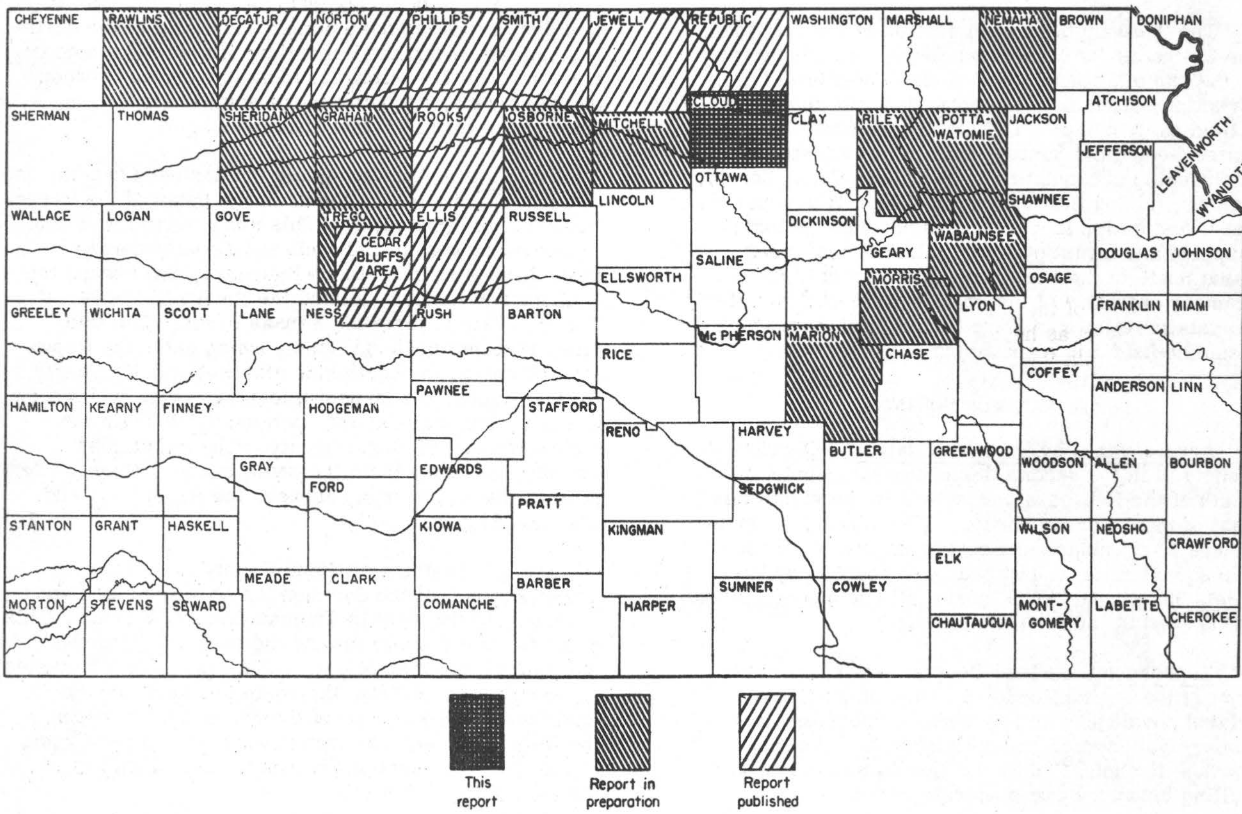


Figure 1.—Index map of Kansas showing areas covered by this report and by other construction materials investigations

showing temperature ranges at Concordia, Kans., was compiled from climatological data for the years 1937 to 1946, inclusive. 6/ The chart indicates, for the 10-year period, the number of days each month in which the maximum daily temperature fell within certain ranges arbitrarily based on temperatures important in certain construction activities

Days in which the maximum temperature does not exceed 32°F. occur only from November to April, inclusive, with a maximum incidence of 9.8 days in January. July is the warmest month in the year, and has an average of 18.8 days in which the daily maximum temperature exceeds 90°F. The chart also shows the average difference between the daily maximum and minimum temperatures. The greatest difference in daily temperatures, 24.5°F., is in July and the least difference, 17.3°F., is in January.

Figure 3 shows the average number of days in which precipitation fell within certain ranges at Concordia, Kans. The ranges are selected arbitrarily to show the effect of precipitation on the number of working days in engineering construction. As based on a 10-year average (Climatological Summary, Kansas section, 1937-46) there are 5 days in June, for example, in which the precipitation is 1.01 inches or more. Most of the precipitation in the range above 1 inch falls as heavy showers of short duration. Rain falling within the lesser precipitation ranges is generally gentle and lasts over longer periods of time.

Roads and railroads.--Two transcontinental highways cross the county. U S 24, a major east-west highway with a bituminous-mat surface, crosses the southern part of the county. U S 81, a major north-south highway, crosses the central part of the county. This highway is surfaced with concrete from the southern boundary to a point two miles north of Concordia. The remaining part of the road in the county is surfaced with bituminous-mat.

Kansas Highway No. 9 is a bituminous-mat road from Clyde to Concordia and is metaled with gravel in the western part of the county. Kansas Highway No. 28, from Concordia through Jamestown, is a bituminous-mat road. Most of the roads maintained by the county are metaled with materials available locally, whereas most of the roads maintained by the townships are graded earth roads. The railroads shown on plate 1 are all branch lines. No rock quarried locally is used as ballast on any of the railroads in Cloud County.

INVESTIGATION PROCEDURE

This report is based on reconnaissance field work. The base map and aerial photographs used in mapping were supplied by the Soil Conservation Service of the United States Department of Agriculture. The areal distribution of the outcropping stratigraphic units was mapped on aerial photographs having a scale of 4 inches equals 1 mile. The outcrop areas were later transferred to a base map having a scale of 1 inch equals 1 mile. Some of the outcrops were mapped in the field directly on the base map. The mapped stratigraphic units are those recognized by the United States Geological Survey 7/ and the Kansas Geological Survey. 8/

The field party obtained all the available records of tests made on the construction materials of Cloud County by the State Highway Commission of Kansas and investigated the sources of the materials. Samples of construction materials not previously reported were collected and subjected to routine laboratory tests in the Road Materials Laboratory of the State Highway Commission in Manhattan, Kansas.

A portion of each sample of aggregate material was examined under a binocular microscope in the laboratory of the Department of Geology, Kansas State College, and the constituent rock and mineral grains were determined. The laboratory tests, mineralogical analyses, and the information from other sources are presented in table 1, a summary of materials tests.

ACKNOWLEDGMENTS

The field procedures and the form of this report follow the practices initiated by Frank E. Byrne of the United States Geological Survey for similar inventories of materials in other Kansas counties. Generous assistance in the compilation of the areal map or of construction materials data by the following is appreciated: the State Highway Commission of Kansas at Topeka, S. E. Horner, chief geologist, and R. D. Finney, engineer of materials, and his associates; the Kansas office of the Ground Water Branch, United States Geological Survey, V. C. Fishel, district engineer, and A. R. Leonard, geologist; the State Geological Survey of Kansas at Lawrence, J. C. Frye, executive director; the Cloud County office of the Soil Conservation Service, United States Department of Agriculture, C. W. Naylor in charge; Clifford A. Palmquist, county engineer of Cloud County; and Don J. Christensen, resident engineer for the State Highway Commission of Kansas at Concordia.

This report, in manuscript form, was reviewed critically by various members of the State Highway Commission of Kansas and the United States Geological Survey. The petrographic determinations were made by R. F. McCormack of the United States Geological Survey.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

GENERAL

This discussion of the geologic formations that crop out in Cloud County emphasizes the areal distribution, the general characteristics, and the thickness of each stratigraphic unit. One or more representative measured sections are given for each formation or member except for those that were homogeneous or very thin. The measured sections are

[6] Weather Bureau, U. S. Department of Commerce, Climatological Data Kansas section, 1937 to 1946.

[7] Wilmarth, M. G., Lexicon of geologic names of the United States: U. S. Geological Survey Bull. 896, pts. 1 and 2, 2396 pp., 1938.

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

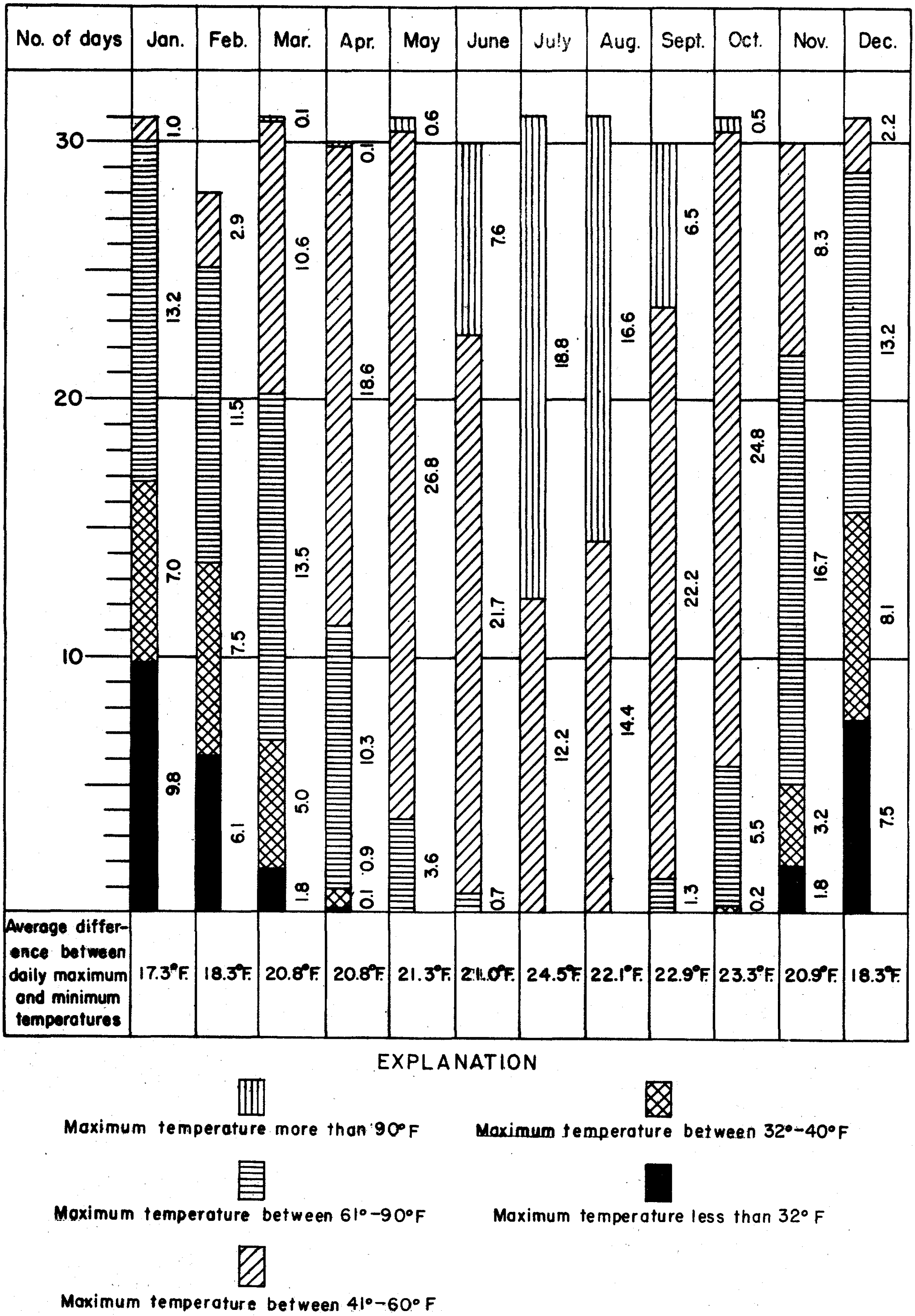


Figure 2.— Chart showing temperature ranges at Concordia, Kansas.

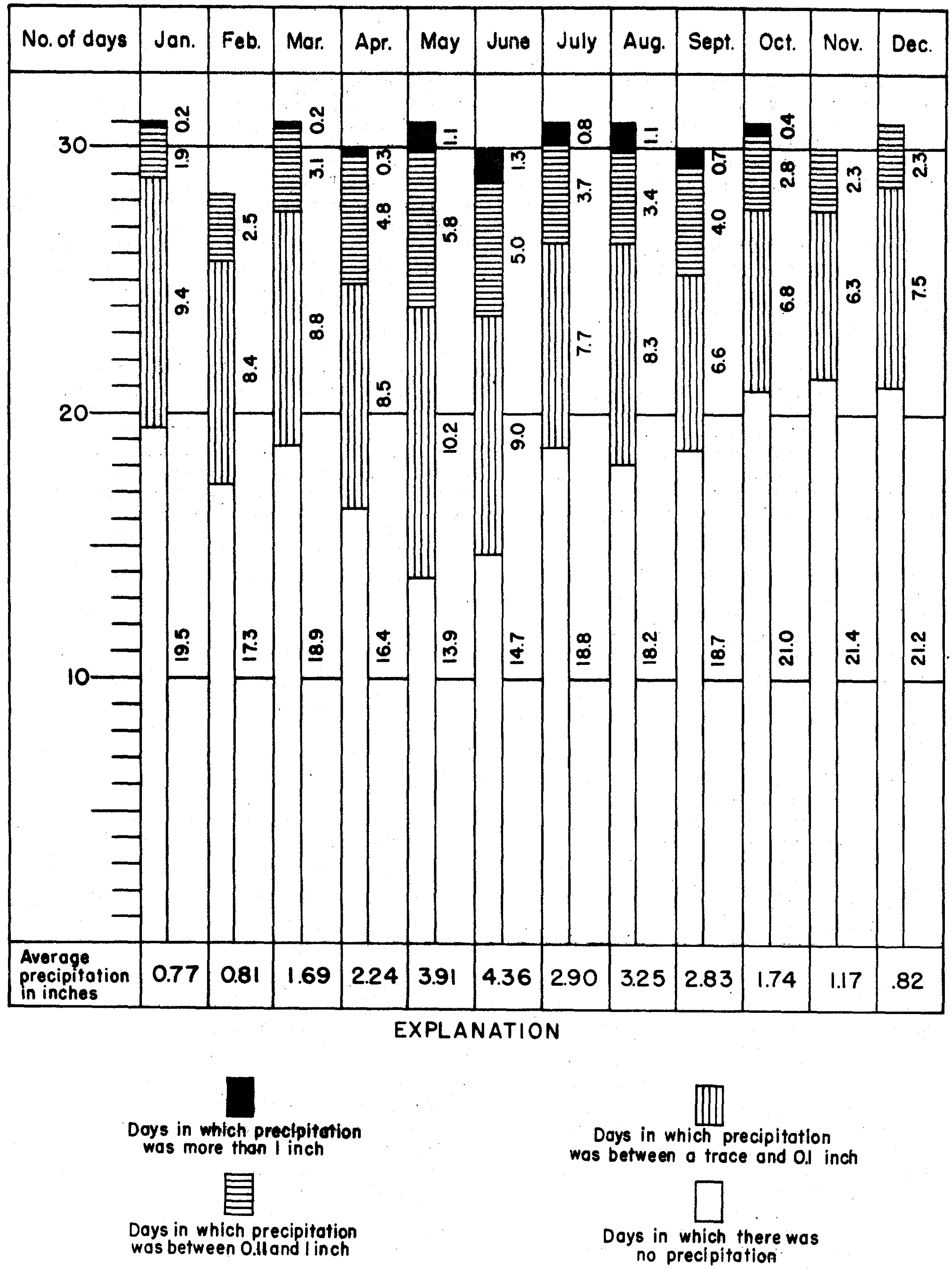


Figure 3.– Chart showing precipitation ranges at Concordia, Kansas.

not intended to be complete but were selected to show typical outcrops of a unit in the county. The construction materials in each stratigraphic unit are listed. This part of the report presents the geological information required for the location and the effective development of the construction materials.

A summary of data for each unit is presented in figure 4, Outcropping stratigraphic units in Cloud County, Kans., and the relationships of these stratigraphic units are illustrated in figure 5, Geologic cross section along the line A-A'.

The areal distribution of the local stratigraphic units is shown on plate 1, Map of Cloud County, Kans., showing construction material resources and geology. Each unit is indicated by an identifying symbol and its outcrop areas are shown by a distinctive pattern overprinted in color. Roads, railroads, and streams are shown on the map to provide a basis for evaluating the accessibility of sources of construction materials.

The locations of pits and quarries are shown also on plate 1. The symbols indicate whether the pit or quarry is or has been operated or is a prospect, the type of construction material available at each site, and the quantity of material (in units of 10,000 cubic yards) that can be removed under no more than moderate overburden (unconsolidated material less than 6 feet thick). Most of these sources are listed in table 1. Materials listed on the map in 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 northwesternmost township and continues along the same tier to the east boundary of the county; it is continued in the next tier south starting again with the township in the westernmost range and proceeds to the east boundary of the county, and so on.

DAKOTA SANDSTONE

Areal distribution.--The Dakota sandstone of Late Cretaceous age is the oldest stratigraphic unit that crops out in Cloud County. (See pl. 1 and fig. 4.) It underlies all of the county but crops out most extensively in the eastern and southern parts. The northeast quarter is generally an area of gentle relief in which resistant sandstones have formed scattered knolls and hills, the largest of them being north of the Republican River and west of Hollis. The most conspicuous exposures of the Dakota sandstone are found in the southeast quarter of the county, and westward to the valley of the Solomon River where cemented and case-hardened sandstones have formed many knolls and large hills. The Dakota sandstone crops out along both the north and south walls of the valley of the Solomon River. South of the river are several large hills of Dakota sandstone. There are minor outcrops along the south valley wall of Buffalo Creek, along both valley walls of Wolf Creek, and south of the Republican River near Concordia. In the divide area between the Solomon and Republican Rivers the Dakota sandstone is overlain by the Graneros shale and Greenhorn limestone.

General description.--The Dakota sandstone consists of clay, shale, siltstone, and sandstone. Locally, it contains iron oxide concretions, quartzitic sandstones, carbonaceous material, and lignite. 9/

A large part of the formation is made up of variously-colored clays and in the areas where they predominate the topographic relief is gentle. Exposures of the clays and shales can be seen occasionally in stream banks and road cuts. The clays are usually mottled light gray and red to purple, and may include white, yellow, or brown zones.

The sandstones are mainly thick, lenticular channel-deposits and generally are cross-bedded fine-grained soft, friable, and gray, tan, or brown. Lenses of hard, cemented sandstones may occur at any place in the section. Cementing materials include iron oxide, calcite, dolomitic calcite, silica, and barite, and mixtures of two or more of them.10/ The most common cementing agent is iron oxide and many of the sandstones contain a high percentage of iron either disseminated throughout or in the form of concretions. Hills are often capped by fine-grained iron-rich sandstone that has case-hardened to a dense, brittle, dark-brown to purple "ironstone."

Concretions in the sandstones may occur in several forms, such as: spherical masses of sand, cemented with iron oxide, ranging from less than an inch to several feet in diameter; iron-cemented shells filled with loose sand or gray clay; pellets of concretionary iron; and gnarled layers of concretionary iron.

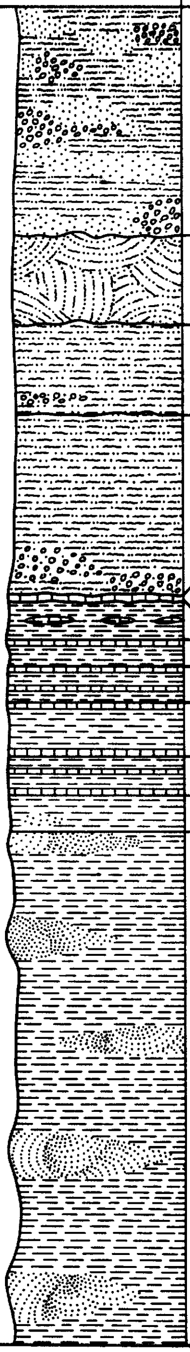
Carbonaceous materials in the Dakota sandstone include fossil leaves, lignitized stems and roots, lignitic clays, and lignite. A lignitic shale bed near the top of the formation outcrops in a stream bank in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 1, T. 5 S., R. 3 W. The lignite is weathered and is shaly to papery, gray to black, and about 1.5 feet thick.

Representative measured sections.--The following section of the Dakota sandstone was measured near the center of the SW$\frac{1}{4}$ sec. 34, T. 8 S., R. 1 W.:

	Feet
Dakota sandstone:	
Top of hill covered with fragments of gnarled iron-cemented sandstone.	
Sandstone, medium-grained; resistant; orange brown to dark brown	10
Sandstone, fine-grained, friable; brown............................	30
Sandstone, medium-grained; cross-bedded; forms bench; dark brown......	5
Sandstone, fine-grained, massive; some beds cross-bedded; brown......	38
Sandstone, fine-grained, hard, iron-rich; cross-bedded; brown...........	2
Sandstone, very fine-grained; cross-bedded; tan gray, gray orange, red brown........................	23

9 Moore, Frye, and Jewett, op. cit., p. 153.

10 Swineford, Ada, Cemented sandstones of the Dakota and Kiowa formations in Kansas: Kansas Geol. Survey Bull. 70, pt. 4, 104 pp., 1947.



Outcrop thickness (feet)	System	Series	Formations and members	Generalized description	Construction materials
0-125	Quaternary	Recent	Alluvium	Light-brown silt with numerous lenses and layers of sand and gravel interbedded.	Aggregate Road metal
0-50	Quaternary	Recent	Dune sand	Tan-gray, cross-bedded, wind-blown silt and sand; characterized by hummocky topography.	Aggregate Mineral filler
0-50	Quaternary	Recent	Terrace deposits	Upper part gray-brown silt locally with buried soil zones; lower part silt with thin lenses of sand and gravel.	Mineral filler Road metal
0-100	Quaternary	Pleistocene and Recent(?)	Sanborn formation	Upper part tan-gray or gray-brown silt locally with buried soil zones; basal part gray-orange to red-brown silt and locally interbedded lenses of sand and gravel.	Mineral filler Aggregate Road metal
0-1	Tertiary	Pliocene	Ogallala formation	Mottled gray and tan, hard algal limestone.	
0-20?	Cretaceous	Upper Cretaceous	Carlile shale		
0-15	Cretaceous	Upper Cretaceous	Fairport shale member	Orange or yellow-brown chalky shales with interbedded thin lenses of chalk.	
0-20	Cretaceous	Upper Cretaceous	Greenhorn ls.: Pfeifer shale member	Interbedded orange-gray chalky shales and thin tan-gray chalky limestones.	Structural stone Road metal
0-28	Cretaceous	Upper Cretaceous	Greenhorn ls.: Jetmore chalk member	Interbedded thin gray chalky limestones and blue-gray calcareous shales.	Structural stone Road metal
0-22	Cretaceous	Upper Cretaceous	Greenhorn ls.: Hartland shale member	Calcareous gray shales interbedded with thin chalky limestones and thin bentonites.	Structural stone Road metal
0-20	Cretaceous	Upper Cretaceous	Greenhorn ls.: Lincoln limestone member	Interbedded thin crystalline limestones, calcareous shales, and thin bentonites.	Structural stone Road metal
	Cretaceous	Upper Cretaceous	Graneros shale	Blue-gray noncalcareous clay shale, thin bentonites; sandstone lenses in basal part.	
0-280	Cretaceous	Upper Cretaceous	Dakota sandstone	Lenses of tan to brown cross-bedded sandstone interbedded with gray, tan, brown, or red silt or clay shales.	Road metal Structural stone Riprap

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

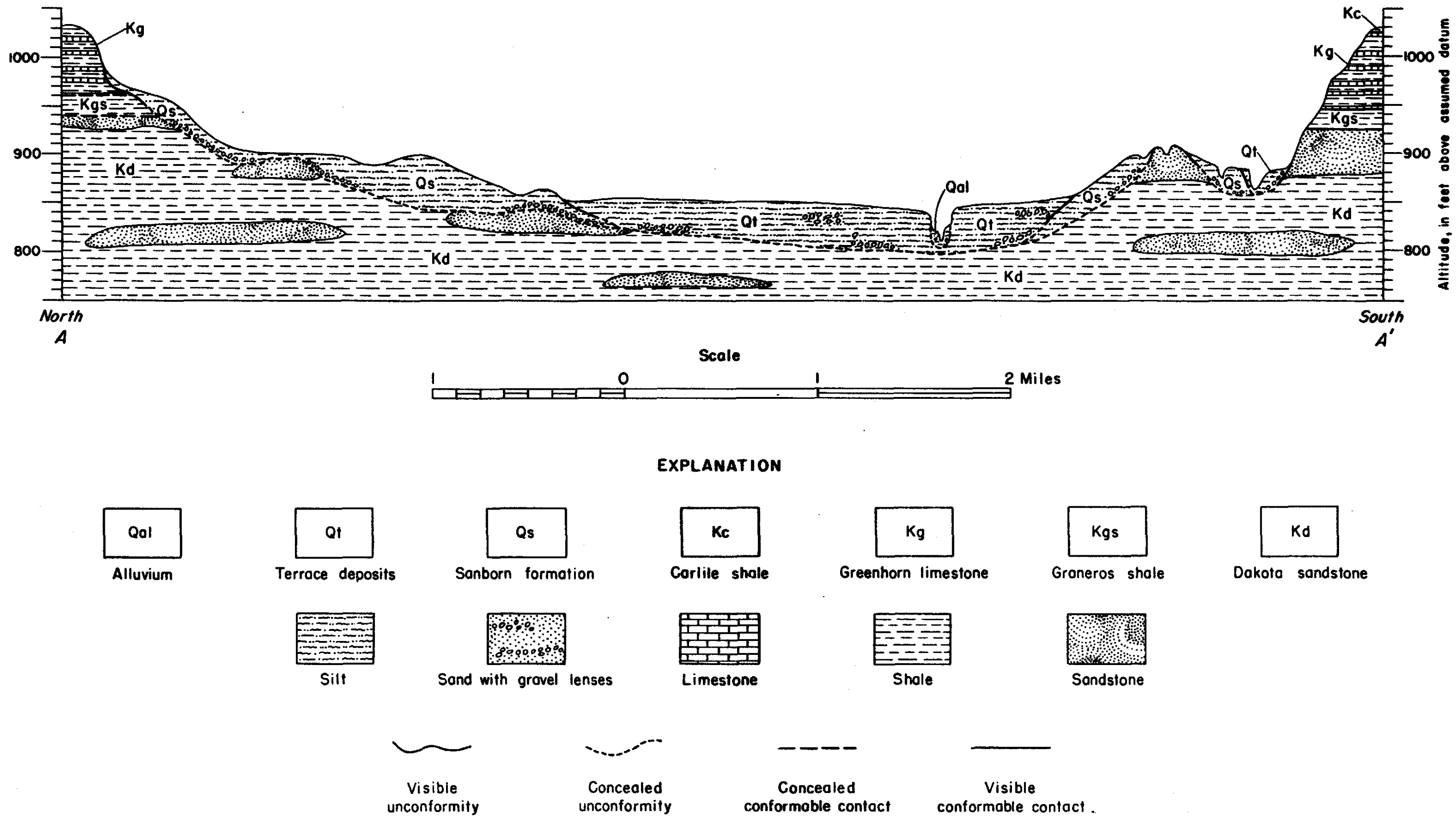


Figure 5.– Cross section along the line A–A' from the northwest corner of sec. 19, T. 7 S., R. 5 W., southward to the southwest corner of sec. 19, T. 8 S., R. 5 W.

Dakota sandstone--Continued.

	Feet
Sandstone, very fine-grained, iron-rich; concretionary; dark brown.....	1
Base covered.	109

A road cut in the NE¼ NE¼ sec. 4, T. 8 S., R. 4 W., shows the following section of the Dakota sandstone:

	Feet
Dakota sandstone:	
Sandstone, fine-grained, friable, massive, gray; contains 3 layers of harder sandstone, red purple, 0.5 to 1 foot thick; several large lenticular masses of concretionary quartzite, silica-cemented, texture fine to coarse, very hard, dense, massive, jointed, gray, tan gray, and red brown......................	17
Sandstone, fine-grained, friable, massive; gray tan to brown; numerous nodular to large round concretions composed of sand cemented with iron oxide........................	25
Base covered.	42

The following section of the Dakota sandstone is exposed in the NW¼ SW¼ sec. 34, T. 8 S., R. 5 W.:

	Feet
Dakota sandstone:	
Sandstone, fine-grained, hard; iron-rich; concretionary; variably red, red brown, brown, bluish-purple; fossilized wood and leaves on bedding planes; numerous hollow pipes lined with ironstone......................	0.5
Clay, slightly silty; tan gray.........	1.5
Clay, sandy, silty; red brown........	7.7
Sandstone, fine-grained, soft, friable; gray orange; composed of compacted fine sand and silt; cross-bedded; lenticular.........................	8.5
Base covered.	18.2

Thickness.--Wing states that nearly 400 feet of the Dakota sandstone outcrops in Cloud and Republic Counties. 11/ By computing the difference in elevation between the lowest and highest outcrops in the vicinity of Miltonvale, an estimate of about 280 feet is obtained as the maximum thickness in any locality in Cloud County. Outcrops range in thickness from a few feet to 110 feet.

Construction materials.--The clay beds in the Dakota sandstone are used as a source of ceramic material. Plummer and Hladik 12/ report that a ceramic slag suitable for use as lightweight aggregate can be manufactured from these clays. Quartzite-like sandstone from this formation is used as: road metal, structural stone, and riprap.

GRANEROS SHALE

Areal distribution.--The Graneros shale of Upper Cretaceous strata outcrops only locally in Cloud County. (See pl. 1 and fig. 4.) It can be seen in only a few outcrops along the divide area between the Solomon and Republican Rivers. Rapid erosion or road cut excavations in these places has stripped away the loess, colluvium, or slope wash that elsewhere conceals the soft shales of the formation. Undoubtedly there are other areas bordering the outcropping Greenhorn limestone where the Graneros shale is only thinly covered by younger sediments.

General description.--The Graneros shale lies on the Dakota sandstone and beneath the Greenhorn limestone. It is a marine formation composed largely of nonfossiliferous clay shale. The shale is blue gray to black and weathers gray or red brown. The upper part contains a bentonite bed, or thin interbedded layers of bentonite, about 1 foot thick. The shale also contains small lenses of iron-stained brown sandstone, and crystals of gypsum which range in size from sand grains to plates nearly a foot long and an inch thick. The basal part of the Graneros shale may contain lenses of channel sandstone locally.

Representative measured section.--The following section of the Graneros shale was measured in a road cut along the west edge of the SW¼ sec. 19, T. 8 S., R. 5 W., on the Cloud-Mitchell county line:

	Feet
Soil:	0.5
Carlile shale:	5.8
Greenhorn limestone:	75.4
Graneros shale:	
Clay shale, thin-bedded; dark gray, weathers red brown; fine gypsum grains between beds................	0.9
Bentonite; cream and orange; partly streaked with iron stains...........	1.0
Clay shale, thin-bedded to papery; non-calcareous; blue gray, weathers light gray; thin seams of gypsum fill joint cracks; streaks of altered bentonite; small lenses of iron-cemented sandstone; becomes darker near top; sandstone lenses more numerous in top 3 feet.........	10.1
Sandstone, thin-bedded, iron-stained; yellow brown to red brown; gypsum and thin seams of calcite..........	.5
Clay shale, thin-bedded to papery; non-calcareous; blue gray mottled with yellow flakes of bentonite, weathers light gray; gypsum crystals and lenses of red-brown clay; joints filled with iron oxide; lenses of red-brown sandstone in upper 2 feet................	6.1
Shale, thin-bedded, soft, non-calcareous; red brown........................	.6
Shale, slightly silty, soft, thin-bedded, non-calcareous; gray, weathers light gray..................................	2.3
Underlain by iron-cemented Dakota? sandstone.........................	21.5

[11] Wing, M. E., The geology of Cloud and Republic Counties, Kansas: Kansas Geol. Survey Bull. 15, p. 31, 1930.

[12] Plummer, N. and Kladik, W. B., The manufacture of ceramic railroad ballast and constructional aggregates from Kansas clays and silts: Kansas Geol. Survey Bull. 76, pt. 4, 112 pp., 1948.

Thickness. --The total thickness of the Graneros shale is about 22 feet. Outcrops range from 5 to 15 feet thick.

Construction materials. --The Graneros shale is not a source of construction materials. Because the formation is largely composed of highly plastic clay shale, its use in engineering construction might contribute to foundation failures and poor embankment or subgrade performance.

GREEHORN LIMESTONE

General. --The Greenhorn limestone of Upper Cretaceous strata (see fig. 4) is divided into four members: (1) the Lincoln limestone (oldest and lowest stratigraphically), (2) the Hartland shale, (3) the Jetmore chalk, and (4) the Pfeifer shale (youngest and highest stratigraphically). The formation is mapped as a single unit on plate 1, although descriptions of the several members will be given.

Areal distribution. --The Greenhorn limestone crops out most extensively in the divide area between the valleys of the Republican and Solomon Rivers (see pl. 1.) where the limestones form prominent terraces along the valley walls. In the upland areas between streams, the Greenhorn limestone is concealed by the younger Sanborn formation and the topography is flat or gently rolling. It outcrops on the hillsides along the county line north of Buffalo Creek and the Republican River, and is also exposed around the high hills near the southwest corner of the county. The formation is absent in the eastern part of the county.

General description. --The Greenhorn limestone is a marine deposit of chalky shales and limestones that lies between the underlying Graneros shale and the overlying Carlile shale. Erosion has removed the Carlile shale from much of the outcrop area and stratigraphic units of Tertiary or Quaternary age locally overlie the Greenhorn limestone.

(1) The Lincoln limestone member consists of beds of shale interbedded with numerous thin layers of limestone and seams of bentonite. The shale layers are silty or clayey, laminated, calcareous, gray or brown, and weather light tan or gray. Most of the limestones are dense, hard, and crystalline. Several are impure and soft but caseharden when exposed to air. The limestones contain fish scales and teeth, fish vertebrae, and shark teeth. The limestone bed at the base of the member and several other limestone beds in the Lincoln member have a petroliferous odor when freshly fractured. The limestones are gray or brown, and weather light gray, tan gray, or brown.

(2) About 75 percent of the Hartland shale member is calcareous silty shale. The shales are soft, thin-bedded to papery, gray, gray orange, or red brown, and weather tan gray. Most of the shale beds contain shells of a fossil clam, fish scales and teeth, and shark teeth. Limestones make up about 18 percent of the member. Most of them are thin-bedded, crystalline, hard, gray or tan gray, and contain shark teeth, fish scales, and clam shells. About 7 percent of the member is bentonite in thin layers ranging from 0.03 to 0.65 foot thick. The bentonite is tan gray, gray orange, or red brown.

(3) The Jetmore chalk member consists of interbedded limy shales and chalky limestones, with a ratio of about 70 percent shale and 30 percent limestone. The shales are very limy, thin-bedded, and tan gray; some are fossiliferous. The limestones are chalky in contrast to the crystalline limestones of the Hartland and Lincoln members. They are buff or tan gray, and contain clam fossils.

The top of the Jetmore chalk member is marked by the "Shellrock" limestone bed, so called because it contains an abundance of clam shells. It is a tan-gray, chalky limestone about a foot thick that forms terraces around the shoulders of hills throughout central and western Cloud County. This bed has been quarried extensively for use as a building stone and grassed-over trenches mark old quarries around many hills where the "Shellrock" outcrops.

(4) The Pfeifer shale member consists of tan-gray or gray-orange, thin-bedded or platy limy shales containing several layers of chalky fossiliferous limestone. At its top, arbitrarily separating the Greenhorn limestone from the overlying Carlile shale, is the "Fencepost" limestone bed. This bed is a tan-gray chalky limestone with a rust-colored band in the middle part; it contains many clam shells. There are few outcrops of the "Fencepost" limestone bed in Cloud County. Outcrops of the Pfeifer shale generally show only a few feet of the lower part of the member.

Representative measured sections. --The following measured sections show the characteristics of the various members of the Greenhorn limestone as they outcrop in Cloud County:

(1) A cut bank along the west edge of the SW$\frac{1}{4}$ sec. 19, T. 8 S., R. 5 W., along the Cloud-Mitchell county line:

	Feet
Soil:	0.5
Carlile shale:	5.8
Greenhorn limestone:	
Pfeifer shale member:	14.3
Jetmore chalk member:	15.9
Hartland shale member:	
Limestone, massive, hard; mottled gray and red brown, weathers light red brown; iron concretions through middle form weak zone; calcite seams; scattered shell fragments, fish scales, shark teeth, fossil coiled cephalopod.....	.4
Bentonite, friable; tan gray............	.2
Shale, silty, calcareous, thin-bedded, soft; tan gray, weathers light gray and has chalky, brittle appearance; iron oxide stains; fish scales, shark teeth, clam shells. (Note: this bed locally is blue black and quite carbonaceous)..	2.4
Shale, very silty, calcareous, thin-bedded, fairly hard; red brown, weathers tan gray; iron-staining on bedding planes; fish scales........................	2.65
Limestone, chalky, soft; tan gray, weathers light gray.................	.15

Hartland shale member of Greenhorn limestone--Continued.

	Feet
Shale, silty, calcareous, thin-bedded, soft; tan gray intermingled with gray orange, weathers tan gray	.85
Bentonite, friable; mottled red brown and gray orange, weathers tan gray	.65
Limestone, very soft, chalky; shows no bedding; light gray, weathers tan gray; iron-stained on fracture surfaces; no fossils noted	.3
Shale, silty, calcareous, soft, thin-bedded; gray orange intermingled with red brown, weathers light gray; iron stains on bedding planes; fish scales and teeth	2.1
Limestone, hard, shows no bedding; tan gray, weathers light tan gray; thin calcite seams; iron stains; fish teeth and scales, shell fragments	.3
Shale, silty, calcareous, thin-bedded; red brown, weathers gray orange; iron stains; fish scales	.45
Shale, clayey, calcareous, blocky, soft; gray orange, weathers gray	.35
Bentonite, friable; orange	.2
Shale, slightly silty, soft; gray orange, weathers light gray; contains some bentonite	.35
Shale, very silty, calcareous, blocky; massive; tan gray and red brown mixed, weathers light gray; iron stains on fracture surfaces; shell fragments, fish scales	1.3
Bentonite, platy; orange	.2
Limestone with shale partings, thin-bedded; gray to gray orange; fish scales and teeth, clam shells	2.2
Limestone, laminated; light gray to gray, weathers tan gray; small limonite concretions; no fossils noted	.2
Shale, silty, calcareous, platy; light gray to red brown, weathers tan gray; thin calcite partings; fish scales and teeth, clam shells	1.40
Bentonite, platy; orange	.05
Shale, silty, calcareous, platy; light gray to red brown, weathers tan gray; thin calcite partings; fish scales and teeth, clam shells	.8
Bentonite, blocky; orange	.1
Shale, silty, calcareous, platy; light gray to red brown, weathers tan gray; thin calcite partings; fish scales and teeth, clam shells	3.3
Bentonite, blocky; orange	.2
Shale, silty, calcareous, platy; gray orange to gray, weathers tan gray, fish scales and teeth, clam shells	.3
Bentonite, blocky; gray orange to brown	.2
Shale, silty, calcareous, platy; brown, weathers tan gray; fish scales and teeth, clam shells	1.0
Bentonite, blocky; orange; lenses of iron oxide	.15
Shale, silty, calcareous, platy; brown, weathers tan gray; fish scales and teeth, clam shells	.6
Limestone, thin-bedded, crystalline; beds separated by very thin shale partings; gray weathers tan gray; fish scales and teeth, clam shells	.5
Shale, silty, calcareous, platy; gray orange intermingled with light gray, weathers tan gray; very thin, gray crystalline limestone partings; fish scales and teeth, clam shells	1.3
Bentonite, platy, orange	.05
Limestone, soft, blocky; gray orange, weathers tan gray; fish scales and teeth, clam shells	.1
Bentonite, blocky; orange	.1
Shale, silty, calcareous, platy; few thin limestone partings; brown to red brown, weathers tan gray; fish scales and teeth	1.4
Limestone with shale partings, thin-bedded; shale partings silty, calcareous; red brown, weathers tan gray; limestone somewhat crystalline; fish scales and teeth	1.0
	27.8

Lincoln limestone member:

	Feet
Limestone, dense, crystalline; tan gray, weathers gray; fish scales, clam shells	.3
Shale, silty, calcareous, platy; brown, weathers gray; fish scales, clam shells	.1
Bentonite, platy; orange	.05
Limestone, thin-bedded; light gray, weathers tan gray; fish scales	.2
Shale, silty, calcareous, platy; brown to black, weathers gray; clam shells	.3
Bentonite, blocky; gray orange	.3
Shale, silty, calcareous; brown	.1
Limestone, platy, soft, impure, silty; dark gray mottled with red brown; casehardens when exposed; color pattern follows jointing; irregular seams of lignite; fish scales, shark teeth, clam shells	.4
Shale, silty, calcareous, thin-bedded, soft; dark gray intermixed with red brown, weathers gray; fish scales, shark teeth	.3
Bentonite, blocky, soft; red brown	.3
Limestone, silty, soft; gray brown, weathers tan gray; abundant fish scales	.05
Shale, silty, calcareous, thin-bedded, soft; gray brown, weathers light gray; fish scales	.1
Limestone, hard, crystalline, very platy; red brown, weathers tan gray; fish scales in bedding planes; shark teeth	.1

Lincoln limestone member of the Greenhorn lime-stone--Continued.

	Feet
Shale, silty, calcareous; red brown, weathers tan gray; red brown streak in middle part containing iron oxide concretions; unfossiliferous.......	.4
Shale, clayey, calcareous, laminated; gray brown to black, weathers tan gray; fish scales; interbedded irregular thin lenses of red brown, hard, crystalline lime-stone containing fish scales and small clay pellets............	.4
Bentonite; cream and red brown...........................	.3
Shale, clayey, calcareous, thin-bedded, soft; blue gray to black with gray orange streaks; small gypsum crystals between bedding planes; unfossiliferous...........	4.9
Shale, slightly silty, thin-bedded, soft; red brown, weathers tan gray; gypsum crystals in fracture joints; unfossiliferous............	5.1
Shale, silty, calcareous, thin-bedded, soft; red brown; thin layers of crystalline limestone.....	1.4
Limestone, crystalline hard, thin-bedded; gray to gray orange; thickness and thins laterally.......	.6
Shale, clayey, calcareous; gray orange; interbedded thin, platy, crystalline limestones............	.8
Limestone, crystalline, hard, persistent; dark gray; fish scales, shark teeth..............	.2
Limestone, crystalline, hard, platy; dark gray, weathers tan gray; fish scales, shark teeth; interbedded layers of brown shale..	.7
Graneros shale:	21.5

Dakota sandstone: Base covered.

(2) A cut bank on U. S. Highway No. 24 in the SW¼ SW¼ sec. 8, T. 8 S., R. 5 W.:

	Feet
Soil: silt, humus, limestone pebbles......................	1.0
Greenhorn limestone:	
Pfeifer shale member:	
Shale, chalky, thin-bedded, soft; tan gray to gray orange; thin lenses of chalky limestone; clam shells..................	4.0
Jetmore chalk member:	
"Shellrock" limestone bed; chalky; tan gray; abundant clam shells; unweathered surfaces soft, weathered surfaces hard; exposed rock fractured and split by frost action in bedding planes........	.9
Shale, chalky, thin-bedded; light gray, weathers tan gray; interbedded thin lenses of chalky, fossiliferous limestone...	2.2
Limestone, dense, hard; gray, weathers tan gray; clam shells........................	.35
Shale, chalky, thin-bedded to platy; gray, weathers tan gray; thin lenses of fossil-iferous limestone..............	.85
Limestone, crystalline dense, hard; gray, weathers tan gray; clam shells......................	.4
Shale, calcareous, thin-bedded to platy; gray, weathers tan gray; clam shells.................	.75
Limestone, crystalline, dense, hard; gray, weathers tan gray; clam shells.....................	.4
Shale, calcareous, thin-bedded to papery; gray, weathers tan gray; clam shells................	.6
Limestone, crystalline, dense, hard; gray, weathers tan gray; clam shells.....................	.35
Shale, calcareous, very thin-bedded to platy; gray, weathers tan gray; clam shells.....................	.45
Limestone, chalky, hard; tan gray...	.2
Shale, calcareous, thin-bedded; top 0.1 foot orange; light tan to tan gray; very chalky at base; clam shells.................	1.5
Limestone, dense, hard; light gray, weathers tan gray; fossil fragments.................	.3
Shale, calcareous, very thin-bedded to platy; gray, weathers tan gray...	.5
Limestone, very chalky, soft; tan gray..........................	.15
Base covered.	9.9

(3) A cut bank on U. S. Highway No. 81 in the SW¼ NE¼ sec. 16, T. 6 S., R. 3 W.:

	Feet
Soil humus, shale and limestone fragments.....................	0.50
Greenhorn limestone:	
Jetmore chalk member, lower part:	
Shale, very limy, platy; tan gray and red brown, weathers light tan gray; thin lenses and layers of limestone; clam shells........	3.35
Limestone, dense, hard; gray, weathers tan gray; iron staining in middle part; fish scales, fossil fragments, clam shells....................	.25
Shale, very limy, thin-bedded; light gray, weathers tan gray; disc-scaped fossiliferous limestone nodules; clam shells............	1.0
Limestone, chalky; light tan gray, weathers light gray; fossil fragments, clam shells....	.25
Shale, limy, thin-bedded; tan gray; shell fragments...........	.75
Limestone, hard, brittle; gray, weathers tan gray; iron stains; clam shells..................	.4

Jetmore chalk member of the greenhorn limestone lower part--Continued.

	Feet
Shale, limy, thin-bedded; tan gray and red brown, weathers tan gray; disc-shaped nodules of fossiliferous limestone; clam shells	1.3
Limestone, chalky; mottled tan gray and red brown; thin lenses of iron oxide material in middle part; thickens and thins laterally; clam shells	.2
Shale, clayey, calcareous, thin-bedded; tan gray to red brown, weathers tan gray	.45
Limestone, chalky; tan gray with red brown iron stains; thickens and thins laterally; clam shells	.15
Shale, chalky, thin-bedded; tan gray	.4
Limestone, very chalky; very light gray, weathers tan gray; clam shells	.35
Shale, limy, thin-bedded; tan gray	.35
Limestone, chalky; mottled light gray, gray tan, red brown; iron stains; clam shells	.35
Shale, limy, thin-bedded; very light tan gray	.45
Limestone, very chalky; tan gray; iron stains; thickens and thins laterally; clam shells	.2
Shale, limy, thin-bedded; tan gray	.3
Limestone, very chalky; tan gray mottled with red brown iron-staining; thickens and thins laterally; clam shells	.2
Shale, limy, thin-bedded; tan gray	.4
Limestone, chalky; mottled tan gray and red brown; iron oxide streaks in middle part; thickens and thins laterally	.3
Shale, limy, thin-bedded to platy; tan gray	.3
Limestone, chalky; tan gray; thickens and thins laterally	.1
Shale, limy; tan gray	.2
Limestone, very chalky; tan gray	.15
Shale, limy; tan gray; shark teeth	.1
Limestone, crystalline, dense, hard; mottled tan gray and red brown, weathers light red brown; iron stains and calcite filled cavities in middle part; persistent, forms ledge; clam shells	.35
	12.6
Hartland shale member; base covered	21.0

Thickness. --The section of the Greenhorn limestone measured on the county line near the southwest corner of the county (see p.10) totaled 75.4 feet thick. The thickness of each member is as follows: Pfeifer shale member 14.3 feet; Jetmore chalk member 15.9 feet; Hartland shale member 27.8 feet; and the Lincoln limestone member 17.4 feet. The formation is somewhat thicker in the central part of the county where the Jetmore chalk member is nearly 20 feet thick. The maximum thickness of the Greenhorn limestone is about 80 feet.

Construction materials. --Materials from the Greenhorn limestone are used as structural stone and road metal.

CARLILE SHALE

Areal distribution. --Only the Fairport chalky shale member of the Carlile shale outcrops in Cloud County. (See pl. 1 and fig. 4.) Outcrops are few in number, small in area, and are limited to the western part of the county.

General description. --The Fairport member is a gray-orange chalky shale which weathers a chalky cream color and contains interbedded thin beds and disc-shaped lenses of soft, chalky, orange-tan fossiliferous limestone. The Fairport member overlies the Greenhorn limestone and the contact is arbitrarily placed at the top of the "Fencepost" limestone, the uppermost bed of the older formation. The Carlile shale is concealed by the overlying Sanborn formation in most places; in at least one locality it is overlain by a thin algallike limestone of the Ogallala formation.

Representative measured section. --The following section of the Fairport chalky shale member of the Carlile shale is exposed in the SW¼ SW¼ sec. 19, T. 8 S., R. 5 W., along the Cloud-Mitchell county line:

	Feet
Soil; shaly, limy	0.5
Carlile shale:	
Fairport chalky shale member:	
Shale, chalky; gray orange, weathers light gray orange; thin discontinuous layers of chalk	1.5
Limestone, chalky; gray orange, weathers to light gray orange; thickens and thins laterally; discontinuous; clam shells	.3
Shale, chalky; gray orange	4.0
Underlain by Greenhorn limestone.	5.8

Thickness. --The thickness of the Carlile shale in Cloud County is about 20 feet. Individual outcrops average about 5 feet thick.

Construction materials. --No materials of value in engineering construction were found in this formation. The shales might be satisfactory for fills and embankments if shoulder slopes are graded to a low angle. However, outcrops of this formation are so thin and small in area that they may be disregarded as productive sources of construction materials.

OGALLALA FORMATION

Areal distribution. --The Ogallala formation of Pliocene age (see fig. 4) is not developed typically in Cloud County. Material that has been assigned to this formation outcrops near the tops of divides in three places. (See pl. 1.) In the SE¼ SE¼ sec. 7, T. 6 S., R. 4 W. a thin layer of the formation rests on the upper part of the Greenhorn limestone and is covered by loess of the Sanborn formation. The same material outcrops in a similar stratigraphic position near the top of a ridge in the SE¼ SE¼ sec. 34, T. 6 S., R. 4 W. It also outcrops in the SW¼ SW¼ sec. 18, T. 7 S., R. 4 W. where it lies on the Fairport chalky shale member of the Carlile shale and is covered by loess of the Sanborn formations.

General description. --The Ogallala formation in Cloud County is a thin, dense, hard limestone with sand grains scattered throughout. It is mottled light gray, tan gray, and red brown. In cross section, the rock shows an irregular whorled pattern. Specimens of this material have been examined by Dr. M. K. Elias, of the Nebraska Geological Survey, and by Dr. J. C. Frye, of the Kansas Geological Survey, who identified them as algal limestone of the Ogallala formation. A more detailed investigation may reveal other scattered outcrops of this formation in the county.

Representative measured section. --No section of the Ogallala formation sufficiently thick to measure was found.

Thickness. --The average thickness of the Ogallala formation is about 1 foot.

Construction materials. --This formation is so poorly developed, thin, and with so few outcrops, that it may be disregarded as a source of construction materials in Cloud County.

SANBORN FORMATION

Areal distribution. --The Sanborn formation of Pleistocene and Recent age is the most widely distributed formation mapped in Cloud County. (See pl. 1 and fig. 4.) The formation was deposited over most of the area of the county, but subsequent erosion has removed it along the courses of the larger streams, and stripped it from the steepest slopes of many hills. The most extensive phase of the formation is that which caps the uplands as a silt blanket of variable thickness. This phase of the formation is similar to, and in places merges with, a colluvial slope phase which extends up the slopes of the larger stream valleys. Silts and clays in the valley bottoms of small intermittent streams merge with the slope phase. Local lenses of sand and gravel in the basal part of the formation represent local slope wash deposits, minor gulley fillings, and terrace deposits or channel fills of former streams.

The characteristics of the silts are similar, and, with the underlying coarse sediments, are mapped as a single stratigraphic unit on plate 1. Frye and Fent 13/ have subdivided the formation into members, but it was not feasible to treat these members separately in the reconnaissance-type mapping on which this report is based. The treatment of the Sanborn formation as an undivided unit seems adequate to serve the purpose of the construction materials inventory.

General description. --The Sanborn formation is composed of material deposited by wind, streams, and slopewash, or material that has been moved down slope by the action of gravity. It consists predominantly of tan-gray, gray-orange, and red-brown silt. Where the formation overlies the Dakota sandstone, in the east and south parts of the county, it is dark red-brown, reflecting the influence of the underlying formation. The silt of the Sanborn is a very homogeneous material that tends to stand in vertical banks and shows a crude type of columnar structure. The formation generally forms a gently rolling surface, but where the headward portion of a stream valley has been cut into the formation multiple steplike scarps have formed on the slope of hills. The term "cat-step" erosion has been applied to the development of these scarps which are a foot or two high and from a few feet to 20 feet wide.

A prominent soil zone is present at the top of the formation, and a buried soil zone, reported by Hibbard, Frye, and Leonard, 14/ was observed in several places in Cloud County. Calcium carbonate occurs in the formation, either disseminated throughout or concentrated in the form of scattered nodules and pipelike concretions.

The largest deposits of gravel in the Sanborn formation occur near the southwest corner of the county along the edges of the valley of the Solomon River. Several deposits have been produced commercially in this area. These deposits are bars or lenses of stream-deposited silt, sand, and gravel, interbedded and cross-bedded. They may contain calcium carbonate, either as a cementing agent or as nodular concretions. The gravel is composed of material the size of pebbles to cobbles derived from older limestones and sandstones outcropping nearby.

Representative measured section. --The silts and clays of the Sanborn formation are so homogeneous it was not thought necessary to measure a section of them. The following section of sand-gravel in the Sanborn was measured in the NW¼ NW¼ sec. 32, T. 7 S., R. 5 W.:

	Feet
Soil, sandy; gray..................	2.0
Sanborn formation:	
Silt, sandy; orange-brown; scattered pebbles of crystalline limestone increasing in number with depth; white lime nodules; becomes more limy with depth................	6.0

13/ Frye, J. C., and Fent, O. S., Late Pleistocene loesses of central Kansas: Kans. Geological Survey Bull. 70, pt. 3, pp. 41-51, 1947.

14/ Hibbard, C. W., Frye, J. C., and Leonard, A. B., Reconnaissance of Pleistocene deposits in northcentral Kansas: Kans. Geological Survey Bull. 52, pt. 1, p. 13, 1944.

Sanborn formation--Continued.

	Feet
Sand-gravel, cross-bedded; slightly cemented with calcium carbonate; gravel predominantly thin, hard, crystalline limestone; sand clean, siliceous...............	10.5
Gravel, coarse to fine; contains scattered cobbles, silt, sand; cemented with calcium carbonate; gravel contains pebbles of fine-grained, hard, iron-cemented brown sandstone and thin crystalline limestone..........	3.5
Base covered.	20.0

Thickness. --Individual exposures of the Sanborn formation in Cloud County usually range between 5 and 20 feet thick. The maximum thickness of the formation is about 100 feet.

Construction materials. --Materials from the Sanborn formation are used as: mineral filler, aggregate for concrete, and road metal.

TERRACE DEPOSITS

Areal distribution. --Terrace deposits of Recent age are extensive in the valleys of the Republican and Solomon Rivers and their larger tributaries, and narrow extensions project into the valleys of the larger feeder streams. (See pl. 1 and fig. 4.) The terraces along Buffalo and Salt Creeks are more than a mile wide in places. Chapman Creek has developed terraces in the southeast part of the county. Terrace deposits in the stream valleys are continuous except along the north side of the Republican River. Two or more terrace levels are present but are mapped as a single unit on plate 1 because their characteristics are similar.

General characteristics. --The terrace deposits overlie older formations and are composed of materials laid down by present-day streams in earlier depositional cycles. The upper part of a deposit consists predominantly of gray-brown silt but contains some clay and sand. This silty phase of the deposits tends to develop a crude columnar structure and to stand in vertical banks. A soil profile is developed at the top of the formation, and a buried soil zone was found in many locations at a depth varying from 2.5 to 5 feet below the top of the terrace. This buried soil usually includes a thick B zone containing calcium carbonate nodules and stains. The B zone is much lighter in color than the overlying thin dark-gray A zone. The deposits may contain thin lenses of sand and gravel in the basal part.

Representative measured section. --The terrace deposits are uniformly silty except in buried soil zones and the gravel lenses in the basal part. The following measured sections illustrate these exceptions.

(1) Section of terrace deposits in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 33, T. 5 S., R. 1 W.:

	Feet
Soil very silty; contains sand, fine to coarse; gray brown....	0.5
Terrace deposits:	
Silt, sandy; contains clay-size binder; plastic when wet; tan gray........................	3.0
Clay, silty, plastic; scattered fine sand; dark gray.................	5.6
Silt; tan gray.....................	2.0
Clay, silty; dark gray brown.......	2.5
Silt, gray brown; contains unstratified gravel, fine to coarse, and cobbles, angular to well-rounded; gravel lens of limited lateral extent..........	7.1
	20.7

(2) Section of terrace deposits measured in a road cut in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 29, T. 5 S., R. 1 W.:

	Feet
Soil zone: silt, fine sand; tan gray..........................	0.8
Terrace deposits:	
Silt; tan gray......................	1.7
Buried soil zone: clay, silty, blocky; dark gray; calcium carbonate nodules and stains near base......	2.5
Silt, blocky; some clay-size binder; tan gray.................	4.0
Base not exposed.	9.0

Thickness. --It is estimated that the total thickness of the terrace deposits along the Republican and Solomon Rivers is no more than 50 feet; along Buffalo and Salt Creeks no more than 30 feet; and along other streams in the county less than 20 feet.

Construction materials. --The terrace deposits are a potential source of mineral filler.

DUNE SAND

Areal distribution. - Dune sand of Recent age (see fig. 4) occurs in the valley of the Republican River. The largest dunes are near the north boundary of the county east of the river. Other large dunes are on the north side of the river south of Hollis, west of Clyde, and south of the river in the eastern part of the county. Other areas of dune sand were noted in the valley of the Republican River but were not mapped on plate 1 because of their limited extent.

General description. --Sand dunes are deposits formed through the depositional activity of the wind. Areas of dunes are characterized by hummocky topography. The material composing the dunes is typically cross-bedded, tan-gray silt, and fine sand. The dunes in the valley of the Republican River probably represent sand spread originally by flood waters and later reworked by the wind. Most of the larger dunes have been anchored by a cover of vegetation.

Representative measured section. --The dune sands are so homogeneous that it was not thought necessary to measure a section of them.

Thickness. --The average height of the dunes is probably 10 to 15 feet, but the crests of several near the north edge of the county stand nearly 50 feet above the flood plain upon which they rest.

Construction materials. --Dune sand is of minor importance as a potential source of mineral filler.

ALLUVIUM

Areal distribution. --The recent deposits (see fig. 4) formed by streams in their present cycles are mapped as alluvium on plate 1. They, and the dune sands that locally overlie them, are the most recent stratigraphic units in Cloud County.

Alluvium is defined in this report as the material underlying the present floodplain of a stream. Alluvium is mapped on plate 1 in the valleys of the Republican and Solomon Rivers and Buffalo Creek, Alluvial deposits are present in many of the smaller valleys but are so narrow that they could not be shown on a map scaled an inch to the mile. The alluvium in the valley of the Republican River averages considerably more than a mile wide, but the alluvium in the valleys of Buffalo Creek and the Solomon River averages less than 0.2 mile wide.

General description. --The alluvium of the Republican River consists of silt and sand underlain by layers and lenses of sand and gravel. At the top, the alluvium is composed predominantly of silt deposited in the valley during floods. In the stream channel, the alluvium is principally sand deposited under the normal flow condition of the stream. Lenses or layers of sand and gravelly sand occur at different depths beneath the surface. Most of the sand and gravel particles are fragments of quartz and feldspar; minor quantities of calcite, chert, basic igneous rocks, or locally derived limestone and sandstone fragments may also be present.

The alluvium of the Solomon River is predominantly silt with only occasional lenses of sand or gravel. The alluvial deposits in other valleys of the county are composed almost entirely of dark-gray or brown silt; they contain only minor quantities of fine sand or gravel disseminated throughout or in thin lenses.

Representative measured section. --Because of the low relief of the alluvium it was impossible to measure a section representative of this formation. Logs of test holes drilled in 1942 by the State Geological Survey of Kansas have been published and a representative section from these tests follows. 15/

Sample log of test hole 89 in the NW¼ SW¼ sec. 28, T. 5 S., R. 2 W., 0.55 mile south of section line and 9 feet east of center of road.

	Feet
Alluvium:	
Soil, silty; dark gray; contains some sand	3.0
Silt, clayey; yellow gray; contains some sand	2.0
(Water level 4.3 feet below land surface)	
Sand, coarse to fine, and fine gravel; green	5.0
Gravel, medium to fine, and coarse to fine sand; green	10.0
Gravel and sand, coarse to fine	10.0
Gravel, medium to fine, and coarse to fine sand; green	10.0
Gravel and sand, coarse to fine	10.0
Gravel, medium to fine, and coarse to fine sand	6.5
Silt, soft; light green; contains some fine sand	0.5
Gravel and sand, coarse to fine	8.0
Silt, soft; buff and green	3.0
Gravel, coarse to fine	4.0
Silt, soft; buff; contains very fine sand	3.0
Gravel, medium to fine	4.0
Silt, soft; buff and blue gray; contains much fine sand	10.0
Underlain by Dakota sandstone.	89.0

Thickness. --The logs of test holes drilled by the Kansas Geological Survey 16/ show that the alluvium in the valley of the Republican River reaches a thickness of 124 feet at the north edge of the county. Test hole data for other valleys in the county are not available. It is probable that the maximum thickness of the alluvium of other streams in the county is less than 50 feet.

Construction materials. --Materials from the alluvium are used as aggregate for concrete and road metal.

INVENTORY OF CONSTRUCTION MATERIALS

GENERAL

The objective of this inventory of construction materials in Cloud County is to define the materials as they are classified in this report and to relate them to the map units in which they occur. Whenever available, laboratory test data have been introduced into the report to aid in the evaluation of the materials. The information given in table 1 is based on the standard testing procedures of the State Highway Commission of Kansas 17/ and the American Association of State Highway Officials. 18/

It is expected that prospects listed in this report will be proved by subsequent drilling, or test pitting, and that the materials themselves will be subjected to laboratory testing prior to acceptance for specific uses. Although numerous prospect pits and quarries were located, no attempt was made to complete an exhaustive survey of all possible sources of materials.

[15] Fishel, V. C., Ground-water resources of Republic County and northern Cloud County, Kansas: Kans. Geological Survey Bull. 73, p. 175, 1948.

[16] Fishel, op. cit., pp. 173-189.

[17] State Highway Commission of Kansas, Standard sepcifications for State road and bridge construction, 512 pp., 1945. Gradation factor, p. 16. Sieve analysis, pp. 333-334. Soundness, pp. 335-336.

[18] American Association of State Highway Officials, Standard specifications for highway materials and methods of sampling and testing, pt. 2, 5th ed., 361 pp., 1947. Absorption, pp. 251-252. Compressive strength, pp. 257-258. Deval abrasion, pp. 235-236. Liquid limit pp. 198-201. Los Angeles abrasion, pp. 237-239. Plasticity indes, pp. 202-204. Specific gravity, pp. 249-250. Toughness, pp. 240-241. Weight per cubic foot, pp. 253-254.

Engineering and geologic characteristics.--In table 1 and on plate 1, aggregate for concrete is classified as fine aggregate or mixed aggregate. The distinction is arbitrarily based on the percentage of material retained on a 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 the grading of almost any aggregate material may be changed by sweetening or screening to conform to required specifications.

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

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

The test characteristics of the materials included in the classification indicate that some of these materials are not suited for use in concrete. The same materials, though, might be acceptable for other aggregate uses, such as aggregate for bituminous construction or cover material.

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

(1) Alluvium. The alluvium of the Republican River is a nearly unlimited source of aggregate. The alluvium is composed of sand and a small proportion of gravel of about 1 inch maximum size. Screened aggregates from the alluvium have been widely used in engineering construction. Unfortunately, these aggregates have a poor performance record in the construction of concrete highways and bridges. An illustration of the deterioration of concrete in which these aggregates were used may be seen in the bridge on U S 81 at Concordia, Kansas. Map cracking has developed in the abutment wing walls, pier caps, and road surface.

Three samples (fa 1 to 3) of fine aggregate and four samples (ma 1 to 4) of mixed aggregate were taken from the Republican River alluvium. These aggregates cannot be rejected on the basis of the standard tests as shown in table 1. The average specific gravity of the samples tested is about 2.61; the gradation factor, about 3.75; the compressive-strength ratio in all samples was well above 1; and the tests show that the aggregates are sound.

Petrographic analyses show that the mineral and rock fragments composing the aggregates of the alluvium are predominantly quartz, potash feldspar, and coarse-grained granite with smaller amounts of other acid igneous rocks and quartzite. The proportion of quartz in the aggregates increases as the particle size decreases. Minor amounts of opaline and chalcedonic chert, which are alkali-reactive, are also present. According to Rhoades and Mielenz 19/ the particles of coarse-grained granite and potash feldspar contribute to the deterioration of concrete subjected to volume change, and the mixture of alkali-reactive rocks and mineral particles will cause a deleterious reaction between the aggregate and the paste.

(2) Sanborn formation. No material from the Sanborn formation is listed as aggregate in table 1. However, the limestone gravel deposits mapped on plate 1 are actual or potential sources of aggregate for concrete. Some of the limestone gravels from the basal part of the Sanborn formation are free of of clay and silt. Limestone gravel from the pit in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 32, T. 7 S., R. 5 W., for example, has been used in concrete construction. A sample from this pit (lg 2) was analyzed and its mineral and test characteristics are given in table 1. The analysis indicates that the coarse fraction of the material contains a high percentage of limestone fragments of local origin. The fragments are predominantly of hard, crystalline limestone, and the test characteristics of the material are apparently within acceptable limits. Undoubtedly there are other potential sources of aggregate material in the basal part of the Sanborn formation which extensive exploration would reveal. Because of the deposits are channel fills, it is likely that all of them would be limited in quantity.

Plummer and Hladik 20/ regard the clays and silts of Pleistocene age as the most promising raw materials available in the State for the manufacture of ceramic slag, if all the economic factors involved in the production are considered. The silt deposits of the Sanborn formation are friable, easily mined, free from excessive overburden, and occur in extensive deposits of uniform properties; and the quality of the finished product compares favorably with that produced from other materials. The Sanborn formation is, therefore, an important potential source of material for the manufacture of ceramic railroad ballast and constructional aggregate.

(3) Dakota sandstone. One sample of Dakota sandstone shown in table 1 (ss 3) was tested and found acceptable, under Section 107 of SHCK specifications, 1945 edition, as crushed stone for use in coarse aggregate for concrete. It is probable that other hard sandstones of the Dakota might also prove acceptable.

[19] Rhodes, Roger and Mielenze, Richard C., Petrographic and mineralogical characteristics of aggregate: American Society for Testing Materials, Materials, Special Technical Publication No. 83, p. 45, 1948.

[20] Op. cit., p. 87.

(4) Dune sand. No samples of dune sand were classified as aggregate because the material is a very fine sand and its gradation factor is below standard. The material might be of some use as an additive in bringing a concrete aggregate to the desired grading. The mineral analysis of sample mf 1 shows the dune sand to be composed predominantly of quartz with minor amounts of feldspar and chert. Additional sources of similar material are mapped on plate 1.

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

(1) Aggregate for concrete.

(2) Limestone gravel. Limestone gravel is defined by the Stated Highway Commission of Kansas as a sedimentary material composed of rounded fragments of local limestone, usually about three-fourths of an inch long, incorporated in a matrix of siltsize particles. Limestone gravel is used extensively as road metal, throughout north-central Kansas especially on secondary roads.

(3) Crushed rock. Indurated rocks are available for use as crushed stone in road construction, and some have been so used. The rocks are: (a) limestone, a compact, massive layer of calcareous material, variable in hardness; (b) quartzite, a compact, massive, hard rock in which sand and/or gravel have been firmly silica-cemented by the action of percolating ground water; and (c) sandstone, a massive rock composed predominantly of sand-size particles of quartz more or less firmly cemented by deposits of calcium carbonate, silica, or iron oxide.

The material included here under crushed rock are listed in table 1 and mapped on plate 1 under the more specific designations of limestone and sandstone because, in addition to their uses as road metal, they may be used as structural stone and riprap.

Stratigraphic sources and performance characteristics.--(1) Aggregate for concrete. Materials listed in the section on Aggregate for concrete have been used, or are available for use, in various types of road construction in Cloud County. The alluvium of the Republican River is the most widely exploited source of material for use in the base course of bituminous-mat roads, as loose road metal on light-traffic roads and in other types of road construction. Gravelly sands in the basal part of the Sanborn formation have been used in the construction of sand-gravel roads, and field observation indicates that these materials perform satisfactorily when used as loose road metal; no information is available on the performance of material from the Sanborn formation in bituminous construction.

(2) Limestone gravel. Several sources of material classified as limestone gravel are mapped on plate 1, and the test characteristics of material from four of these sources (lg 1 to 4) are given in table 1. The gravels occur as channel deposits in the basal part of the Sanborn formation. They contain limestone particles derived largely from the lower part of the Greenhorn limestone, and sandstone particles derived from iron-cemented Dakota sandstone. Because these gravels are found in channel deposits, the quantity of material in any one location is limited and several quarries appear to have been depleted. The only area in the county where this material is quarried is along both walls of the valley of the Solomon River. Additional deposits undoubtedly occur in the area and might be found by intensive search of the margins of the outcrop areas of the Sanborn formation shown on plate 1.

(3) Crushed rock.

(a) The Dakota sandstone is a potential source of material for use in road construction. Iron-cemented sandstone from the Dakota has been used in the eastern part of the county as a loose road metal on light-traffic roads. The material appears to be staisfactory when so used, but it is reported to make a "rough-riding" surface that causes excessive tire wear. The hard sandstones may also be acceptable for crushed stone base course and crushed aggregate for bituminous surfacing and resurfacing. The loosely cemented fine sandstones of this formation have a bad performance record when used as a sub-base for bituminous-mat surfacings; the mat breaks up rapidly when laid on a soft sand base. The softer sandstones are easily pulverized, admix readily, and might be used in combination with other aggregate to bring the total aggregate within grading requirements for use in a bituminous surface course.

The quartzitic sandstones (silica-cemented) or quartzitelike sandstones (lime-cemented) of the Dakota sandstone might also be used in road construction as loose road metal, or to sweeten aggregates to the grading desired for other uses. The quantity of silica-cemented sandstone is limited. One outcrop was observed in the NE¼ NE¼ sec. 4, T. 8 S., R. 2 W. This material is a massive, dense, very hard quartzite occurring in round concretionary masses within a friable gray-tan to red-brown sandstone. (See measured section, p.12) The deposit is too small to be of economic value. No lime-cemented sandstones were found in Cloud County. Intensive search of the mapped outcrop area of the Dakota sandstone might reveal additional sources of these materials.

(b) Greenhorn limestone. The limestones and shales of the Greenhorn limestone have been used rather extensively as road metal in Cloud County. Two samples of limestone (ls 1 and 2) were tested and the data given in table 1; the sources are mapped on plate 1. The thicker limestone beds near the top of the formation are quarried and the fragments stock-piled. Weathering by slaking and freeze-and-thaw causes the surficial portion of each limestone fragment to slough off. The fragments are then crushed, mixed with shales from the same formation, and applied to the road. The material tends to cement and to form a traffic-bound macadam which is acceptable for light-traffic surfacing with satisfactory performance in wet weather and little tendency toward forming dust in dry weather. Field observation indicates that a layer at least 6 inches thick should be applied or the macadam will tend to break out in critical places along the road. For the past few years high labor costs have made the quarrying and crushing of limestone and its use on light-traffic roads so expensive, that road metal from commercial pits along the Republican River is being used in Cloud County almost excusively for county and township roads. An almost unlimited amount of chalky limestone and shale from the upper part of the Greenhorn limestone is available throughout the mapped area of outcrop of this formation. No attempt has been made to map all of the operated quarries on plate 1.

MINERAL FILLER

Engineering and geologic characteristics. --Material composed predominantly of silt-size particles (50 percent or more of which pass the No. 200 sieve) is classified in this report as mineral filler. It has no more than a trace of sticks or other organic debris, but may contain minor amounts of fine sand or clay. To qualify for mineral filler, laboratory tests must indicate that this material has a low coefficient of cementation. Deficiencies of the samples tested for this characteristic are noted under Remarks in table 1. Failure of the material to pulverize easily, a factor of cementation, increases the difficulty of obtaining its uniform distribution throughout the mixture.

Stratigraphic sources and performance characteristics. --(1) Sanborn formation. Test data on two samples of mineral filler (mf 2 and 3) taken from the Sanborn formation indicate that the material is acceptable as mineral filler on the basis of the sieve analysis; but the test results show a high cementation factor, 84. 6, for sample mf 2. Sample mf 3,taken froma different locality, has a much lower cementation factor, 28. The Sanborn formation is the most widespread source of mineral filler in Cloud County and pits could be opened at any convenient site throughout the area of its outcrop. For this reason only two prospect pits are mapped on plate 1. It is recommended that, prior to the development of a site, the material be laboratory tested and its cementation factor determined.

(2) Terrace deposits. No sample of mineral filler from the terrace deposits was tested in the laboratory, but this stratigraphic unit is a potential source of mineral filler and has been so used in other counties in the State. Silts of some of the terrace deposits are similar lithologically to silts of the Sanborn formation; it is probable, therefore, that the test characteristics are about the same. A sample should be laboratory-tested to determine the cementation factor prior to the development of a site.

(3) Dune sand. Two samples of dune sand (mf 1 and 4) were tested in the laboratory. The sieve analysis of sample mf 1 indicates that the material from this source is too coarse to classify as mineral filler as only 6. 27 percent passed the No. 200 sieve. The analysis of sample mf 4 indicates that the dune sand from this source is fine enough to classify as mineral filler. Seventy-four percent passed No. 200 sieve; and the cementation factor is within acceptable limits. Other dunes are mapped on plate 1 and might prove to be sources of acceptable material. Because the sand composing the dunes is variable in particle size and limited in quantity, dune sand is only of minor importance as a potential source of mineral filler in the county.

RIPRAP

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

Stratigraphic sources and performance characteristics. --(1) Dakota Sandstone. The quartzitic sandstones and the quartzitelike sandstones in the Dakota are acceptable for use as riprap. The rock is sound and the Los Angeles abrasion loss is within acceptable limits; the absorption factor is not excessive; and the specific gravity is well above the minimum limit. (See table 1.) Similar material from the Dakota sandstone has been used as riprap on numerous earthen dams in central and northcentral Kansas, including the recently constructed Kanopolis dam. Field observations indicate that the rock is acceptable for this use. The less well-cemented zones of the Dakota sandstone are probably not acceptable for use as riprap because of excessive losses through abrasion and freeze-and-thaw.

(2) Greenhorn limestone. Chalky limestones from the upper part of the Greenhorn limestone have been used for riprap in northcentral Kansas and two dams riprapped with this material were observed in Cloud County. Field observation indicates that this stone is not satisfactory when so used. It disintegrates rapidly through slaking and freeze-and-thaw and soon loses its protective value. The development of the Greenhorn limestone as a source of riprap is inadvisable.

STRUCTURAL STONE

Engineering and geologic characteristics. --Structural stone, as defined in this report, is any hard, dense rock material that can be quarried and cut to the desired size and shape. Materials fulfilling these requirements occur in the Dakota sandstone and the Greenhorn limestone in Cloud County.

Stratigraphic sources and performance characteristics. --(1) Dakota sandstone. The Dakota sandstone is used as structural stone, to a limited extent, in Cloud County and other counties in which the formation outcrops. The quartzitic and quartzitelike phases of the formation are probably entirely acceptable as structural stone; the iron-cemented and loosely cemented sandstones are probably not acceptable, although the iron-cemented sandstone has been used in some buildings in the county. The amount of quartzitic and quartzitelike sandstone now known in Cloud County is quite limited. Intensive exploration of the outcrop area (see pl. 1) may yield additional sources.

(2) Greenhorn limestone. Two limestone beds in the Greenhorn limestone have been used in Cloud County and adjacent counties as structural stone. The "Fencepost" limestone bed at the top of the Pfeifershale member of the Greenhorn is used extensively throughout a wide area in northcentral Kansas, even to a considerable distance from the area of outcrop. A few buildings constructed of "Fencepost" limestone were observed in western Cloud County. The area of outcrop of this bed is mainly in T. 7 S., R. 5 W., where small outcrops were found in section 7, 13, 14, and 24. It is possible that test pitting elsewhere in this township might reveal other sources of this stone.

The "Shellrock" limestone bed at the top of the Jetmore chalk member of the Greenhorn limestone has been extensively quarried and used in Cloud County for structural stone; so many quarries have been opened in this bed that only a few of them have been mapped on plate 1. Additional quarries could be opened at any convenient site in the area of outcrop. Field observation indicates that this limestone is suitable as a structural stone in this area. Structures built of it stand up very well in the relatively dry climate of northcentral Kansas. A church in the SW¼ SW¼ sec. 18, T. 8 S., R. 3 W. was built of the "Shellrock" limestone in 1880. The rough-hewn stone has weathered well and there is no indication of serious deterioration of the stone itself, although mortar has come out from between blocks in many places necessitating tuck pointing. Other old buildings were observed in which the stone was pitted by weathering but otherwise little affected.

The "Shellrock" limestone bed has also been used in the construction of small bridges, culverts, and retaining walls for bridge approaches or terraces. The rock used in the arches of several old stone bridges is well preserved. However, in many bridges, culverts, and retaining walls where the rock is subjected to surface-water run-off or ground-water seepage, the more highly fossiliferous blocks have been split by freeze-and-thaw action along the surfaces of the fossil shells. Under these conditions, the "Shellrock" limestone is not entirely satisfactory and care should be used to select only the most massive and least fossiliferous stone available.

Interior—Duplicating Section, Washington, D. C. 88545

Table 1. Summary of materials tests

(Blank spaces indicate data not available)

Location, thickness, and sieve analysis

Classification of the material	Number on Plate 1	Location: Fraction of 1/4 section	Location: 1/4 section	Location: Section	Location: Township (S)	Location: Range (W)	Estimated quantity of material (in cubic yards)	Average thickness: Material (in feet)	Average thickness: Overburden (in feet)	Accessibility	Geologic formation or member	Authority for test data[1]	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)
Fine aggregate	fa1	NW	SW	14	5	4	150,000	90	0	Fair	Alluvium	SHCK USGS	7-29-48	0	0	1	68	97	2.55
	fa2	NE	SW	26	5	3	150,000	90	0	Good	Alluvium	SHCK USGS	8-10-48	0	0	0	17	100	0.25
	fa3	NE	NW	35	5	1	150,000	90	0	Good	Alluvium	SHCK USGS	8-10-48	0	0	0	22	99	0.80
Mixed aggregate	ma1	NE	SW	26	5	3	150,000	90	0	Good	Alluvium	SHCK USGS	8-10-48	0	2	11	60	99	0.51
	ma2	NE	SW	26	5	3	150,000	90	0	Good	Alluvium	SHCK USGS	8-10-48	0	4	15	71	96	2.89
	ma3	SW	NW	33	5	2	150,000	90	0	Good	Alluvium	SHCK USGS	7-19-48	0	4	14	80	98	1.35
	ma4	NE	NW	35	5	1	150,000	90	0	Good	Alluvium	SHCK USGS	8-10-48	0	4	18	82	99	0.90
Limestone gravel	lg1	SE	SE	30	7	5	5,000	10	1-4	Good	Sanborn formation	SHCK USGS	1-28-42	3	8	13	40	99	0.50
	lg2	NW	NW	32	7	5	50,000	11	5-10	Good	Sanborn formation	SHCK USGS	3-9-46	3	5	9	26	99	0.90
	lg3	SW	NW	27	8	5	10,000	10	2	Fair	Sanborn formation	SHCK USGS	4-29-46	5	11	24	61	86	13.0
	lg4	SW	NE	16	8	4	10,000	12	2	Good	Sanborn formation	SHCK USGS	9-14-48	16	34	52	77	89	9.29
Mineral filler	mf1	SE	SE	4	5	4	50,000	15	1	Poor	Dune sand	SHCK USGS	7-17-48	0	0	0	0	75	6.27
	mf2	SE	NE	31	5	3	24,000	10	1	Good	Sanborn formation	SHCK	7-17-48	0	0	0	0	2	95.4
	mf3	NE	SE	35	5	2	100,000	10	1	Good	Sanborn formation	SHCK	7-17-48	0	0	0	0	0	97.4
	mf4	NE	NE	2	6	1	10,000	8	1	Good	Dune sand	SHCK	1-20-42	0	0	0	1	7	74.0
Sandstone	ss1	SE	NE	4	6	2	1,000	8	2-5	Good	Dakota sandstone	SHCK	9-15-48						
	ss2	SE	SE	10	8	4	5,000	20	1	Good	Dakota sandstone	SHCK	5-19-36						
	ss3	SW	SW	24	8	3	5,000	32	1	Good	Dakota sandstone	SHCK	5-4-46						
	ss4	NW	NW	11	8	1	8,000	10	1	Good	Dakota sandstone	SHCK	10-13-48						
Limestone	ls1	NE	NE	20	6	4	1,000	1	4-8	Fair	Jetmore shale member	SHCK	9-14-48						
	ls2	NW	NE	16	6	3	1,000	1	3-5	Fair	Jetmore shale member	SHCK	5-2-36						

Description of the material[2]

Number on Plate 1	Fraction	Quartz	Feldspars	Acid igneous rocks	Basic igneous rocks	Quartzite	Limestone or chalk	Calcareous shale	Sandstone	Chert, opal or chalcedony	Magnetite	Mica
fa1	C	20	25	35		20		tr				
	F	75	10	3		2	tr			10		
fa2	C											
	F	85	5	5		tr	tr			5		
fa3	C											
	F	85	3	5		2				5		
ma1	C	15	30	35		10			tr	10		
	F	70	10	5		5	tr			10		
ma2	C	15	40	45				tr		tr		
	F	55	40	5			tr			tr		
ma3	C	5	15	55		15	5			5		
	F	50	20	20		5	tr			5		
ma4	C	5	30	45	tr	10	10					
	F	60	25	5	tr					10		
lg1	C	tr					60	40				
	F	80	10	tr			5			5		
lg2	C	10					90					
	F	85	10				5		tr			
lg3	C						95		5			
	F	5					85		10			
lg4	C						60		40			
	F	20					20		60			
mf1	C											
	F	90	5							5	tr	tr
mf2	C											
	F											
mf3	C											
	F											
mf4	C											
	F	85	5							5	tr	5
ss1	Mottled gray, purple, and brown sandstone											
ss2	Red-purple iron-cemented sandstone											
ss3	Dark red-brown sandstone											
ss4	Dark brown iron-cemented sandstone											
ls1	Light blue-gray limestone; large fossils											
ls2	Light blue-gray limestone; large fossils											

Laboratory test data

Number on Plate 1	Weight per cubic foot (dry)	Specific gravity (saturated)	Gradation factor	Compressive strength ratio: 1 day	Compressive strength ratio: 3 days	Los Angeles percent loss	Soundness[3] ratio (25 cycles)	Toughness	Cementation	Absorption	Liquid limit	Plasticity index	Color[4]	Remarks
fa1	109.4	2.60	3.94	1.31	1.55	33.1	0.96						st	Acceptable for concrete in culverts if material complies with sieve analysis and deleterious substance requirements.
fa2	105.6	2.62	2.78	1.21	1.20								st	Opaline and chalcedonic particles are deleterious because of reactivity with cement alkalies.
fa3	106.4	2.61	2.86	1.44	1.32								cl	
ma1	113.8	2.61	3.87	1.71	1.64								cl	Fairly high percentage of alkali-reactive opaline and chalcedonic particles.
ma2	113.1	2.60	4.08	1.70	1.69								st	
ma3	107.7	2.60	4.29	1.45	1.47								st	
ma4	110.5	2.61	4.43	1.38	1.51								st	Fairly high percentage of alkali-reactive opaline and chalcedonic particles in fine fraction.
lg1	114.0	2.62	3.55	1.33	1.12	32.4	0.97							Calcite cements together many of the grains of the fine fraction and surrounds many pebbles of limestone and shale.
lg2	110.5	2.63	3.09	1.68	1.40	28.3	0.94						cl	Mixed aggregrate for concrete, bituminous surface course, sheet asphalt, cover material, surfacing by SHCK specifications of 1945.
lg3			3.85			33.4								Acceptable for clay-gravel surface course under SHCK specifications of 1945.
lg4			5.13				0.90							
mf1														Percent on No. 100 sieve too high; material might be used as blending sand.
mf2	100.0	2.63							84.6					Material consists of gray-orange calcareous silt and clay. Cementation factor too high.
mf3	78.8	2.60							28.0					Material consists of tan-gray silt and clay.
mf4	81.3								12.0					Material consists of gray-brown silt and fine sand.
ss1		2.63				35.7	0.97			2.18				Tested by SHCK for earthworks and culverts 4-23-46 and found acceptable for Type I wash checks.
ss2	139.0	2.35					OK	5		3.20				Deval abrasion loss, 17.0 percent. Tested and accepted by SHCK for bituminous mat base course.
ss3	153.5	2.56				32.0	0.98	7		3.22				Coarse aggregate for concrete, aggregate for bituminous surfacing or or resurfacing, or crushed stone base course.
ss4		2.44				61.5	0.94			5.99				
ls1		2.21				49.5	0.87			10.0				Not sound; fairly high absorption factor.
ls2	130.0	2.25					OK			7.53				Fairly high absorption factor. Pronounced satisfactory for riprap under SHCK specifications of 1934.

1. SHCK, State Highway Commission of Kansas. SHCK and USGS, sieve analysis and laboratory tests by State Highway Commission of Kansas; sample collection and description of material by U. S. Geological Survey.
2. C, coarse fraction, retained on No. 4 sieve; F, fine fraction, passed through No. 4 sieve; tr, trace.
3. Loss ratio.
4. Color, st, straw; cl, clear.