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GEOLOGIC CONSTRUCTION-MATERIAL RESOURCES IN REPUBLIC COUNTY, KANSAS

By

Frank E. Byrne, Henry V. Beck,
Vincent B. Coombs, and Wendell B. Johnson

PREPARED IN COOPERATION WITH THE
STATE HIGHWAY COMMISSION OF KANSAS

R. C. Keeling, State Highway Engineer
S. E. Horner, Chief Geologist
R. D. Finney, Engineer of Materials

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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. A field party composed of personnel from the two cooperating agencies was sent into Republic County, Kans., in the summer of 1947 to investigate sources of engineering construction materials and to map their geologic occurrence. This report of the Republic 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 Republic County that would be of use in the construction of dams, irrigation canals, highways, railways, airports, or other engineering projects. Additional geologic data are included in this report, but only to the extent of providing information useful in the development of the prospects reported in the inventory or for the location of other materials required for future engineering needs.

Area covered by the investigation

Republic County is in the first tier of counties south of the Kansas-Nebraska border and in the eighth tier east of Colorado. (See fig. 1.) It comprises 20 townships and covers an area of about 720 square miles. The county is bounded by parallels 39°39'15" and 40°00' north latitude and meridians 97°22'15" and 97°54'45" west longitude. It is bounded on the east by Washington County, on the south by Cloud County, on the west by Jewell County, all in Kansas, and on the north by Nuckolls and Thayer Counties in Nebraska.

Geography of the area

Topography.--Republic County is near the eastern boundary of the Plains Border division of the Great Plains physiographic province. 2/ The boundary between the Great Plains province and the Central Lowlands province is about 10 miles to the east in Washington County, Kans. The land surface in Republic County has been dissected to a rolling topography of moderate relief. Valleys cut into the unconsolidated sediments that cap the divides are rather shallow and have widely flaring walls, whereas valleys that have been cut through the unconsolidated sediments into the underlying consolidated rocks generally are 100 feet or more below the rolling upland surface and have steep walls. Outcrops of limestones of Cretaceous age (see fig. 4) form prominent rock terraces along these valleys, and in the southeastern part of Republic County the Dakota sandstone, also of Cretaceous age, forms a conspicuous series of rounded hillocks along the sides of the valleys.

The lowest altitude in the county, about 1,320 feet, is near the southeast corner where Elk Creek leaves the county. The points of highest altitude, about 1,680 feet, are the crests of the divides in the north-central part of the county.

The wide valley of the Republican River is the most conspicuous topographic feature in the western part of Republic County. The valley walls are moderately steep, and the floor of the valley, which is more than 2 miles wide in some places, is flat and is broken only by terrace remnants and occasional sand dunes.

Drainage.--The Republican River, the principal stream in Republic County, rises in Colorado and flows generally toward the east until it reaches the northwest corner of Republic County, at which point it turns sharply and flows in a southerly direction to the south boundary of the county. (See pl. 1.) White Rock Creek in the northwestern part of the county and Salt and Elk Creeks in the southeastern part are its most important tributaries. Other tributaries to the Republican River in this county are less than 10 miles long. Mill Creek in the northeastern part of the county and Rose Creek in the north-central part are parts of the drainage system of the Little Blue River. Both Mill and Rose Creeks are much longer streams than any of the tributaries of the Republican River. A change in the course of the Republican River during glacial (Pleistocene) time will be described in the section on the Belleville formation.

There is a shallow basin a short distance southeast of Talmo in the south-central part of the county. As recently as the latter part of the nineteenth century, this basin was occupied by a salt marsh from which important supplies of salt were obtained by early settlers in the area. The history of the marsh, of which only a trace now remains, is described by Fishel and Lohman. 3/

Climate.--Republic County is in an area of continental-type climate in which the summers are long and hot and the winters short and fairly cold. The average annual precipitation is about 26.5 inches. 4/ The average date of the last killing frost in spring is April 27, and the average date of the first killing frost in fall is October 12. 5/ The average number of cloudy days is about 75 a year; of partly cloudy days, about 90 a year; and of clear days, about 200 a year. 6/

Figure 2, a chart showing temperature ranges at Belleville, Kans., was compiled from Climatological Data 7/ for the years 1937 to 1946, inclusive, to provide a basis for evaluating the temperature factor in terms of days in which construction may be carried on without detriment to the engineering structure. The chart indicates, for the 10-year period, the number

[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, fig. 1 and p. 76, 1946.

[3] Fishel, V. C., and Lohman, S. W., Geology and ground water resources of Republic County and northern Cloud County, Kans.: Kansas Geol. Survey Bull. 73, pp. 16 and 17, 1948.

[4] Flora, S. D., The climate of Kansas, Kansas State Board Agr., Rept. vol. 67, no. 285, p. 84, 1948.

[5] Op. cit., pp. 223 and 224.

[6] Op. cit., pp. 239 and 240.

[7] U. S. Dept. Commerce, Weather Bur. Climatological Data (Kansas section).

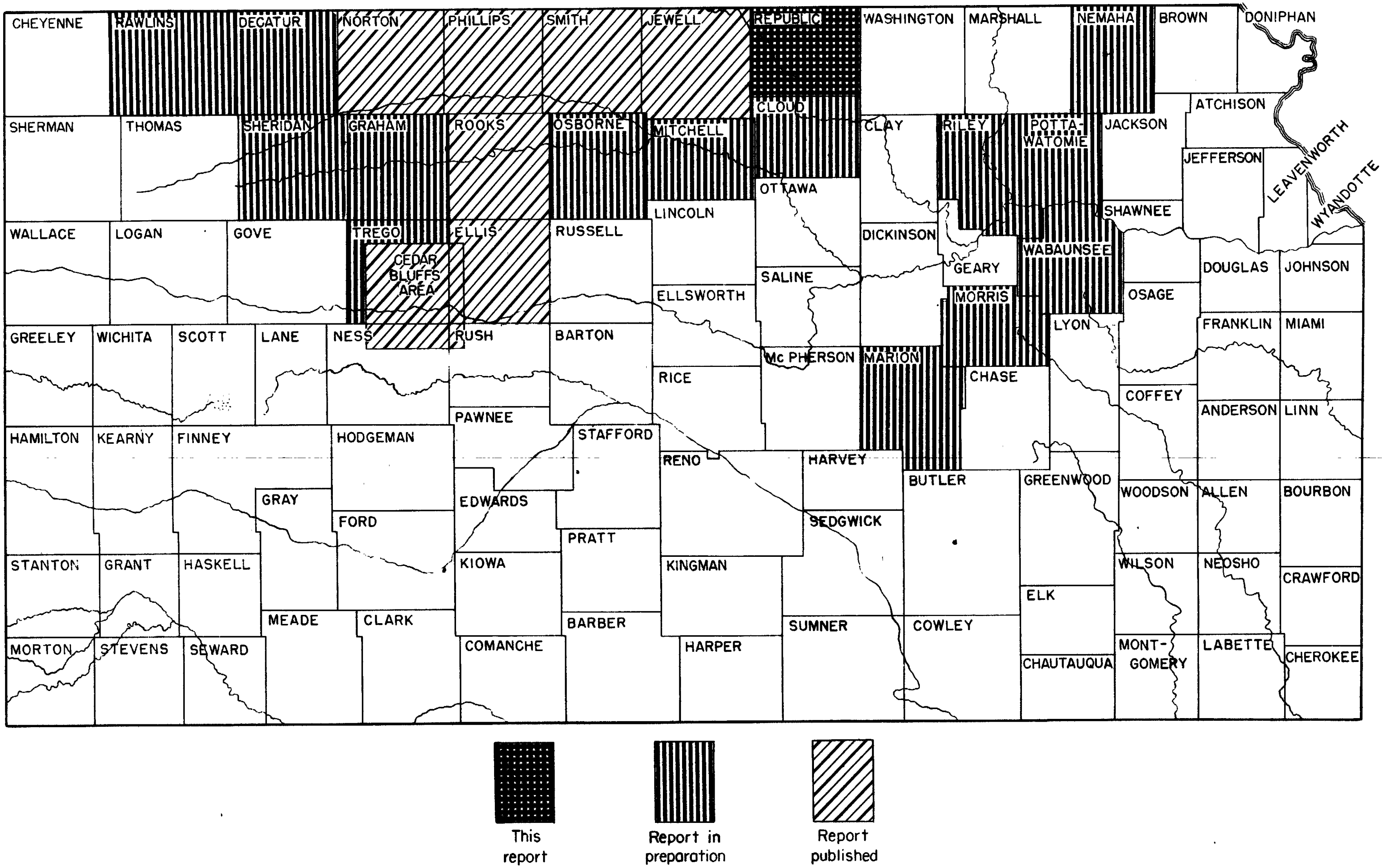
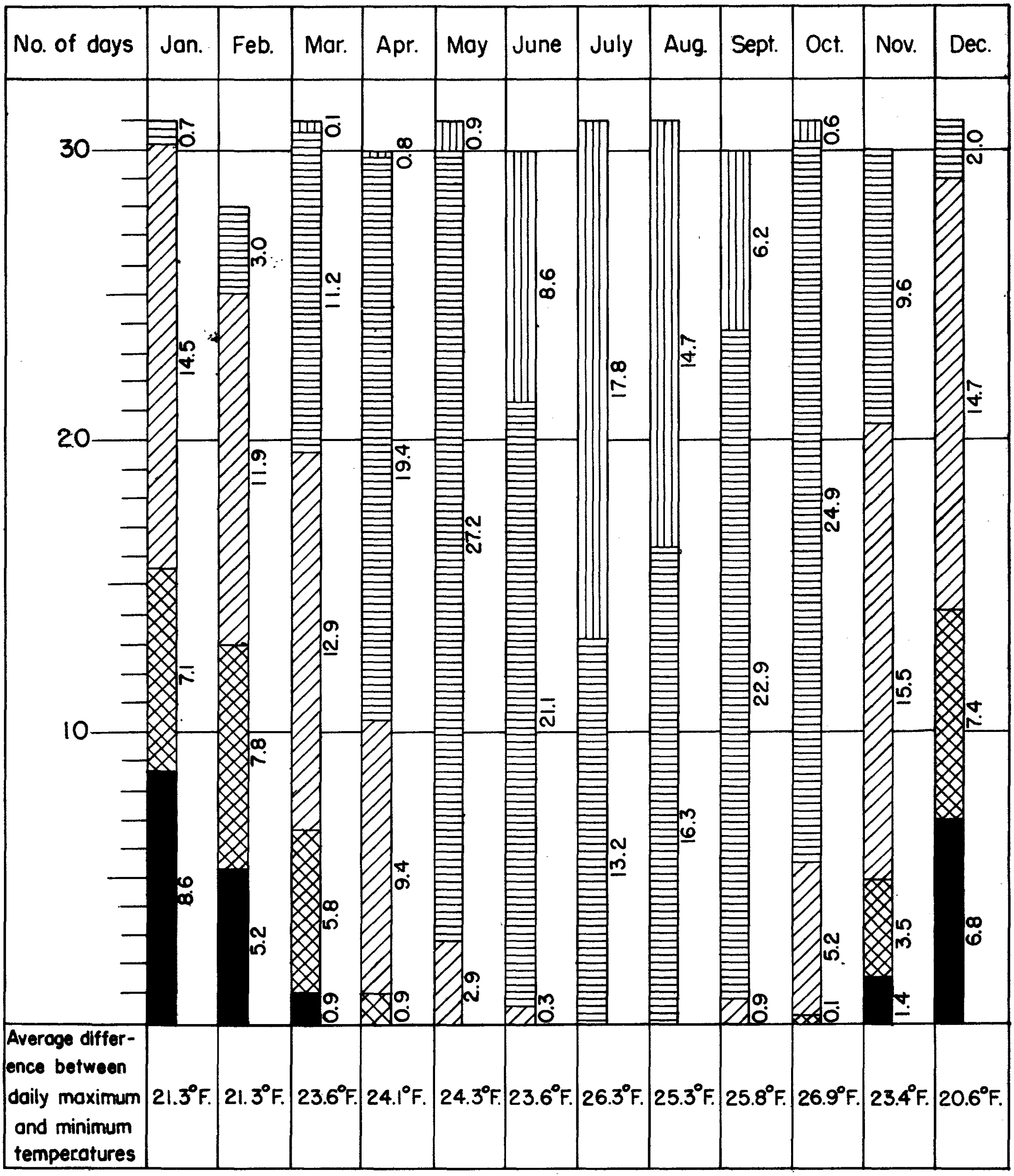


Figure 1.—Index map of Kansas showing areas covered by this report and by other construction-materials investigations.



EXPLANATION

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

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

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

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

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

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

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

of days each month in which the maximum daily temperature fell within certain designated ranges arbitrarily based on temperatures important in various phases of engineering construction. A temperature of 32° F. is the minimum temperature for laying concrete without protection; and 90° F. is the maximum temperature at which concrete may be poured without being subjected to undue evaporation loss. Bituminous construction should not be undertaken if the temperature drops below 60° F.

Days in which the maximum temperature does not exceed 32° F. occur only from November to March, inclusive, with the maximum incidence 8.6 days in January. July is the warmest month in the year, and on an average of 17.8 days maximum temperature exceeds 90° F. moreover, as the chart shows, the average difference between the daily maximum and minimum temperatures varies. The greatest difference in daily temperatures 26.9° F. is in October, and the least difference 20.6°F. is in December.

Inasmuch as precipitation also limits the number of working days in engineering construction, figure 3, a chart showing precipitation ranges at Belleville, Kans., is presented to show the effect of this climatic factor. The ranges in precipitation were selected arbitrarily. Grading and concrete construction may be carried on, with perhaps only short interruptions in the work, if no more than an inch of rain falls; bituminous surfacings probably should not be laid if the rainfall has exceeded 0.1 inch; and most construction work should cease if there has been more than 1 inch of rain.

Based on a 10-year average, 8/ there are 5 days in June, for example, in which the precipitation ranges from 0.11 to 1.00 inch and 1.8 days in which the precipitation is 1.01 inches or more. Most of the precipitation amounting to 1.01 inches or more falls as a heavy shower of short duration. Rain that amounts to 1.00 inch or less generally is gentle and lasts over a longer period of time.

Railways.--Republic County is traversed by four railways. One of the main lines of the Chicago, Rock Island & Pacific Railway enters the county at about the midpoint of the west boundary and extends eastward to Belleville. The main line then turns toward the northeast and leaves the county near the northeast corner. A branch line leading to Kansas City leaves Belleville in a southeasterly direction. Belleville, the county seat and principal city, Scandia, Courtland, Munden, Narka, Cuba, and Agenda are located along the Rock Island. A branch line of the Atchison, Topeka & Santa Fe Railroad trends south and southeast through the southwestern part of Republic County. Courtland and Kackley are served by this railroad. A branch line of the Missouri Pacific Railroad parallels the Republican River in the western part of the county; Warwick, Republic City, Scandia, and Norway are located along it. One branch line of the Chicago, Burlington, & Quincy Railroad enters from the south and extends generally northeastward through the southeastern part of Republic County, serving the cities of Wayne and Cuba. A second branch line of the same railroad approximately parallels the Kansas-Nebraska boundary line and makes two loops into the northern part of Republic County. Harbine and Warwick are located along this branch line.

Roads.--U. S. Highway 36, a major transcontinental highway, crosses from east to west through the center of the county. Belleville, Scandia, and Courtland are on this highway, and the city of Cuba is less than a mile south of it. U. S. Highway 81, an important north-south highway, crosses the middle of the county and intersects U. S. Highway 36 at Belleville. No state highways enter Republic County. The area is well served, however, by a system of county and township roads that generally follow section lines. The two Federal highways are of a bituminous type of construction, whereas the county and township roads are constructed of macadam in which local materials have been used, are surfaced with loose road metal from sources in or near the county, or are unsurfaced earth roads maintained by grading only.

Investigation procedure

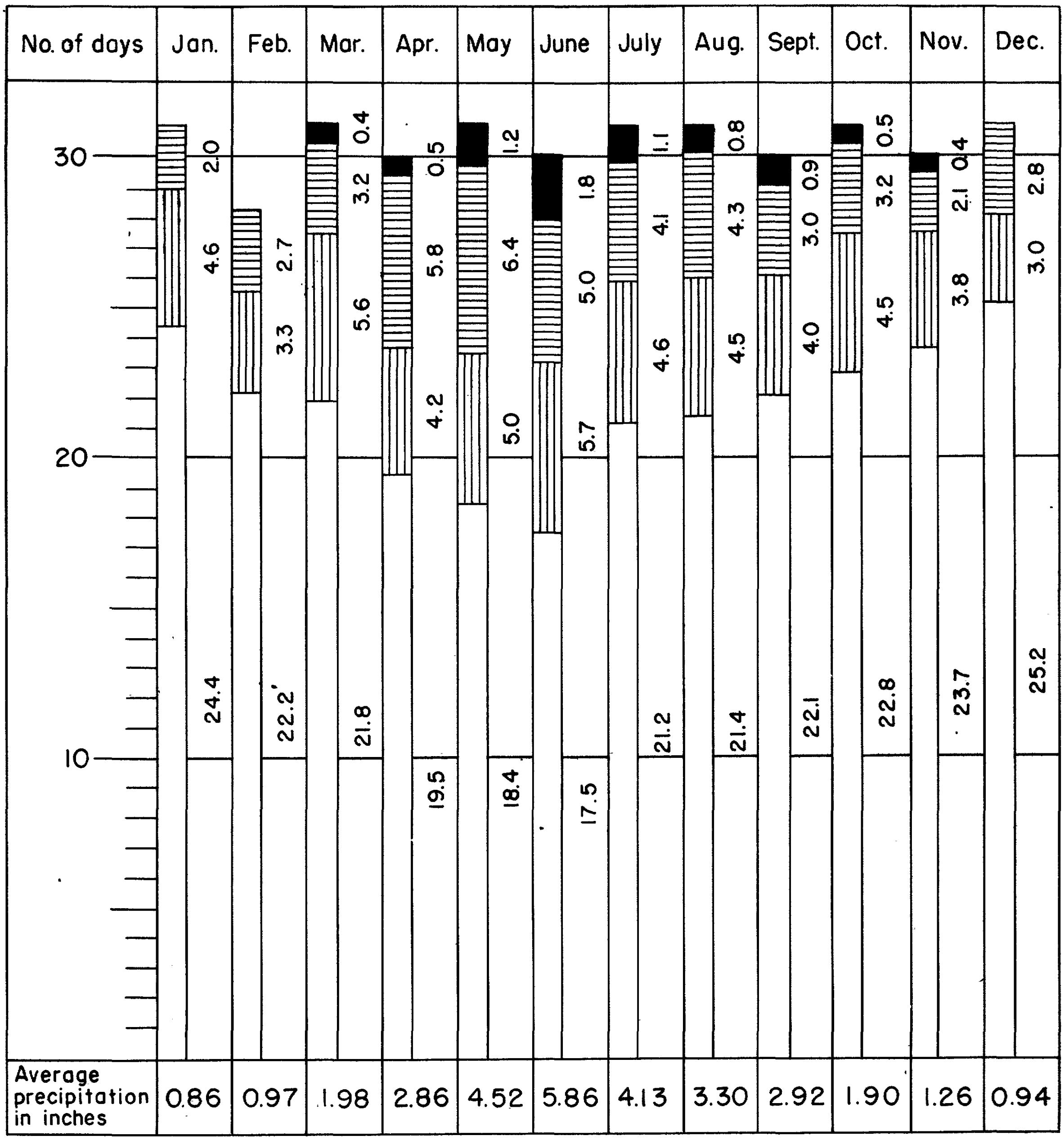
This report is based on field work of the reconnaissance type. The base map was one compiled by the State Highway Planning Department (scale, 1 inch = 1 mile), to which drainage was added from large-scale aerial photographs made available for that purpose by the Republic County office of the Soil Conservation Service, United States Department of Agriculture. The areal distribution of the stratigraphic units that crop out in Republic County was then mapped in the field. The mapped stratigraphic units are those recognized as of 1947 by the United States Geological Survey 9/ and the Kansas Geological Survey. 10/ Because the principal emphasis of the project is on construction materials, geologic problems not critically related to the presentation of information on construction materials are considered to be of secondary importance and are ignored insofar as the validity of the information presented is not affected.

An effort was made to accumulate all existing data pertaining to construction materials in the county. These data, together with their sources, are incorporated in this report. In addition, the field party collected samples of construction materials not reported previously. The samples were subjected to routine laboratory tests in the Road Materials Laboratory of the State Highway Commission in Manhattan, Kans. A portion of each sample of aggregate material was analyzed under a binocular microscope in the laboratory of the Department of the Department of Geology, Kansas State College, and the constituent rock and mineral grains were determined. The laboratory tests and mineralogical analyses, together with the information from other sources, are presented in table 1, Summary of materials tests.

[8] U. S. Dept. Commerce, Weather Bur., Climatological Summary (Kansas section), 1937-46.

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

[10] 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.



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)*

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

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

Acknowledgments

Appreciation is expressed to the following for their aid in contributing information found useful in the compilation of the geologic map or the construction-materials data included in this report: 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 Division, United States Geological Survey, V. C. Fishel, district engineer; the State Geological Survey of Kansas at Lawrence, J. C. Frye, executive director; the Republic County office of the Soil Conservation Service, United States Department of Agriculture; and the county engineer of Republic County.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

General

This discussion of the geologic formations cropping out in Republic 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. The measured sections are not necessarily 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 effective development of the construction materials.

A summary of the data for each unit is presented in figure 4, Outcropping stratigraphic units in Republic 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 Republic County, Kans., showing construction-material sources and geology. Each unit is indicated by an identifying symbol, and its outcrop areas are shown by a distinctive pattern overprinted in color. Railroads, roads, and streams are shown on the map to provide a basis for evaluating the accessibility of sources of construction materials. For more convenient use in the field, plate 1 is printed in four parts, each of which covers about one-quarter of the county. An overlap of 1 mile along the boundaries between quarters is provided, again as a convenience for field use when work is being done in the border area of one of the quarters of the map.

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 northeasternmost 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 township in the easternmost 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

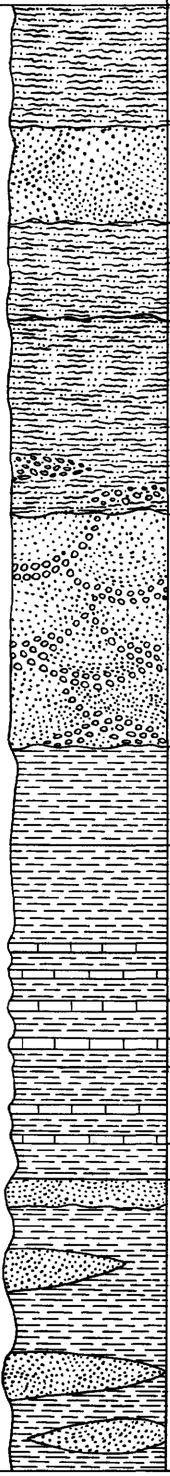
Areal distribution. --The Dakota sandstone, of Upper Cretaceous age, is the oldest stratigraphic unit that crops out in Republic County. (See fig. 4 and pl. 1.) This formation underlies the entire county but crops out only in the southeastern part. The Dakota sandstone has been eroded to form rounded, hillocklike benches along the valley walls of Mill Creek in the east-central part of the county and Elk, Cool, and salt Creeks in the southeastern part. The formation is often concealed in these valleys by younger, unconsolidated sediments: the Sanborn formation, terrace deposits, and alluvium, from which it is separated by intervening erosional breaks, or unconformities (see fig. 5). The Dakota sandstone is overlain without an intervening erosional break (conformably) by the Graneros shale, also of Upper Cretaceous age.

General description. --The Dakota sandstone consists of massive layers of cross-bedded sandstone interbedded with thick clay shales. The layers of sandstone are light gray, tan gray, or brown and vary in thickness. The cross bedding characteristic of the sandstones indicates the stream-deposited origin of the formation in contrast to the overlying, uniformly bedded marine formations of Upper Cretaceous age (see fig. 4). The constituent fine to coarse quartz grains are generally only loosely cemented by interstitial deposits of calcium carbonate or iron oxide, but locally the grains are much more firmly cemented by interstitial deposits of iron oxide and form a hard, dense ledge of ironstone. The color of the sandstone indicates the approximate quantity of iron oxide cement present, the light-gray beds containing little or no iron oxide, the tan-gray beds containing only small quantities of iron oxide, and the dark-brown ledges containing an abundance of this substance.

An outcrop of the Dakota sandstone was noted about a half mile east of Agenda in the NE¼NW¼ sec. 15, T. 4 S., R. 1 W., in which the constituent sand grains have been very firmly cemented by the deposition of silica in the pore spaces, presumably by percolating subsurface water. The cementation is so complete that the rock is classified as a quartzite. This ledge of quartzitic sandstone appears to be about 40 feet below the top of the formation but is of local extent only. Swineford 11/ reports that many quartzitelike ledges in the Dakota sandstone in several other parts of the State are calcite- or dolomite-cemented rather than silica-cemented as observed in this Republic County occurrence.

The silt and the clay shales interbedded with the sandstones have an aggregate thickness greater than that of the sandstone layers. The outcrops of the shales,

[11] Swineford, Ada, Cemented sandstones of the Dakota and Kiowa formations in Kansas: Kansas Geol. Survey Bull. 70, pt. 4, pp. 53-104. 1947.



Thickness (feet)	System	Series	Formations and members		Generalized description	Construction materials
0-60	Quaternary	Pleistocene and Recent	Alluvium		Predominantly light-brown silt with numerous sand lenses and some gravel lenses interbedded.	Aggregate Road metal
0-50	Quaternary	Pleistocene and Recent	Dune sand		Tan-gray, cross-bedded, wind-blown sand; characterized by hummocky topography.	Aggregate
0-50	Quaternary	Pleistocene and Recent	Terrace deposits		Dark-brown, gray, or tan silt with occasional lenses of sand and gravel interbedded; buried soil zone present locally.	Aggregate Road metal Mineral filler
0-100	Quaternary	Pleistocene and Recent	Sanborn formation		Predominantly gray-brown or red-brown silt but with local lenses of cross-bedded sand and gravel in basal part; buried soil zone present locally; may contain lenses of volcanic ash; tends to stand in vertical banks and may develop columnar structure.	Aggregate Road metal Mineral filler
120	Quaternary	Pleistocene and Recent	Belleville formation		Cross-bedded, tan-gray sand and gravel composed principally of quartz, feldspar, and igneous rock particles; occasional lenses of silt and clay.	Aggregate Road metal
50	Cretaceous	Upper Cretaceous	Carlile shale	Blue Hill shale member	Blue-gray, generally noncalcareous clay shale, often limonite-stained and containing septarian concretions and selenite crystals.	
80	Cretaceous	Upper Cretaceous	Carlile shale	Fairport chalky shale member	Beds of orange-brown and yellow-brown chalky shale interbedded with thin beds of soft, tan-gray, chalky limestones.	
20	Cretaceous	Upper Cretaceous	Greenhorn ls.	Pfeifer shale member	Tan, orange-gray, and gray shales interbedded with thin beds of orange-gray and gray chalky or crystalline limestones and very thin bentonite layers.	Structural stone Road metal
15	Cretaceous	Upper Cretaceous	Greenhorn ls.	Jetmore chalk member		
40	Cretaceous	Upper Cretaceous	Greenhorn ls.	Hartland shale and Lincoln limestone members		
20	Cretaceous	Upper Cretaceous	Graneros shale		Blue-black, noncalcareous clay shale with sandstone lenses in basal part.	
150	Cretaceous	Upper Cretaceous	Dakota sandstone		Lenses of tan to brown cross-bedded sandstone interbedded with lenses of gray, tan, brown, or red silt or clay shales.	Road metal Structural stone Riprap

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

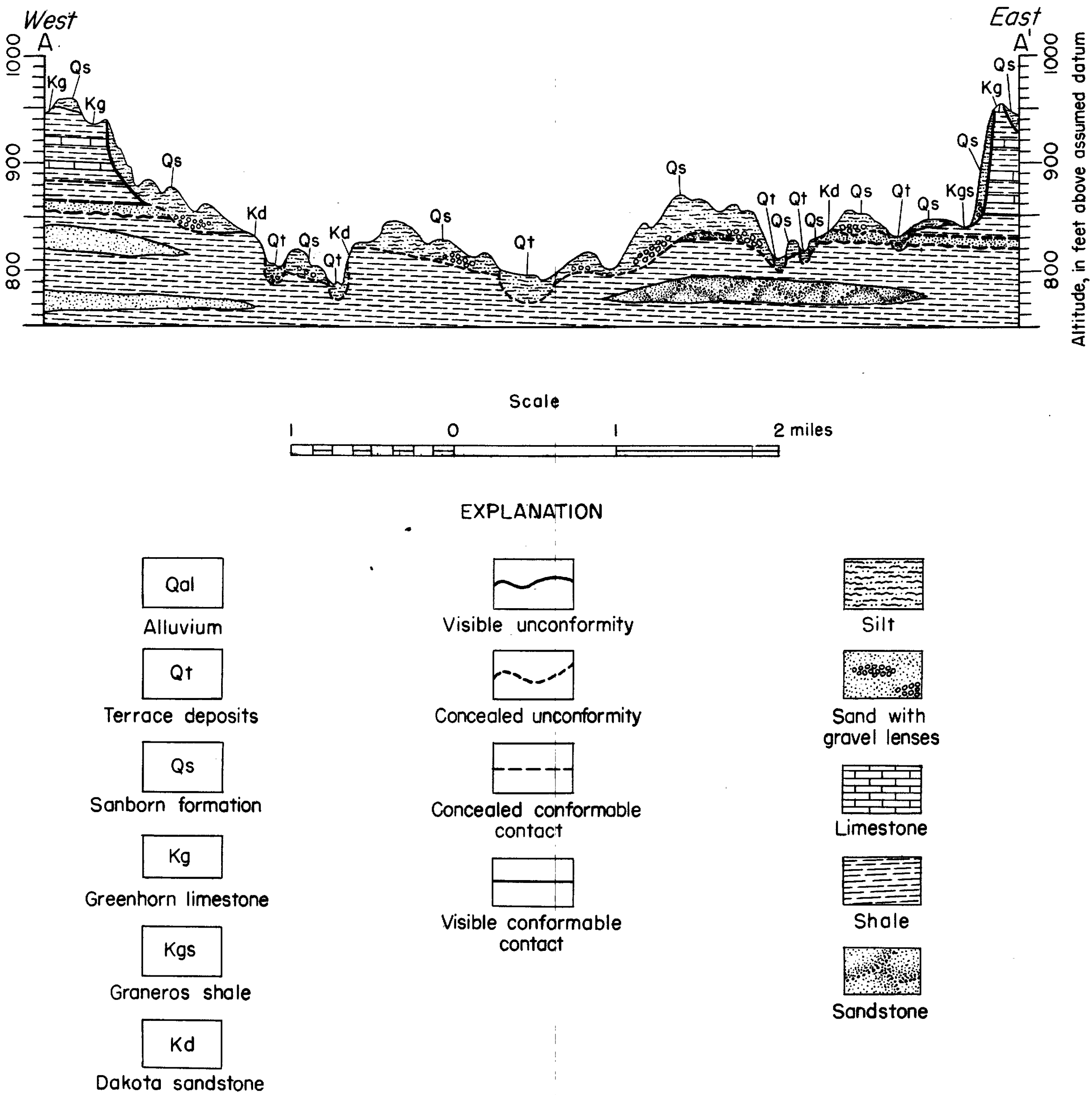


Figure 5.—Cross section along the line A-A' from the southwest corner of sec. 6 eastward to the southeast corner of sec. 1, T. 4 S., R. 1 W.

however, are not so conspicuous as those of the sandstones, because the relatively soft shales are eroded quite rapidly and the surfaces of their outcrops become masked by sandstone fragments weathered from overlying sandstone ledges. The shales are noncalcareous, blocky or thin-bedded, and exhibit a variety of colors: light to dark gray, tan, brown, and red. Fracture planes in the shales are often stained with iron oxide.

Local concentrations of carbonaceous material occur in the shales, and some lenses are sufficiently pure to be classified as lignitic coal. Wing 12/ states that a bed of coal about 2 feet thick and about 12 feet below the top of the uppermost sandstone bed was mined near Minersville in the south-central part of Republic County and the north-central part of Cloud County.

Concretions of iron oxide (limonite and hematite) are characteristic of some of the sandstone ledges, and the shales locally contain appreciable amounts of salt and gypsum. The removal of the salt by percolating ground water has resulted in salt marshes in the south-central part of Republic County. The salt and gypsum are not concentrated in the shales, but are disseminated throughout certain zones. Concretions of pyrite also occur in many of the shale layers.

Representative measured section. --The following section of the Dakota sandstone was measured along the west valley wall of Salt Creek in the SE¼NW¼ sec. 7, T. 4 S., R. 2 W.:

	Feet
Soil	1.5
Dakota sandstone:	
Sandstone, massive, soft; tan gray weathers tan; limonite-streaked	9.7
Shale, silty, noncalcareous; blocky; light blue gray; limonite-stained along fracture planes	1.0
Shale, silty, noncalcareous; very thin bedded; blue black, weathers light blue gray; interbedded thin lenses of iron-cemented sandstone	1.0
Siltstone, massive, soft; light gray; limonite-stained	1.5
Shale, silty, noncalcareous; blocky; blue gray; iron-stained on fracture planes; thin carbonaceous zones and included small crystals of gypsum; thin sandstone lenses in basal part	2.4
Shale, silty, noncalcareous; blocky; light blue gray; limonite-stained throughout	6.0
	21.6

Base covered.

Thickness. --It is estimated that a total thickness of about 150 feet of Dakota sandstone crops out in Republic County. Individual outcrops average about 20 feet in thickness, although exceptional ones may be as much as 60 feet thick. Outcrops of the Dakota sandstone are thickest near the southeast corner of the county.

12 Wing, M. E., Geology of Cloud and Republic Counties, Kans.: Kansas Geol. Survey Bull. 15, p. 34, 1930.

Construction materials. --The clay beds in the Dakota sandstone are used as a source of ceramic material, and Plummer and Hladik 13/ report that a ceramic slag suitable for use as aggregate can be manufactured from these clays. Materials from this formation have the following construction-materials uses:

Road metal.
Structural stone.
Riprap.

Graneros shale

Areal distribution. --The Graneros shale of Upper Cretaceous age, crops out only in isolated places in Republic County. (See fig. 4 and pl. 1.) The formation occurs in the valley walls in the area in which the Dakota sandstone crops out but is gennerally masked by silt of the Sanborn formation and by colluvial material carried down onto it from the overlying Greenhorn limestone. The Graneros shale has been eroded from the stream courses in the southeastern part of the county but is present in the subsurface throughout the remainder of Republic County.

General description. --The Graneros shale is composed principally of blue-black, very thin bedded, noncalcareous clay shales. Lenses of sandstone are present in the basal part of the formation and are difficult to distinguish in some places from the sandstones of the underlying Dakota. Limonitic concretions are present in the shales, and crystals of a variety of gypsum (selenite) occur locally. The Graneros shale conformably overlies the Dakota sandstone (see fig. 5). This shale and the overlying formations of Upper Cretaceous age were deposited in marine waters.

Representative measured section. --The following section of the Graneros shale and the upper part of the Dakota sandstone is exposed in a road cut in the NE¼SW¼ sec. 7, T. 4 S., R. 2 W.:

	Feet
Soil, silty, brown	1.5
Graneros shale:	
Shale, clayey, noncalcareous; light blue, weathers gray	.5
Shale, clayey, noncalcareous; very thin bedded; black, weathers blue gray; limonite-stained	6.5
Shale, clayey, noncalcareous; very thin bedded; dark gray, weathers light gray; limonite-stained	3.5
Total thickness of Graneros shale exposed	10.5
Dakota sandstone	12.0

Thickness. --The total thickness of the Graneros shale in Republic County is about 20 feet; individual outcrops of the formation, however, are seldom more than 10 feet thick.

13 Plummer, N., and Hladik, W. B., The manufacture of ceramic railroad ballast and constructional aggregates from Kansas clays and silts: Kansas Geol. Survey Bull. 76, pt. 4, p. 95, 1948.

Construction materials. --No use of material from this formation was observed in engineering structures in Republic County. The high clay content indicates that the shoulder slopes should be graded to a low angle if the Graneros shale is used in fills or embankments.

Greenhorn limestone

Areal distribution. --The Greenhorn limestone, of Upper Cretaceous age (see fig. 4), forms prominent rock terraces along the valley walls of most of the streams in all but the northwest quarter of Republic County (see pl. 1). It is concealed in the divide areas by the younger, overlying Sanborn formation and has been eroded from the valley of Elk Creek in the vicinity of Agenda and from the valleys of Cool, East, and Salt Creeks near Talmo and Wayne.

The Greenhorn limestone is divided into four members: the Lincoln limestone stratigraphically the oldest and lowest, the Hartland shale, the Jetmore chalk, and the Pfeifer shale stratigraphically the youngest and highest. However, the first two members, the Lincoln limestone and the Hartland shale, are not differentiated in this county. The Greenhorn is mapped as a single stratigraphic unit on plate 1, although discussions of the several members will be given to aid in field recognition.

General description. --The Greenhorn limestone conformably overlies the Graneros shale and is overlain in similar fashion by the Carlile shale. (See fig. 4.) It is separated by unconformities from still younger stratigraphic units, the Belleville and Sanborn formations and terrace deposits, that overlie it locally.

The sequence of undifferentiated Lincoln limestone and Hartland shale members consists of beds of shale interbedded with thin layers of limestone and seams of bentonite. The shales are thin-bedded, buff-colored in the basal part and gray blue in the upper part, and are calcareous in contrast to the underlying Graneros shale, which is noncalcareous. The shales generally are clayed but may be silty in some zones.

The thin beds of limestone, which are more numerous in the lower part of the sequence, usually are crystalline, hard, and rather massive, although in the upper part of this unit they tend to be chalky. They are tan gray to dark gray and weather buff or light gray. Invertebrate fossils are not so common in these limestone beds as they are in the limestones of the overlying Jetmore chalk and Pfeifer shale members. Fossilized shark teeth are locally abundant in the Lincoln and Hartland sequence and fossil vertebrae of bony fish have been collected from it.

Numerous persistent beds of bentonite occur in the Lincoln and Hartland sequence. The bentonites vary from 0.01 to 0.5 foot in thickness, and the thickest bed is that which is found about 5 feet below the base of the Jetmore chalk member. The unweathered bentonite is white to light gray and is often stained with limonite; it weathers a characteristic orange gray. The swelling phenomenon often associated with bentonite is only poorly developed in the bentonites of this unit.

The Lincoln and Hartland sequence erodes to rather steep sided banks from which some of the crystalline limestones project as narrow, though conspicuous, ledges formed, not by a single bed, but usually by two crystalline limestones that are close together. The limestones that form the most conspicuous of these ledges occur in the upper part of the Lincoln limestone member.

The Jetmore chalk member consists of fairly thick layers of tan-gray and blue-gray chalky shales interbedded with thinner layers of gray or cream-colored chalky limestones. Both the shales and limestones contain numerous fossil shells of a clam (Inoceramus).

The top of the Jetmore chalk member is arbitrarily defined as the top of the "shell rock," a bed of chalky limestone in which there are abundant fossil clam shells. The shell-rock bed is about a foot thick and forms conspicuous, rounded rock terraces high on the walls of many of the valleys in the county. The unweathered shell rock is quite soft, but when weathered it case-hardens markedly.

The youngest member of the Greenhorn limestone, the Pfeifer shale, consists of fairly thick beds of tan-gray shales interbedded with thinner beds of orange-gray chalky limestones that tend to be concretionary. Fossilized clam shells are fairly numerous in both the shales and limestones. The top of the Pfeifer shale member is arbitrarily defined as the top of the "Fencepost" limestone bed. The "Fencepost" limestone is about a foot thick and is easily recognized by a characteristic rust-brown band in its middle part. This bed forms an angular rock terrace throughout the area of its occurrence.

The "Fencepost" limestone and the upper part of the Pfeifer shale have been eroded from much of the eastern and southeastern parts of the county but are present in the remainder of the mapped outcrop areas of the Greenhorn limestone. The occurrence of the "Fencepost" limestone is indicated by the angular rock terrace about 20 feet above the rounded terrace formed by the shell-rock bed at the top of the Jetmore chalk and by the presence of small, crescent-shaped, abandoned quarries on the shoulders of the valley walls. The "Fencepost" bed is always present along the mapped line of contact between the Greenhorn limestone and the overlying Carlile shale. (See pl. 1.)

The shales in the Pfeifer shale member are chalky, fossiliferous, tan gray to orange gray, and thin-bedded or platy. Several thin seams of bentonite are interbedded with the shales. These are white or light gray when unweathered but weather a characteristic orange gray. Occasional thin layers of gray crystalline limestone occur in the basal part of the member.

Representative measured section. --An excellent section of all but the basal part of the Greenhorn limestone was measured by Denzil Bergman, of the United States Geological Survey, in a road cut along U. S. Highway 36 in the SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 4, T. 3 S., R. 1 W., as follows:

	Feet
Sanborn formation: Brown silt..........	20.0±
Greenhorn limestone:	
Pfeifer shale member:	

Pfeifer shale member.--Continued.

	Feet
"Fencepost" limestone bed, chalky; massive; tan gray with rust-brown streak in middle part; upper part badly weathered; fossil clam shells	1.0
Shale, silty, calcareous; platy; light gray	.1
Limestone, chalky; platy; tan gray, weathers light gray	.1
Shale, clayey, calcareous; platy; gray orange	.9
Bentonite; gray, weathers light gray	.05
Shale, clayey, calcareous; platy; gray orange	.1
Shale, somewhat silty, calcareous; platy; tan gray, weathers light gray	.4
Shale, silty, calcareous; platy; tan gray, weathers light gray; fossil clam shells	.3
Shale, silty, calcareous; platy; tan gray, weathers light gray; fossil clam shells	0.2
Limestone; massive; light gray; limonite-stained; fossil clam shells	.1
Shale, silty, calcareous; blocky; alternating zones of gray orange and light gray; fossil clam shells	1.3
Limestone, crystalline; massive; red brown and tan gray, weathers light gray	.2
Shale, silty, calcareous; blocky; gray orange and light gray; fossil clam shells	1.7
Bentonite, white	.1
Limestone; massive; gray orange, weathers tan gray; fossil clam shells	.5
Shale, silty, calcareous; platy; gray orange, weathers light gray; fossil clam shells	.2
Bentonite; light gray, with limonite stains	.05
Shale, silty, calcareous; platy; gray orange, weathers light gray; abundant fossil clam shells	0.7
Limestone; massive; tan gray, weathers light gray; limonite-stained on fracture planes; abundant fossil clam shells	.2
Shale, silty, calcareous; platy; tan gray, weathers light gray; limonite stains on fracture planes; fossil clam shells	.5
Limestone, crystalline; massive; red brown and tan gray, weathers light gray	.05
Shale, silty, calcareous; platy; gray orange, weathers light gray; fossil clam shells	.8
Limestone, crystalline; massive; red brown and tan gray, weathers light gray	.2
Shale, silty, calcareous; platy; gray orange, weathers light gray; abundant fossil clam shells	.2
Limestone, crystalline; massive; red brown and tan gray, weathers light gray	0.2
Shale, silty, calcareous; platy; gray orange, weathers light gray; abundant fossil clam shells	.5
Limestone, crystalline, interbedded with shale, silty, calcareous; limestones red brown and tan gray, weather light gray; shales gray orange, weather light gray; abundant fossil clam shells	2.9
Bentonite, gray	.5
Limestones, crystalline; red brown and tan gray; interbedded with shales, silty, calcareous, platy, gray orange, weathering light gray; abundant fossil clam shells	6.4
Jetmore chalk member:	
Shell-rock limestone bed, chalky, massive; case-hardens upon weathering; tan gray, weathers tan; abundant fossil clam shells	1.3
Shale, silty, calcareous; platy; gray orange; abundant fossil clam shells	1.15
Limestone, chalky, crystalline in middle part; massive; tan gray, weathers light gray	.2
Shale, silty, calcareous; platy, gray orange, weathers light gray; fossil clam shells	.4
Limestone, chalky, crystalline in middle part; massive; gray orange, weathers light gray; abundant fossil clam shells	.15
Shale, silty, calcareous; platy; gray orange, weathers light gray; abundant fossil clam shells	.6
Limestone, chalky, with interbedded crystalline layer; massive; tan gray, weathers light gray; abundant fossil clam shells	.4
Shale, silty, calcareous; platy; gray orange, weathers light gray; abundant fossil clam shells	.4
Limestone; massive; tan gray, weathers light gray; abundant fossil clam shells	0.1
Shale, silty, calcareous; platy; gray orange, weathers tan gray; abundant fossil clam shells	.4
Limestone, chalky, with thin crystalline zones; massive; gray orange; abundant fossil clam shells	.4
Shale, silty, calcareous; platy; light gray and gray orange; abundant fossil clam shells	.9
Limestone, chalky, with thin crystalline zones; massive; gray orange; abundant fossil clam shells	.4
Shale, silty, calcareous; platy; gray orange and light gray; abundant fossil clam shells	.8
Limestone, chalky, somewhat crystalline; massive; tan gray; small ironstone concretions; abundant fossil clam shells	.2

Jetmore chalk member.--Continued.

	Feet
Shale, silty, calcareous; platy; gray orange and light gray; abundant fossil clam shells	.7
Limestone; massive; gray orange, weathers tan gray; occasional fossil clam shells	0.2
Shale, silty, calcareous; platy; gray orange at top, grading into gray blue at base; fossil clam shells	.6
Undifferentiated Hartland shale and Lincoln limestone members:	
Limestone; massive; light gray to gray orange, weathers light gray; fossil clam shells	.2
Shale, silty, calcareous; blocky; blue black, weathers gray blue; fossil clam shells	1.5
Limestone; massive; gray, weathers tan	.4
Shale, silty, calcareous; platy; dark gray, weathers blue gray; occasional fossil clam shells	.7
Limestone; massive; gray, weathers tan	.15
Shale, silty, calcareous; platy; dark gray, weathers blue gray; some fossil clam shells	.7
Limestone, massive; dark gray, weathers light gray	0.2
Shale, silty, calcareous; platy; blue gray; some fossil clam shells	.6
Limestone; massive; dark gray, weathers light gray	.2
Shale, silty, calcareous; platy; blue gray; occasional fossil clam shells	.5
Limestone; massive; dark gray, weathers light gray	.15
Shale, silty, calcareous; platy; dark blue, weathers light blue gray; occasional fossil clam shells	.6
Limestone; blocky; gray, weathers light gray; occasional fossil clam shells	.3
Bentonite; light gray, with limonite streaks	.1
Shale, silty, calcareous; very thin bedded; dark blue black, weathers light blue gray; occasional fossil clam shells	3.0
Total thickness of Greenhorn limestone exposed	38.6
Base covered.	

Thickness.--The total thickness of the Greenhorn limestone is estimated to be about 75 feet. The thickness of the Lincoln and Hartland sequence is about 40 feet, the Jetmore chalk member is about 15 feet thick, and the Pfeifer shale member is about 20 feet thick. Individual outcrops of the formation range from several feet to about 40 feet in thickness. At no one place in the county is the total thickness of the Greenhorn limestone exposed; the representative measured section given previously is the most complete exposure of the formation.

Construction materials.--
Structural stone.
Road metal.

Carlile shale

Areal distribution.--The Carlile shale, of Upper Cretaceous age (see fig. 4), is the youngest deposit of marine origin in Republic County. It consists of three members: the Fairport chalky shale (the oldest), the Blue Hill shale, and the Codell sandstone (the youngest). The Fairport chalky shale and the Blue Hill shale members crop out in Republic County and are mapped on plate 1 as a single stratigraphic unit, the Carlile shale, because neither of them is especially important as a source of engineering construction material. General descriptions and representative measured sections of the two members will be given as aids to field recognition. The Codell sandstone member occurs a short distance to the west in Jewell County but was not identified in Republic County.

Outcrops of the Carlile shale are not numerous in Republic County; the most extensive outcrops occur along the west border of the county, and small, isolated outcrops are present in the vicinity of Belleville. Two small areas of outcrop are mapped on plate 1 in the southwestern part of the county. The formation underlies many of the divides of the county but is concealed beneath the overlying Sanborn formation. At one time the Carlile shale covered the entire area of the county, but subsequently it has been eroded from all but the divide areas.

General description.--The Fairport chalky shale, the oldest member of the Carlile shale, lithologically resembles the underlying Pfeifer shale member of the Greenhorn limestone, with which it is in conformable contact. Its separation from the Greenhorn limestone is arbitrarily based on the "Fencepost" limestone bed at the top of the older formation. The Fairport chalky shale member consists of beds of orange-brown and yellow-brown chalky shale interbedded with thin beds of soft, tan-gray chalky limestones that are most numerous in the basal part of the member.

The Blue Hill shale member of the Carlile shale occurs locally only along the west border of Republic County. It is a blue-gray, generally noncalcareous clay shale. Some zones in this member are heavily limonite-stained and are rust-colored. Crystals of a variety of gypsum (selenite) are quite common in the Blue Hill shale, as are septarian concretions often as much as 2 feet in diameter.

The Cretaceous formations that crop out in Republic county dip from 12 to 15 feet per mile toward the northwest. The estimate of dip is based upon altitudes of the contact between the Carlile shale and the underlying Greenhorn limestone. Minor variations in the regional dip were not studied by the field party.

Representative measured sections.--Two measured sections of the Carlile shale are cited by Wing 14/ and

14 Wing, M. E., Geology of Cloud and Republic Counties, Kans.: Kansas Geol. Survey Bull. 15, pp. 22 and 23. 1930.

are adapted here. The first of these is a section of the basal part of the Fairport chalky shale member, and the second is a section of the lower part of the Blue Hill shale member.

(1) Section of the lower part of the Carlile shale near the southeast corner of sec. 20, T. 2 S., R. 2 W.:

	Ft.	in.
Carlile shale:		
Limestone, reddish buff at top...		5
Shale, blue-gray; calcareous. Contains numerous Ostrea shells......................	5	
Limestone, dark-buff. Varies greatly in thickness. Splits into thin layers...............		3-7
Shale, light-gray; calcareous....	6	
Limestone. Splits into three distinct layers. Two upper layers separated by an ocher-red seam of clay along which limestone is reddish buff in color. Middle layer more compact than other two and slightly banded. Lowermost layer chalky; weathers rapidly..................		
Shale, gray; calcareous..........	2	10
Limestone, gray. Intermediate quarter-inch cross-laminated..		1
Shale, gray; calcareous.........	2	6
Limestone. Lower part light buff; upper part reddish buff........................		3½-4
Shale, calcareous..............		2
Greenhorn limestone (Pfeifer shale, member): "Fencepost" limestone...		9

(2) Section of the middle part of the Carlile shale exposed in the SW¼ sec. 2, T. 2 S., R. 5 W.:

	Ft.	in.
Clay, sand, and gravel belonging to the Tertiary...............	10-12	
Shale, blue-gray. Contains lemon-yellow flakes and fragments of large-shelled Inoceramus....................	23	
Bentonite, thin, white..........		½
Shale, blue-gray. Contains numerous fragments of large-shelled Inoceramus..........	10	
Clay, brown. Contains thin flakes and small crystals of gypsum. Has bentonitic seam at center....................		2
Shale, blue....................	5	
Gray limestone bed. Contains many small shells of Inoceramus. At top is zone containing small brownish concretions 1 to 4 inches in diameter......		4
Shale, blue....................		5
Clay, similar to bed 10.........		3
Shale, blue, papery. Contains numerous fragments of large Inoceramus shells and Ostrea..	2	
Clay, similar to bed 10...............		2
Shale, blue.........................	4	
Clay, brownish......................		1
Shale, blue, papery. Contains numerous Ostrea shells............	12	

Thickness.--The aggregate thickness of the Carlile shale in Republic County is estimated to be about 230 feet. The full thickness of the Fairport chalky shale member, about 80 feet, is present in the county, but only the lower 150 feet of the Blue Hill shale member occurs here. Conspicuous exposures of the upper part of the Blue Hill shale are present beneath the Fort Hays limestone member of the Niobrara formation only a short distance west of the county line in Jewell County.

Individual outcrops of the Carlile shale usually are rather thin; the two measured sections are the thickest outcrops found in Republic County.

Construction materials.--No materials of especial significance in engineering construction occur in the Carlile shale as it is developed in Republic County. If material from this source is used in the construction of fills or embankments, the high content of clay in the shale is an important factor in determining the angle to which the shoulder slopes should be graded. Plummer and Hladik 15/ suggest that the Blue Hill shale member of the Carlile shale is a promising source of material for the manufacture of ceramic slag useful as a light-weight aggregate.

Belleville formation

Areal distribution.--The Belleville formation of Pleistocene age crops out only in the northern part of Republic County, principally in the area northwest of Belleville. (See fig. 4 and pl. 1.) The outcrops are limited in areal extent and are isolated from each other. The full extent of the Belleville formation can be determined only by test drilling, because so much of it is concealed by the overlying Sanborn formation. The boundaries of the formation are given by Wing. 16/

General description.--The Belleville formation was named by Wing 17/ from exposures in the vicinity of Belleville, Republic County, Kans. As originally described, the age of the formation was considered to be Tertiary, but subsequent work by Fishel and Lohman 18/ and by others indicates quite conclusively that its age is early Pleistocene. Apparently the Belleville formation was deposited as a result of the damming of the Republican River by a glacier of early Pleistocene age.

[15] Plummer, N., and Hladik, W. B., The manufacture of ceramic railroad ballast and constructional aggregates from Kansas clays and silts: Kansas Geol. Survey Bull. 76, pt. 4, p. 86, 1948.
[16] Wing, M. E., Geology of Cloud and Republic Counties, Kans.: Kansas Geol. Survey Bull. 15, pl. 2, 1930.
[17] Op. cit., pp. 19-21.
[18] Fishel, V. C., and Lohman, S. W., geology and ground water resources of Republic County and northern Cloud County, Kans.: Kansas Geol. Survey Bull. 73, pp. 89-92, 1948.

The gravel, sand, silt, and clay that compose this formation accumulated on the floor of a lake. Probably the bulk of the sediments, having been eroded from the area to the west, was deposited in the lake by the Republican River, but some of the pebbles of quartzite in the Belleville formation indicate that glacial outwash was an additional source of sediments.

Lohman 19/ believes that the preglacial Republican River flowed northeastward through the northwestern part of Republic County; that its course through eastern Nebraska was dammed by an early Pleistocene glacier (the preglacial channel in Nebraska has been traced by test drilling); and that the river excavated a new channel leading southward and southeastward to the site of Junction City, Kans., where it merges with the Smoky Hill River to form the Kansas River. Most of the Valley of the Republican River in Republic County, therefore, was eroded in the early Pleistocene epoch, and the river has continued since then to follow its glacially diverted course.

The Belleville formation consist predominantly of cross-bedded lenses of sand composed of quartz and gravel-size fragments of igneous rocks. Subordinate amounts of quartzite and chert particles are present also. Occasional lenses of clay, silt, and very fine sand are interbedded with the rest of the material, and clay balls 4 to 15 inches in diameter are present in the formation. The color usually is tan gray, but locally it may rust brown because of staining by iron oxide.

In some places the Belleville formation appears to grade upward into the overlying Sanborn formation. The contact between the two formations, therefore, is often hard to determine. As an arbitrary basis for field mapping, the deposits in which sand is the predominant material are mapped as Belleville and those in which silt is the predominate material are mapped as Sanborn. The Belleville formation usually erodes to form a rather hummocky type of topography in contrast with the generally rolling topography developed by erosion of the Sanborn formation.

Representative measured section. --The following section of the Belleville formation was measured in the wall of a small valley in the SE¼NE¼ sec. 13, T. 1 S., R. 5 W.:

	Feet
Soil: Silt, gray	1.0
Sanborn formation:	
Silt, noncalcareous; dark brown, weathers dark gray; organic matter present	1.3
Silt, calcareous; exhibits columnar structure and stands in vertical bank; gray	8.4
Belleville formation:	
Sand, silty, brown	2.7
Sand, fine, gray	1.2
Sand, brown	1.2
Sand, clayey, dark-brown	1.0
Sand, light-brown	3.0
Sand and gravel; particles range from fine sand to gravel an inch or more in diameter; gray and brown; occasional interbedded lenses of silt	15.0
Total thickness of Belleville formation exposed	24.1
Base covered.	

[19] Op. cit., pp. 29-32.

Thickness. --The thickness of the Belleville formation ranges from a featheredge along the south margin of its occurrence to a maximum estimated by Fishel and Lohman 20/ to be between 30 and 40 feet along the north boundary of the county. Their determination of the thickness of the formation is based on test drilling in the area. A test hole drilled near Chester, Nebr., penetrated a thickness of 120 feet of this formation.

Construction materials. --
- Aggregate for concrete.
- Road metal.

Sanborn formation

Areal distribution. --The Sanborn formation, of Pleistocene and Recent (?) age, is the most widely distributed stratigraphic unit that crops out in Republic County. (See fig. 4 and pl. 1.) At one time the formation undoubtedly extended over most of the area of the county, but subsequently it has been removed along the courses of many of the streams. The formation occurs in two phases; the more extensive phase is that which caps the tops of the divides as a blanket of silt of variable thickness, and a less extensive phase occurs along the walls of some of the larger stream valleys in the county, such as those of Salt and Mill Creeks. The lithologies of the two phases are similar, and both phases are mapped as a single stratigraphic unit on plate 1. Frye and Fent 21/ have subdivided the formation into members, but it was not feasible to attempt the mapping of these members in the reconnaissance-type field work on which this report is based, as to do so would have required a greatly expanded field program, including test drilling. The treatment of the Sanborn as an undivided unit seems adequate to serve the purpose of a construction-materials inventory.

General description. --The Sanborn formation consists predominantly of gray-brown and red-brown silt, but there may be local lenses of sand and limestone gravel present in its basal part. The particles composing the sand and gravel lenses are derived from older stratigraphic units cropping out in the area.

In the southeast corner of the county, where the formation overlies the Dakota sandstone, its color is dark brown and reflects the influence of the Dakota sandstone. The contact between the Sanborn formation and the underlying Dakota sandstone is often hard to define because of this similarity in color.

[20] Op. cit., p. 91.
[21] Frye, J. C., and Fent, O. S., Late Pleistocene loesses of central Kansas: Kansas Geol. Survey Bull. 70, pt. 3, pp. 41-51, 1947.

There is a prominent soil profile at the top of the formation, and Hibbard, Frye, and Leonard 22/ have reported a buried soil zone in the formation. Such a buried soil zone was noted in several localities in Republic County by the authors of this report.

Deposits of gravelly sand were observed in the basal part of the Sanborn formation near the head of Mill Creek in the northeastern part of the county. The sand and gravel particles in all likelihood were derived by erosion of the Belleville formation a short distance toward the west. Deposits of limestone gravel occur in numerous localities along the western border of Republic County. The limestone particles appear to have been derived from the Niobrara formation, which crops out in Jewell County. The deposits of limestone gravel are lenticular and, in all cases, are found in the basal part of the Sanborn where the formation rests unconformably on the Carlile shale.

The field party noted a single deposit of impure volcanic ash in the basal part of the Sanborn formation in the SE¼SE¼ sec. 35, T. 1 S., R. 4 W. The deposit consists principally of silt with only a small amount of intermixed volcanic ash. It is probable that this occurrence correlates with the Pearlette ash described by Frye and Fent. 23/

Although fossil shells of snails (gastropods) were found in the Sanborn formation in other counties, none was discovered by the field party in Republic County.

The silt of the Sanborn formation exhibits a well-marked tendency to stand in vertical banks and often shows a crude type of columnar structure. The formation generally erodes to form a gently rolling surface, but the headward portions of stream valleys cut into the Sanborn develop the phenomenon known as "catstep erosion." The catsteps are slump blocks from several feet to about 20 feet wide defined by scarps a foot or two high. Apparently they are the result of the sliding of water-saturated silt down toward the streams under the influence of gravity as material is removed from the toe of the deposit by stream erosion.

Representative measured section. --The Sanborn formation is shown in a road cut in the SE¼SE¼ sec. 28, T. 3 S., R. 4 W., as follows:

	Feet
Soil: Silt, dark-brown	0.5
Sanborn formation:	
Silt, light-tan	4.0
Silt; shows columnar structure; nodules of secondary calcium carbonate present; brown, weathers gray orange	9.2
	29.5

Base covered.

Thickness. --The Sanborn formation varies in thickness from a featheredge to a maximum estimated to be about 100 feet. Individual outcrops usually range from several feet to about 15 feet in thickness. The formation is thickest in a north-trending ridge, the axis of which lies a short distance east of Scandia, and generally becomes thinner from the north border of the county toward the south.

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

Terrace deposits

Areal distribution. --Terrace deposits of Recent age are conspicuously developed in the valleys of the Republican River and Salt Creek. (See fig. 4 and pl. 1.) Narrow extensions of the terraces project into the valleys of the larger tributaries of these streams, as well as into the valleys of other streams in the county. Terrace deposits in the smaller stream valleys are continuous, but those in the valley of the Republican River are discontinuous, although each segment may cover an area of several square miles or more. Two or more terrace levels are present but are mapped as a single stratigraphic unit on plate 1 because their lithologic characteristics are similar.

General description. --The terrace deposits unconformably overlie older formations and are composed of materials laid down by present-day streams in earlier gradational cycles. The deposits consist predominantly of silt, but there may be occasional lenses of crossbedded sand and gravel present, as in the deposit exposed in a cut bank in the NW¼NW¼ sec. 24, T. 1 S., R. 5 W. Undoubtedly similar lenses occur in terrace deposits in other places but are concealed by silt of the upper part of the formation. The silt usually is dark brown but may be gray or tan.

A buried soil zone was found in numerous localities at a depth varying from 3 to 6 feet below the top of the terrace. The B zone of the soil profile usually is lighter in color than the other zones because of the calcium carbonate disseminated through it. The B zone also contains nodules of calcium carbonate.

The silty phase of the terrace deposits tends to develop a crude columnar structure and to stand in vertical banks. Streams reworked most of the sediments composing the terrace deposits from older, locally outcropping formations.

Representative measured section. --Terrace deposits are so uniformly silty, except for occasional sand and gravel lenses in the basal part, that it was not thought necessary to measure a section of the formation.

Thickness. --The thickness of this formation could have been determined accurately only by test drilling. It is estimated that the terrace deposits in the valley of the Republican River may be as much as 50 feet thick; that those of White Rock Creek are no more than 45 feet thick; that those of Mill Creek are about 30 feet thick; and that terrace deposits in the other streams of the county are less than 20 feet thick.

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

[22] Hibbard, C. W., Frye, J. C., and Leonard, A. B., Reconnaissance of Pleistocene deposits in north-central Kansas: Kansas Geol. Survey Bull. 52, pt. 1, p. 13, 1944.
[23] Op. cit., p. 49.

Dune sand

Areal distribution. --Dune sand of Recent age (see fig. 4) occurs, in Republic County, in the valleys of the Republican River and Otter Creek. (See pl. 1.) The principal dunes in the valley of the Republican River are along the east side of the valley at the south border of the county, on the west side of the river northwest of Scandia, and south of Republic City at the base of the east valley wall. Smaller areas of dune sand were noted in the valley of the Republican River but are not mapped on plate 1 because of the small quantity of material in each of them.

General description. --Dune sands are deposits formed through the gradational activity of the wind. Areas of dunes are characterized by a hummocky topography, and the sands composing them are typically cross-bedded and are tan gray in color. The dunes in the valley of the Republican River probably represent sand originally spread by flood waters and later reworked by the wind. The dunes in the valley of Otter Creek were undoubtedly formed of sand reworked from the Belleville formation, which crops out along the walls of this valley, and are being shifted by the wind at the present time. Most of the larger dunes in the valley of the Republican River have been anchored by the growth of 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 dunes vary considerably in height; the average height is probably 10 to 15 feet, but the crests of some of the dunes northwest of Scandia stand approximately 50 feet above the level of the flood plain upon which they rest.

Construction material. --
Aggregate for concrete.

Alluvium

Areal distribution. --The deposits (see fig. 4) formed by streams in their present gradational cycles are mapped as alluvium on plate 1. Alluvium is defined in this report as the material underlying the present flood plain of a stream. The flood plain is the area adjacent to the stream channel that is covered by water during normal flood stage. Alluvium is mapped on plate 1 in the valleys of the Republican River and White Rock, Beaver, and Mill Creeks. Alluvial deposits are present, also, in many of the smaller valleys in the county but are so narrow that they could not be shown on a map of the scale used. Alluvium in the valley of the Republican River varies in width from 1 to 2 miles, but similar deposits in the other streams of the county are no more than 0.25 mile wide.

General description. --The alluvium of the valley of the Republican River is composed predominantly of silt, but many lenses of sand and gravelly sand are included also. The majority of the sand and gravel particles are fragments of quartz and feldspar; minor quantities of calcite and chert fragments and occasional particles of basic igneous rocks may also be present. The alluvial deposits in other valleys in Republic County are composed almost entirely of dark-gray or brown silt, and only occasional and very thin lenses of fine sand and gravel are interbedded in the silt.

White Rock Creek is noteworthy in that in its present-day gradational cycle it has incised its channel 25 to 30 feet below the previous gradational level. Mill Creek is similar in this respect, although the depth to which it has incised its channel is only about 20 feet.

Representative measured section. --Because of the low relief of the alluvium it was impossible to measure a section representative of this formation.

Thickness. --Accurate determinations of the thickness of the alluvium could not be made in the absence of test-hole data. Fishel and Lohman 24/ determined from such data that the alluvium in the valley of the Republican River reaches its maximum thickness, more than 100 feet, in the vicinity of Norway. It is probable that the maximum thickness of the alluvium in the valleys of other streams in the county is no more than about 50 feet.

Construction materials. --
Aggregate for concrete.
Road metal.

INVENTORY OF CONSTRUCTION MATERIALS

General

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

Whenever available, laboratory test data have been introduced into the report to aid in the evaluation of the materials. The information given in table 1 is based on standard testing procedures of the State Highway Commission of Kansas 25/ and the American Association of State Highway Officials. 26/ 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 exploitation for specific uses.

Although numerous prospect pits and quarries were located in the field, no attempt was made to complete an exhaustive survey of all possible sources. The purposes of this report are to inventory the available construction materials that occur in Republic County and to establish the geologic pattern required for the location and development of materials that future

[24] Fishel, V. C., and Lohman, S. W., geology and ground water resources of Republic County and northern Cloud County, Kans.: Kansas Geol. Survey Bull. 73, p. 97, 1948.

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

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

Classification of the material	Number on plate I	Location					Estimated quantity of material (cubic yards)	Average thickness						Remarks
		1/4 fraction	1/4 section	Section	Township (S)	Range (W)		Material (feet)	Overburden (feet)	Absorption	Liquid limit	Plasticity index	Color [4]	
Fine aggregate	fa 1	SE	NE	20	1	4	50,000	16	0					Average of four augered samples.
	fa2	SW	SE	28	1	4	5,000	10	0-2					
	fa 3	SE	SE	6	1	5	150,000	8-10	0-2					
	fa4	SE	NE	13	1	5	50,000	15	0					High percentage of wash.
	fa5	SE	SW	34	1	5	75,000	15	1-5					Overburden is silt.
	fa6	SW	NW	17	2	1	12,000	5-8	1					
	fa 7	SE	NE	19	2	1	5,000	9	3					Average of two augered samples; overburden is silt.
	fa 8	NE	NE	35	2	1	5,000+	4-6	0-3					Very high percentage of wash; gradation factor very low.
	fa 9	NE	SW	21	2	3	25,000	7	6					Average of seven augered samples; high percentage of wash.
	fa10	SW	SE	13	2	4	5,000+	4-6	1-5					Overburden is silt.
	fa11	NW	SW	2	2	5	25,000	20	2-6					Overburden is silt of Sanborn formation; gradation factor low.
	fa12	NE	NE	4	3	2	105,000	21	1-8					Sample obtained by augering; fairly high percentage of wash.
	fa13	NW	NW	32	3	4	150,000	20	0					
	fa14	SE	NE	1	3	5	50,000	10-50	0-1					Fairly high percentage of wash.
Mixed aggregate	ma 1	SE	SW	11	1	5	40,000	10	3				dk st	
	ma 2	NE	NE	18	1	5	30,000	15	5				st	
	ma 3	NW	NW	24	1	5	50,000	8-10	0-2					
	ma 5	SW	SE	16	2	1	1,000	4	0				cl	
	ma 6	NE	SW	24	2	2	6,000	5-12	2-10				cl	Overburden is silt.
	ma 7	SW	SE	17	3	4	10,000	15	3-4					
Limestone gravel	lg 1	NE	SE	7	2	5	1,000	3-6	1-10		41	25		Overburden is silt.
Mineral filler	mf 1	NE	NW	4	1	4	150,000	15	0-1					Cementation factor excessive.
	mf 2	SE	SE	14	2	5	150,000	20	2					Cementation factor excessive.
Sandstone	ss 1	NE	NW	15	4	1	1,200	3	0-2	)8				
	ss2	NW	SW	27	4	2	1,000	4	0-1	)6				High abrasion loss.
Limestone	ls 1	SE	SE	32	2	2	20,000	20	0	9				Not sound; fairly high absorption factor.
	ls 2	NW	NE	6	3	2	2,000	5	0-2	9				One (No.38392) of nine samples tested from same quarry; Deval abrasion loss, 6.9 per cent; not sound.
Shale	sh 1	NE	NE	2	1	2	50,000	10	0-2	y sh	29 34	12 17		Sampled from road cut; tested for stabilization.
	sh 2	NE	SW	2	2	5	150,000	10-15	2-5	y sh	37 40	16 18		Sampled from open face of quarry; tested for stabilization.
	sh 3	NW	NE	5	3	2	150,000	80	0-5	y sh	32 33	13 14		Limestone and shale tested for stabilization.
	sh 4	SE	SW	12	4	2	50,000	15	0-1	y sh	31 33	13 16		Limestone and shale tested for stabilization.
	sh 5	SE	SW	16	4	5	50,000	10-15	1-3		30	12		Sampled from face of road cut; tested for stabilization.

engineering needs may demand. A certain stratigraphic unit may contain one or more construction materials. If the geologic factors of that occurrence are established, the resultant geologic pattern will facilitate the discovery of additional sources.

Aggregate for concrete

Engineering and geologic characteristics. --Aggregate for concrete is distinguished as fine and mixed aggregate in table 1 and on plate 1. The distinction is an arbitrary one based on the percentage of material retained on a standard No. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. The material is classified as a mixed aggregate if the coarse fraction is 5 percent or more by weight of the whole sample 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 by 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 deleterious substances, if in quantities thought to be excessive, is noted under "Remarks" in table 1: materials passing the No. 200 sieve (wash); shaly, soft, or flaky fragments; sticks or other organic debris; clay lumps; and minerals that, 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 usually not included in this classification because of the added expense in the removal of the material, nor are relatively inacessible deposits; exceptions to this practice are noted under "Remarks" in table 1.

The test characteristics of some of the materials included in this classification indicate that 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 concrete or cover material.

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

(1) Dakota sandstone. One sample of loosely cemented Dakota sandstone (fa 8) was tested. The data are given in table 1; the source of the sample is mapped on plate 1. The test data indicate that there is an excessive percentage of wash present and that the gradation factor is far below the minimum acceptable for a fine aggregate. It is doubtful, therefore, that the Dakota sandstone will prove an adequate source of fine aggregate for portland cement concrete.

(2) Belleville formation. Eight samples of fine aggregate (fa 2, 4, 5, 7, and 9 to 12) and three samples of mixed aggregate (ma 1, 2, and 5) were taken from the Belleville formation. The sampled localities are mapped on plate 1, and the test characteristics of the samples are given in table 1. Sand and gravel of the Belleville formation are composed predominantly of particles of quartz and feldspar; minor amounts of fragments of acid igneous rocks and basic igneous rocks, as well as fragments of carbonate minerals, quartzite, and chert, may be present also. Quartzite and chert are the only two minerals in this list that might prove deleterious if aggregate from the Belleville were used with high-alkali portland cement, but the percentages present are so small that the detrimental effect would be essentially negligible.

The test characteristics of material from this formation indicate that it may be acceptable for use in portland cement concrete. The gradation factor of most of the samples tested is within acceptable limits; fa 11 is the only sample tested that is markedly deficient in this respect. The amount of wash in samples fa 4 (13.6 percent), fa 9 (17.3 percent), and fa 12 (9.7 percent) may be excessive. The color test of sample ma 1 showed dark straw, but the results of the color tests of several other samples were satisfactory, as were the results of the Los Angeles and soundness tests of several additional samples.

The quantity of sand and gravel that can be obtained from the Belleville formation is almost unlimited. Numerous additional sources of material occur in the northwestern part of the county. In much of this area, however, the Belleville formation is concealed beneath silt of the Sanborn formation and pit sites must be located by augering. The thickness of the overburden (Sanborn formation) is variable; it is least along the streams and increases somewhat toward the north boundary of the county. The overburden, however, may be used in some phase of construction and, in any case, may be removed easily.

(3) Sanborn formation. One sample of fine aggregate (fa 6) and one of mixed aggregate (ma 4) were obtained from the Sanborn formation. Although the coarse fractions of both samples show an unusually high percentage of chalk fragments (see table 1), the test characteristics of the material are apparently within acceptable limits. Despite the softness of the chalk fragments, the compressive strength ratios for both samples are well above the minimum limit.

Additional supplies of sand and gravel from the Sanborn formation are undoubtedly present in the basal part of the formation. They can best be located by intensive search of the margins of the mapped outcrop area of the Sanborn formation (see pl. 1), especially in places where streams have cut through the Sanborn into underlying stratigraphic units. The sands and gravels occur as lenses of variable extent however, generally with only limited quantities of material available. In some places noted by the writers, the sand and gravel lenses were too limited quantitatively considering the thick overburden of silt, to justify development.

Plummer and Hladik 27/ regard the clays and silts

[27] Plummer, N., and Hladik, W. B., The manufacture of ceramic railroad ballast and constructional aggregates from Kansas clays and silts: Kansas Geol. Survey Bull. 76, pp. 87-89, 94, 95, 1948.

of Pleistocene age as the most promising raw materials available in the State for the manufacture of ceramic slag. Used as an aggregate in concrete, the slag has an additional advantage in its light weight.

(4) Terrace deposits. Only one sample of sand and gravel from the terrace deposits (ma 3) was tested (see table 1 and pl. 1). The test data available for this sample are incomplete, but the material is probably satisfactory for use in portland cement concrete. Sands and gravels occur in the terrace deposits, but usually at a prohibitive depth below the top of the formation; the expense of removing the overburden would be too great, in most cases, for the economical development of the sand and gravel. Lenses of material in this classification can probably be found by intensive exploration of the basal part of the terrace deposits in the valley of the Republican River; exploration of terrace deposits in the valleys of other streams in the county would probably not be productive.

(5) Dune sand. Two samples of dune sand (fa 1 and 14) are classified as fine aggregate in table 1; their sources are mapped on plate 1. The test characteristics indicate that this material may be used as an additive to reduce the gradation factor of a mixed aggregate to specified requirements. The sand might also be used as a mortar sand. A large quantity of dune sand is available within the mapped areas on plate 1.

(6) Alluvium. Two samples of alluvium (fa 3 and fa 13) are classified as fine aggregate, and one sample (ma 6) is classified as mixed aggregate in table 1; the localities from which the samples were obtained are mapped on plate 1. Mineral analyses of the samples indicate that deleterious substances are not present in critical quantities. The test results show that the gradation factor for all samples tested is within acceptable limits and that the compressive strength ratio, Los Angeles abrasion loss, and soundness ratio for the sample of mixed aggregate are within required limits.

An almost unlimited quantity of sand and gravel is available for exploitation in the alluvium of the valley of the Republican River. The material occurs in lenses of variable extent within the area mapped on plate 1. Lenses of sand are more numerous than lenses of gravelly sand, but exploration of the alluvium would certainly reveal adequate quantities of both fine and mixed aggregate. The overburden is negligible for these occurrences, but much of the material will probably have to be removed from below the water table.

Road metal

Engineering and geologic characteristics. --Road metal, known also as surfacing material, crushed stone, and aggregate, is defined in this report as any material that may be applied to a road to improve the performance characteristics of that road. Many geologic materials fulfill this requirement, and the list of such materials will vary from one area to another. The following materials in Republic 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 State 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 silt-size particles. Limestone gravel is used extensively throughout north-central Kansas as road metal on secondary roads.

(3) Crushed rock. Indurated rocks are available in Republic County for use as crushed stone in road construction or in railway ballast, and some of them have been so used. The rocks are (a) limestone, a compact, massive layer of calcareous material, variable in its hardness; (b) quartzite, a massive, compact, hard rock in which sand or gravel or both, 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 interstitial deposits of calcium carbonate, silica, or iron oxide.

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

Stratigraphic sources and performance characteristics. --

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

(2) Limestone gravel. One sample of limestone gravel (lg 1) was obtained from the Sanborn formation; the test characteristics are given in table 1. This material, so far as is known, occurs only in lenses in the basal part of the Sanborn formation, and in Republic County the lenses are restricted to the western part of the county where the Sanborn formation overlies the Carlile shale. The gravel-size particles of limestone appear to have been eroded from nearby outcrops of the Niobrara formation in Jewell County. The material is acceptable road metal for light-traffic roads, and additional deposits of limestone gravel undoubtedly occur in other places along the west boundary of the county.

(3) Crushed rock.

(a) Dakota sandstone. The Dakota sandstone is used as loose road metal on some of the light-traffic roads in the eastern and southeastern parts of Republic

County. The material appears to be satisfactory when so used but is reported to cause excessive tire wear. Field observation indicates that rock from ledges in the Dakota sandstone cemented by iron oxide is most often used for this purpose. The test characteristics of two samples (ss 1 and 2) secured from the Dakota sandstone are given in table 1, and the locations from which the samples were obtained are mapped on plate 1. Additional sources of sandstone occur within the mapped ourcrop area of the formation, as shown on plate 1, and other quarries could be opened at convenient sites within that area.

The loosely cemented beds of Dakota sandstone may be used in the construction of certain kinds of bituminous-mat roads, but such beds are not nearly so numerous as are the lime- or iron-cemented beds. The poor cementation of the sand grains permits easy pulverization and, therefore, ready admixing with other materials required in the construction of the roads.

The quartzitic sandstones (silica-cemented) or quartzitelike sandstones (lime-cemented) in this formation might also be used in road construction. The material, if crushed and applied to the road in particles less than 0.5 inch in maximum dimension, should serve adequately as loose road metal. This use of quartzite of the Ogallala formation has been observed on light-traffic roads in north-central Kansas. The crushed quartzite might also be used to sweeten aggregates to the gradings desired for other construction materials uses. Both silica-cemented quartzitic sandstone and lime-cemented quartzitelike sandstone occur in Republic County, but the silica-cemented rock is not nearly so abundant as the lime-cemented. Intensive search of the mapped outcrop area of the Dakota sandstone (see pl. 1) would undoubtedly reveal additional sources of these materials.

(b) Greenhorn limestone. The limestones and shales of the Greenhorn limestone have been used rather extensively in various types of road construction in Republic County. Two samples of limestone (ls 1 and 2) were tested, and the data are given in table 1. Five samples of shales and limestones (sh 1 to 5) were tested as stabilized fill, and the results are presented in table 1. All sources are mapped on plate 1.

The shales, on the basis of the test data, appear to be acceptable as material for stabilization. The chalky limestones and shales of the Pfeifer shale and Jetmore chalk members are used throughout the outcrop area of the Greenhorn limestone in the construction of the traffic-bound macadam kind of light-traffic road. The limestone fragments are stock-piled over the winter season. Weathering by slaking and freeze-and-thaw causes the surficial portion of each limestone fragment to slough off. The residual portion is then crushed, mixed with the shales from the same formation, and applied to the road. The mixture compacts to form an acceptable light-traffic surfacing in which the wet-weather performance is satisfactory and which shows little or no tendency toward dry-weather dusting. Field observation indicates that a course at least 6 inches thick should be applied or the macadam will tend to break out in critical places along the road. An almost unlimited amount of chalky limestone and shale from the upper part of the Greenhorn limestone is available throughout the mapped outcrop area of this formation in Republic County; a quarry could be opened at any convenient site within that area.

Mineral filler

Engineering and geologic characteristics. --Material composed predominantly of silt-size mineral particles (50 percent or more of which pass the No. 200 sieve) is classified in this report as mineral filler. It has no more than a trace of sticks or other organic debris but may contain minor amounts of fine sand or clay. The State Highway Commission of Kansas 28/ states that material will qualify for mineral filler if laboratory tests indicate a low coefficient of cementation. Deficiencies of the tested samples in this characteristic are noted under "Remarks" in table 1. Failure of the material to pulverize easily, a factor of cementation, increases the difficulty of obtaining its uniform distribution throughout the mixture.

Stratigraphic sources and performance characteristics. --

(1) Sanborn formation. Two samples of mineral filler (mf 1 and 2) taken from the Sanborn formation were tested in the Road Materials Laboratory of the State Highway Commission; the test data are given in table 1, and the localities from which the samples were collected are mapped on plate 1. The sieve analyses indicate that both samples are acceptable as mineral filler, but in both cases the cementation factor is probably excessive (100+). It is probable that the two samples were taken from the B zone of the soil profile, in which secondary deposits of calcium carbonate tend to cement the particles of silt. If the samples had been secured from the underlying C zone of the soil profile, however, the cementation factor would probably have been within acceptable limits, inasmuch as secondary deposits of calcium carbonate are not characteristic of the C zone. The Sanborn formation is the most widespread source of mineral filler in Republic County, and pits could be opened in it at any convenient site throughout the area of its outcrop. For this reason, only a few prospect and operated pits are mapped on plate 1. It is recommended that, prior to the development of the site, the material be laboratory-tested and its cementation factor determined.

(2) Terrace deposits. No samples of mineral filler from the terrace deposits of Republic County were tested in the laboratory, but this stratigraphic unit is a potential source of mineral filler and has been exploited in other counties of the State. Silts 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.

Volcanic ash

Engineering and geologic characteristics.

[28] Horner, S. E., letter dated Jan. 4, 1947.

Volcanic ash is sometimes classified as mineral filler, but in this report it is distinguished as a special type of mineral filler because it is suitable for certain uses other than those of the usual silty filler. Volcanic ash consists predominantly of the fine, glasslike shards ejected during the explosive phase of a volcanic eruption. The material may include silt-size particles of other origins and occasional thin seams of gravel, sand, and clay.

Two important engineering uses are made of volcanic ash. This material is used as mineral filler in bituminous surface courses for roads and airports because it has a low plasticity index, generally is only poorly cemented, is free from organic matter and other deleterious constituents, and combines well with the bituminous material. Road surfacing in which volcanic ash has been used in this manner generally gives better service than that in which a silty filler has been used. Rather recently, volcanic ash has been considered again for use in making puzzolan cements. Puzzolan cements are more satisfactory for certain types of engineering construction than are the portland cements.

Stratigraphic sources and performance characteristics. --The Sanborn formation appears to be the only potential source of volcanic ash in Republic County. The field party found one deposit of very impure ash near the base of this formation. (See section on Sanborn formation.) It is possible that other deposits of sufficient purity to be developed economically occur in the basal part of the Sanborn formation. Prospecting for such deposits should be done near the margin of the mapped outcrop area of the formation, especially where streams have cut through the Sanborn into underlying stratigraphic units. If found, the deposits will prove to be limited in quantity because of the lenslike masses in which the volcanic ash is known to occur. Numerous lenses of volcanic ash have been found in the northern part of Jewell County in the basal part of the Sanborn formation.

Riprap

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

Stratigraphic sources and performance characteristics. --

(1) Dakota sandstone. The quartzitic and quartzitelike sandstones of the Dakota are acceptable materials 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. Test characteristics of two samples (ss 1 and 2) are given in table 1, and the localities from which the samples were obtained are mapped on plate 1. Similar materials from the Dakota sandstone have been used as riprap on numerous earthen dams in central and north-central Kansas, including the recently constructed Kamopolis 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 abrasion and freeze-and-thaw losses.

(2) Greenhorn limestone. Some use of the chalky limestones from the upper part of the Greenhorn limestone as riprap has been observed in north-central Kansas. Field observation indicates, however, that this stone is not satisfactory when so used. It disintegrates quite rapidly through slaking and freeze-and-thaw and soon looses its protective value. The development of the Greenhorn limestone as a source of riprap is highly 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 desired size and shape. Materials fulfilling these requirements occur in the Dakota sandstone and Greenhorn limestone in Republic County.

Stratigraphic sources and performance characteristics. --

(1) Dakota sandstone. Limited use of the Dakota sandstone as a source of structural stone has been observed in Republic County and in other counties in which this formation crops out. The quartzitic and quartzitelike phases of the formation are probably entirely acceptable for use as structural stone; the iron-cemented phase and the loosely cemented sandstones are probably not acceptable, although blocks of the iron-cemented sandstone have been observed in buildings in the area. The amount of quartzitic and quartzitelike sandstone now known in Republic County is quite limited, but intensive exploration of the western margin of the mapped area of outcrop (see pl. 1) will probably yield additional sources.

(2) Greenhorn limestone. Two limestone beds in the Greenhorn limestone are used in this and adjacent areas as structural stone. The shell-rock bed at the top of the Jetmore chalk member is quarried and used in the eastern part of Republic County, and the "Fencepost" limestone bed at the top of the Pfeifer shale member is quarried and used in the western part of the county. Field observation indicates that these beds are acceptable sources of structural stone. Buildings constructed of them 50 years or more ago are still standing and show no sign of serious deterioration of the stone itself. The "Fencepost" limestone offers a far more pleasing appearance than does the shell rock. The latter tends to weather irregularly and to develop a somewhat unpleasing appearance; the iron-stained band in the middle part of the "Fencepost" limestone bed, however, imparts a pleasing appearance to the finished structure. The "Fencepost" limestone is used rather extensively, also, as structural stone in the construction of small bridges in the area and seems acceptable for this use.

Interior—Duplicating Section, Washington, D. C.
79970