GEOLOGICAL SURVEY CIRCULAR 38

May 1950

CONSTRUCTION MATERIALS IN JEWELL COUNTY, KANSAS

By

Frank E. Byrne, Max S. Houston,
and Melville R. Mudge

PREPARED IN COOPERATION WITH THE
STATE HIGHWAY COMMISSION OF KANSAS
R. C. Keeling, State Highway Engineer
S. E. Horner, Chief Geologist

Prepared as Part of a Program
of the Department of the Interior
for Development of the Missouri River Basin

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
GEOLOGICAL SURVEY
W. E. Wrather, Director

WASHINGTON, D. C.

Free on application to the Director, Geological Survey, Washington 25, D. C.

CONSTRUCTION MATERIALS IN JEWELL COUNTY, KANSAS

By
Frank E. Byrne, Max S. Houston, and Melville R. Mudge

CONTENTS

	Page
Introduction	1
Purpose of the investigation	1
Area covered by the investigation	1
Geography of the area	1
Investigation procedure	2
Acknowledgments	2
Characteristics of the outcropping stratigraphic units	3
General	3
Dakota sandstone	3
Areal distribution	3
General description	3
Representative measured section	6
Thickness	6
Construction materials	6
Graneros shale	6
Areal distribution	6
General description	6
Representative measured section	6
Thickness	7
Construction materials	7
Greenhorn limestone	7
Areal distribution	7
General description	7
Representative measured sections	8
Thickness	9
Construction materials	9
Carlile shale	9
Areal distribution	9
General description	10
Representative measured sections	10
Thickness	10
Construction materials	10
Fort Hays limestone member of Niobrara formation	10
Areal distribution	10
General description	11
Representative measured section	11
Thickness	11
Construction materials	11
Smoky Hill chalk member of Niobrara formation	11
Areal distribution	11
General description	12
Representative measured section	12
Thickness	12
Construction materials	12
Ogallala formation	12
Areal distribution	12
General description	12
Representative measured section	14
Thickness	14
Construction materials	14
Belleville formation	14
Areal distribution	14
General description	14
Representative measured section	14
Thickness	14
Construction materials	14
Sanborn formation	14
Areal distribution	14
General description	14
Representative measured section	15
Thickness	15
Construction materials	15
Terrace deposits	15
Areal distribution	15
General description	15
Representative measured section	16
Thickness	16
Construction materials	16
Alluvium	16
Areal distribution	16
General description	16
Representative measured section	16
Thickness	16
Construction materials	16
Inventory of construction materials	16
General	16
Aggregate for concrete	17
Engineering and geologic characteristics	17
Stratigraphic sources and performance characteristics	17
Belleville formation	17
Sanborn formation	17
Alluvium	17
Road metal	18
Engineering and geologic characteristics	18
Aggregate for concrete	18
Limestone gravel	18
Crushed rock	18

CONTENTS
(Continued)

	Page
Inventory of construction materials--Continued.	
Road metal--Continued.	
Stratigraphic sources and performance characteristics........	18
Aggregate for concrete.......	18
Limestone gravel...........	18
Crushed rock...............	18
Dakota sandstone.......	18
Greenhorn limestone...............	18
Fort Hays limestone...............	18
Smoky Hill chalk.......	19
Ogallala formation......	19
Mineral filler........................	19
Engineering and geologic characteristics................	19
Stratigraphic sources and performance characteristics........	19
Sanborn formation...........	19
Terrace deposits............	19
Volcanic ash.........................	19
Engineering and geologic characteristics................	19
Stratigraphic source and performance characteristics........	20
Riprap..............................	20
Engineering and geologic characteristics...............	20
Stratigraphic sources and performance characteristics.........................	20
Dakota sandstone............	20
Greenhorn limestone and Niobrara formation........	20
Ogallala formation...........	20
Structural stone......................	20
Engineering and geologic characteristics................	20
Stratigraphic sources and performance characteristics.........................	20
Greenhorn limestone.........	20
Fort Hays limestone member of the Niobrara formation...................	20
Calcareous binder.....................	21
Engineering and geologic characteristics................	21
Stratigraphic sources and performance characteristics.........................	21

ILLUSTRATIONS

		Page
Plate 1.	Map showing construction materials and geology of Jewell County, Kans..................	In pocket
Figure 1.	Index map of Kansas showing areas covered by this report and by other construction-materials investigations..........	1
Figure 2.	Outcropping stratigraphic units in Jewell County, Kans., and their construction materials..........	4
Figure 3.	Geologic cross section along the line A-A'..........	4
Figure 4.	Map showing outcrops of rocks tentatively assigned to the Ogallala formation..........	13

TABLE

Table 1.	Summary of materials tests..........	Faces page 17

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 Jewell County, Kans., in the summer of 1947 to investigate sources of engineering construction materials. This report of the Jewell County investigation is a part of the general inventory and a contribution to the geologic mapping and investigation of mineral resources being carried on in connection with studies of the Missouri River Basin. 1/

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

Area covered by the investigation

Jewell County is in the first tier of Kansas counties south of the Nebraska border and in the seventh tier east of Colorado. (See fig. 1.) It comprises 25 townships and covers an area of about 900 square miles. The county is bounded by parallels 39°34' and 40° north latitude and meridians 97°56' and 98°30' west longitude. It is bounded on the east by Republic and Cloud Counties, on the south by Mitchell and Osborne Counties, on the west by Smith County, all in Kansas, and on the north by Webster and Nuckolls Counties, Nebr.

Geography of the area

Jewell County is in the Plains Border division 2/ of the Great Plains physiographic province only a short distance west of the Central Lowlands province. Streams flowing east toward the Central Lowlands have dissected Jewell County to a region of moderate relief. The divides between streams are flat, gently rounded, or ridgelike. The area of maximum relief is in the east central part of the county and extends from White Rock Creek for a distance of 8 miles toward the south. The streams within this area have cut steep-sided valleys from 100 to almost 200 feet below the divide tops. The south valley walls are the steeper; the north walls slope much more gently. Stream valleys in other parts of the county are not so steep-sided and usually are less than 100 feet deep.

The most conspicuous topographic feature of the county is the steep escarpment formed by the Fort Hays limestone member of the Niobrara formation. It extends from the northeast corner southwest

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

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

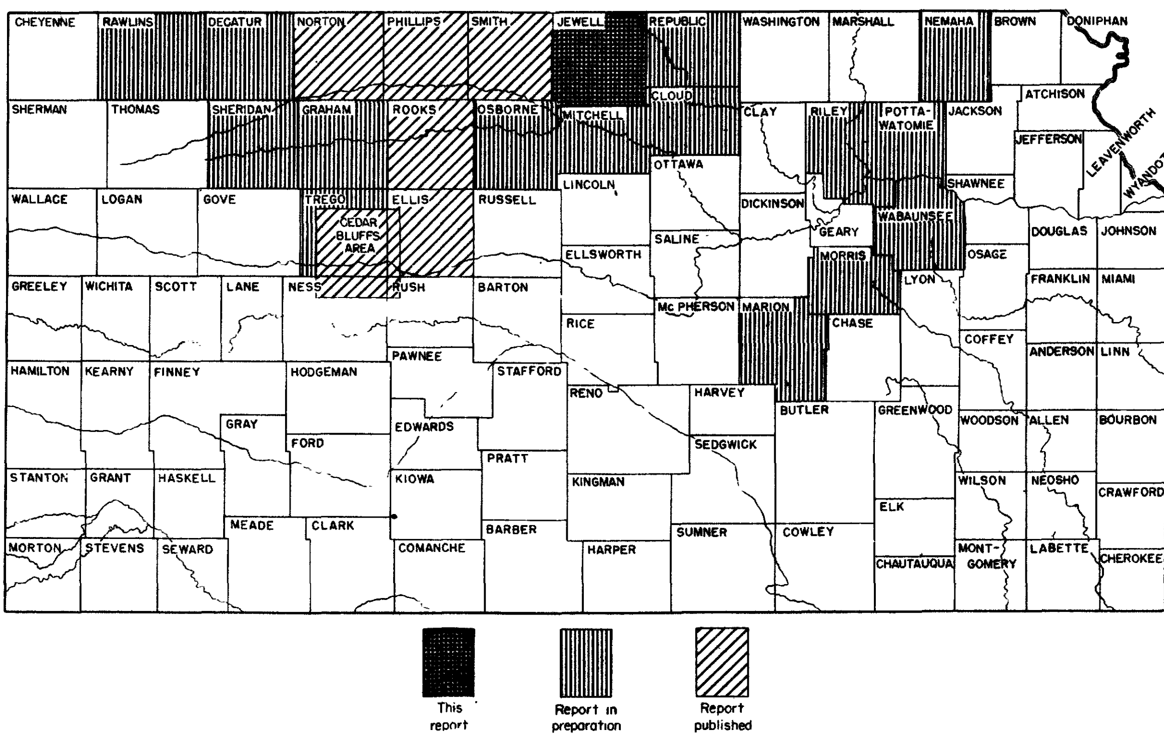


Figure 1.–Index map of Kansas showing areas covered by this report and by other construction-materials investigations.

across the county. Several large, steep-sided outliers formed by the Fort Hays limestone lie south and southeast of the escarpment, rising conspicuously above the surrounding plain.

The lowest point in Jewell County, about 1,400 feet above sea level, is near the southeast corner where Buffalo Creek enters the county; the highest points are the crests of the divides near the northwest corner, which rise to altitudes of slightly more than 1,900 feet.

All except the southwest quarter of the county lies in the drainage basin of the Republican River, which rises in Colorado and, flowing generally toward the east, crosses the extreme northeast corner of Jewell County. Its largest tributary in the county, White Rock Creek, rises in Smith County, flows eastward across the northern part of Jewell County, and enters the Republican River in the northwestern part of Republic County. Marsh and Buffalo Creeks are somewhat smaller tributaries of the Republican River and drain the southeast quarter of the county. Limestone Creek, a tributary of the Solomon River, rises in Jewell County and drains its southwest quarter. The smaller tributaries exhibit a size relationship apparently characteristic of north central Kansas: the southward-flowing tributaries generally are appreciably longer but less numerous than those flowing toward the north.

Jewell County is served by three railways. The main line in Kansas of the Chicago, Rock Island, and Pacific Railroad crosses from east to west approximately through the center of the county. Mankato (the largest city and the county seat), Esbon, Otego, Montrose, and Formoso are located along this railroad. A branch line of the Missouri Pacific Railroad starts in Burr Oak, extends toward the southeast through Mankato, Jewell, and Randall, and leaves the county several miles north of the southeast corner. A branch line of the Atchison, Topeka, and Santa Fe Railroad crosses the northeastern part of the county, and along it are located the cities of Webber and Lovewell. There is less than a mile of trackage belonging to a second branch line of the Missouri Pacific Railroad in the northeast corner of the county.

U. S. 36, a major east-west transcontinental highway of a bituminous-mat type of construction, crosses through the center of the county. Several State highways serve the county and are either of a bituminous-mat type or have been surfaced with loose road metal. Kansas Highway 28 enters near the southeast corner of the county, extends west to Randall, turns north for 2 miles, and then continues west to its junction with Kansas Highway 14 at Jewell. Kansas Highway 14 enters the county from the south and extends through Jewell to its intersection with U. S. 36 several miles east of Mankato; it turns east with U. S. 36 for about 2 miles, turns north again, and extends to the north boundary of the county. Kansas Highway 28 is merged with U. S. 36 for a distance of about 5 miles west from Mankato, at which point Kansas Highway 28 turns north and extends to the north boundary of the county. Kansas Highway 128 starts at a point on the U. S. 36 that is 7 miles west of Mankato; it then extends south to the county boundary. County and township roads generally follow section lines. Some of them are metaled with materials available locally, whereas others are maintained by grading only.

Investigation procedure

This report is based on field work of the reconnaissance type. The base map was made from a map compiled by the Soil Conservation Service of the United States Department of Agriculture. The original map scale of 1 inch equals 2 miles was enlarged photographically to the scale of 1 inch equals 1 mile, and the areal distribution of the stratigraphic units that crop out in Jewell County was then mapped in the field. The mapped stratigraphic units are those recognized as of 1947 by the United States Geological Survey 3/ and the Kansas Geological Survey. 4/ 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 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.

Acknowledgments

Generous assistance in the compilation of data pertaining to geology and construction materials by the following is appreciated: the State Highway Commission of Kansas at Topeka (S. E. Horner, chief geologist, R. D. Finney, engineer of materials, and associates); the Kansas office of the Ground Water Branch, United States Geological Survey (V. C. Fishel, district engineer, and A. R. Leonard, geologist); the State Geological Survey of Kansas at Lawrence (J. C. Frye, executive director); the Jewell County office of the Soil Conservation Service, United States Department of Agriculture; and Clarence Smith, Jewell County engineer in 1947.

This report, in manuscript form, was reviewed critically by various members of the State Highway Commission and by A. R. Leonard and other members of the United States Geological Survey. Illustrations were prepared by draftsmen of the United States Geological Survey. The petrographic determinations included in table 1 were made by C. W. Matthews, and the manuscript was typed by Ruth M. Soelter, both of the United States Geological Survey.

---

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

[4] 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.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

General

This discussion of the geologic formations cropping out in Jewell 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. The principal purpose of this part of the report is that of presenting the geological information required for the location and the effective development of the construction materials contained in each stratigraphic unit.

A summary of the data for each unit is presented in figure 2, Outcropping stratigraphic units in Jewell County, Kans., and the relationships of these stratigraphic units are illustrated in figure 3, Geologic cross section along the line A-A'.

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

The locations of pits and quarries 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 materials 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 the 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 Jewell County. (See pl. 1 and fig. 2.) Its outcrops are restricted to the basal part of the south wall of the valley of Buffalo Creek near the southeast corner of the county. There is an outcrop of a similar sandstone in a small valley tributary to that of Buffalo Creek just east of the county line (center sec. 18, T. 5 S., R. 5 W., Cloud County, Kans.). Undoubtedly the Dakota sandstone underlies most of the rest of Jewell County, but it is concealed by younger stratigraphic units. The map, plate 1, includes beds assigned to Dakota (?) sandstone.

General description.--The Dakota sandstone, as it is exposed in Jewell County, is a fine-grained, rust-brown to light-tan sandstone generally cemented by silica deposited in the pores between sand grains. There are thin lenses of light-gray clay interbedded with the sandstone layers, but these lenses are thinner in proportion to the sandstone lenses than in other outcrop areas of the Dakota sandstone. The sandstone often exhibits cross bedding on weathered surfaces, and most of it probably was deposited by streams. Some sandstone lenses are very firmly cemented, are therefore harder than the remainder of the formation, and form more conspicuous outcrops. The cementing substances are calcium carbonate, silica, iron oxide, or some combination of them.

The formation crops out as a low terrace on the south wall of the valley of Buffalo Creek but largely is masked by deposits of unconsolidated sediments. The presence of this unit can be detected, however, by the characteristic terrace.

It seems probable that the uppermost part of the sandstone here described should be assigned to the basal part of the next younger formation, the Graneros shale. This is indicated by a zone in the upper part of the sandstone which is characterized by an abundance of fossil shark teeth. Certainly the contact between the two formations lies in the upper part of the sandstone. In the opinion of the authors, most of the sandstone is Dakota because it is too thick to be entirely one of the sandstones in the basal part of the Graneros shale and because many of the sandstone layers are cross-bedded, a phenomenon typical of the Dakota but not of the Graneros.

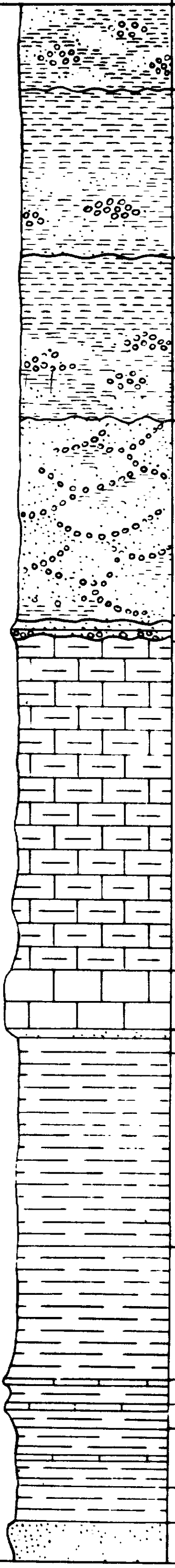
This assignment of the uppermost part of the sandstone to the Graneros and the remainder to the Dakota is confirmed by thermal analyses of a clay zone about 25 feet below the top of the sandstone and of a stratigraphically higher clay lens 0.4 foot thick near the top of another outcrop about 20 feet from the measured section. The upper clay was found to be illite, the dominant clay mineral in the Graneros shale; the lower clay is composed of 80 percent illite and 20 percent kaolinite. Kaolinite is characteristically found in the clay lenses of the Dakota sandstone, but one would not expect to find it in the Graneros shale. 5/

The geologic map of Cloud County compiled by Wing 6/ shows the Dakota sandstone dipping beneath the land surface at a point about 7 miles east of the Jewell County line. The map of Mitchell County compiled by Landes 7/ shows the Dakota sandstone dipping underground at a point about 8 miles south of the southeast corner of Jewell County. The outcrop of Dakota sandstone in Jewell County probably is the result of an anticlinal fold that has raised the sandstone to the level of the present land surface in this locality. This

[5] Plummer, N., and Romary, J. F., Stratigraphy of the pre-Greenhorn Cretaceous beds of Kansas: Kansas Geol. Survey Bull. 41, pt. 9, p. 346, 1942.

[6] Wing, M. E., Geology of Cloud and Republic Counties, Kansas: Kansas Geol. Survey Bull. 15, pl. 1, 1930.

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



Outcrop thickness (feet)	System	Series	Formation	Member	Generalized description	Construction materials
0-50	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	Terrace deposits		Upper part, brown to brown-gray silt locally with buried soil zone; basal part, silt with thin lenses of sand and fine gravel.	Mineral filler Road metal
0-100	Quaternary	Pleistocene and Recent	Sanborn formation		Upper part, gray-brown silt locally with buried soil zone; lower part, buff or tan silt and interbedded lenses of sand and gravel; numerous lenses of white or light-gray volcanic ash in basal part.	Mineral filler Volcanic ash Aggregate Road metal
0-120	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
0-4	Tertiary	Pliocene	Ogallala formation		Light-gray limestone; some sand, gravel, mortar bed.	
0-200	Cretaceous	Upper Cretaceous	Niobrara formation	Smoky Hill chalk member	Blue-gray and orange-gray chalky shales interbedded with white or blue-gray massive or blocky chalks; forms badlands.	Road metal Calcareous binder
0-35	Cretaceous	Upper Cretaceous	Niobrara formation	Fort Hays limestone member	Massive, soft, cream to white chalky limestones alternating with thin layers of chalky shales.	Structural stone Calcareous binder Road metal
0-1	Cretaceous	Upper Cretaceous	Carlile shale	Codell member	Buff to brown sandy siltstone.	
0-175	Cretaceous	Upper Cretaceous	Carlile shale	Blue Hill shale member	Blue-gray, noncalcareous, thin-bedded clay shale; contains septarian concretions, forms badlands.	
0-80+	Cretaceous	Upper Cretaceous	Carlile shale	Fairport chalky shale member	Orange or yellow-brown chalky shales with interbedded thin beds of chalk in basal part.	
0-15	Cretaceous	Upper Cretaceous	Greenhorn	Pfeifer member	Chalky shales and thin chalky limestones.	Structural stone Road metal
0-12	Cretaceous	Upper Cretaceous	Greenhorn	Jetmore member	Thin gray chalks and blue-gray calcareous shale.	
0-35	Cretaceous	Upper Cretaceous	Greenhorn	Hartland-Lincoln members	Gray or dark gray calcareous shales interbedded with thin limestones and very thin bentonites.	
0-20	Cretaceous	Upper Cretaceous	Graneros shale		Dark gray or black noncalcareous clay shale; thin bentonites.	
25	Cretaceous	Upper Cretaceous	Dakota sandstone		Brown or tan fine-grained sandstone; locally quartzitic.	Road metal Riprap Structural stone

Figure 2.—Outcropping stratigraphic units in Jewell County, Kans., and their construction materials.

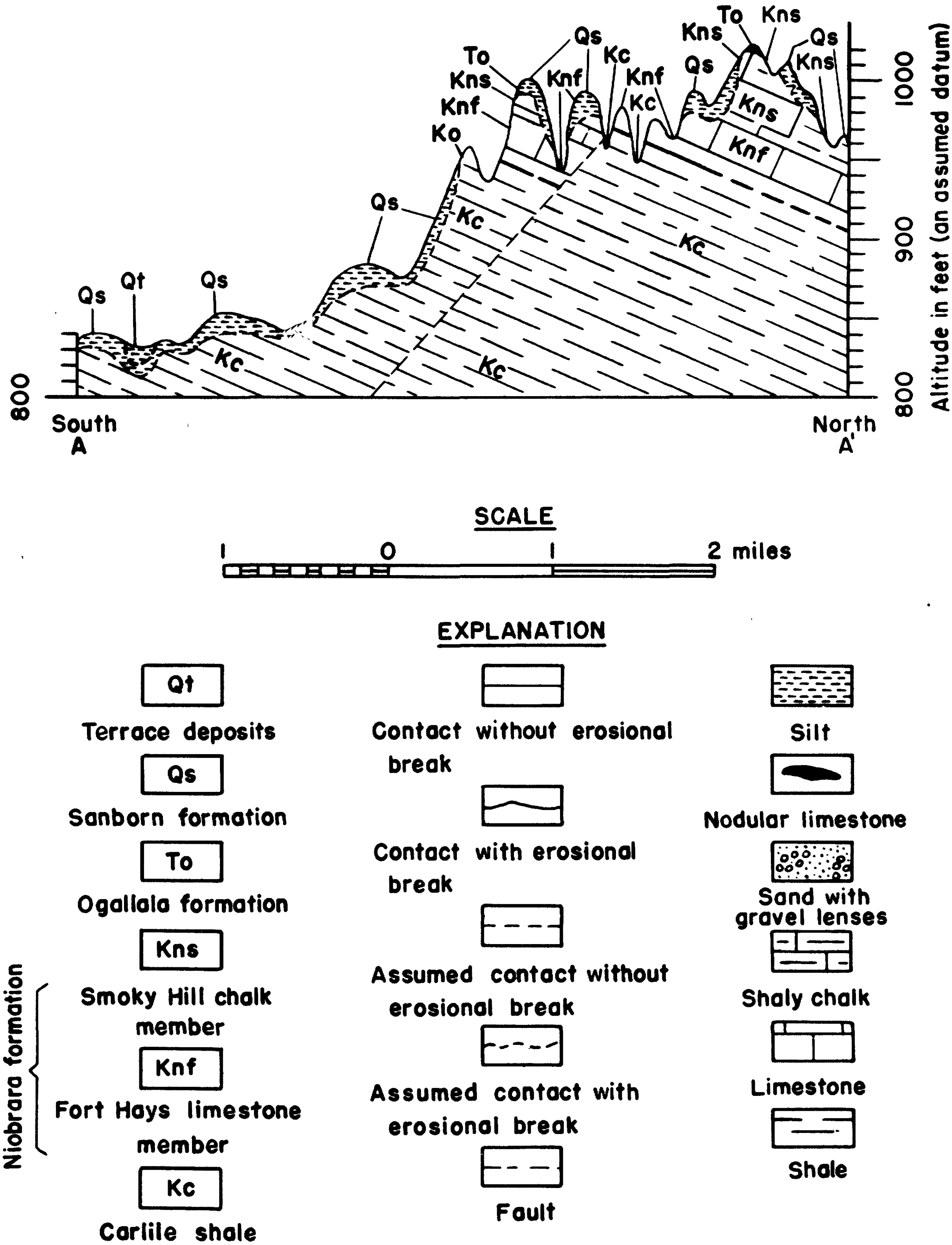


Figure 3.—Geologic cross section along the line *A–A'* between secs. 27 and 28, T. 4 S., R. 10 W. and secs. 21 and 22, T. 5 S., R. 10 W.

outcrop of the sandstone is near the center of an area of 12 square miles which, according to one of the landowners, is currently leased by an oil company.

Because the separation of the basal sandy phase of the Graneros shale from the Dakota sandstone is based on rather technical features not easily distinguishable in this field, this sandy phase is mapped as Dakota sandstone on plate 1.

Representative measured section.--The following section of the Dakota sandstone, including 6 feet believed by the authors to be Graneros shale, was measured near the base of the south wall of the valley of Buffalo Creek in the SE¼SW¼ sec. 12, T. 5 S., R. 6 W.:

	Feet
Sanborn formation: Brown silt	2.0+
Dakota (?) sandstone:	
Quartzite, fine-grained, massive, hard; brown, weathers gray brown; firmly cemented; slightly calcareous; fossil shark teeth numerous in a conglomeratic zone at top; thickness ranges from 0.3 foot to 2 feet, usually about	2.0
Sandstone, fine-grained, massive, soft, poorly cemented; buff, weathers light gray	3.0
Sandstone, fine-grained, massive, soft, noncalcareous; light gray, weathers rust gray	1.0
Dakota sandstone:	
Sandstone, fine-grained, soft, massive, noncalcareous, cross-bedded; buff, weathers light gray; rust-colored and yellow zones in lower part; has been quarried as plaster sand	15.6
Covered	1.5
Sandstone, fine-grained, hard, thin-bedded; brown, weathers rust brown; lenticular	.4
Sand, loose, fine-grained; buff, weathers rust brown	1.0
Clay, illite and kaolinite; blue gray, weathers light gray; limonite-streaked; crops out in road ditch	.4
Sand, loosely cemented, fine-grained; buff to light gray; limonite streaks	2.2
Clay, sandy; blue gray; limonite-stained	.2
Sand, loosely cemented, fine-grained; buff to gray; interbedded thin clay seams and one iron-cemented sand lens	5.6
Clay; blue gray; limonite-stained	.4
Sand, loosely cemented, fine-grained; limonite-stained; interbedded thin seams of clay	.6

Dakota sandstone--Continued.

	Feet
Sand, loosely cemented, fine-grained; limonite-stained	1.2
Sand, clay, fine-grained; limonite-stained	2.1
Sand, fine-grained, loosely cemented; light gray; rust-yellow limonitic zone at top	.7
Sandstone, hard; rust brown; auger would not penetrate.	
Total thickness of Dakota sandstone measured (including 6 feet at top of section that might be Graneros shale)	37.9

Thickness.--The maximum exposed thickness of the Dakota sandstone in Jewell County may be stated as approximately 25 feet, provided one includes the 6 feet that may belong to the basal sandy part of the Graneros shale. Using a 4-inch soil auger, the field party sampled an additional 13 feet before a hard zone was encountered and the test hole abandoned. Wells drilled in this part of Kansas indicate that the total thickness of the Dakota sandstone is slightly more than 200 feet; only the upper part of the formation, therefore, crops out in Jewell County.

Construction materials.--
Road metal.
Riprap.
Structural stone.

Graneros shale

Areal distribution.--The Graneros shale of Upper Cretaceous age was found cropping out in only two places in the county, both of these in the southeastern part. (See pl. 1 and fig. 2.) The better exposure is in sec. 23, T. 4 S., R. 6 W., and the other is in secs. 12, 13, and 14, T. 5 S., R. 6 W. Undoubtedly, other occurrences of this stratigraphic unit are concealed at shallow depths by younger sediments, and the formation extends under most of the county at increasing depths toward the northwest.

General description.--The Graneros shale lies conformably, without an intervening erosional break, above the Dakota sandstone and below the Greenhorn limestone. It was deposited in marine water. The upper part of the formation is a noncalcareous, dark-gray to black, laminated to very thin bedded clay shale. Thin interbedded zones of bentonite ranging from 0.1 to 0.4 foot thick are fairly numerous. The fresh surfaces of the bentonite are white to light gray but weather orange gray. The lower part of the member is composed of noncalcareous, very thin bedded black shales that weather gray. A sandstone bed, possibly the basal part of the Graneros shale, has been discussed previously under the Dakota sandstone.

Representative measured section.--The following measured section of the Graneros shale is in the lower part of a cut bank exposed in the NW¼SW¼ sec. 23, T. 4 S., R. 6 W. The upper part of this same cut bank is cited as one of the measured sections of the Greenhorn limestone.

	Feet
Greenhorn limestone	33.35
Graneros shale:	
Shale, clay, noncalcareous, laminated; very dark gray, weathers light gray	.5
Bentonite; light gray, weathers orange gray	.3
Shale, clay, noncalcareous, laminated; dark gray, weathers light gray	1.3
Bentonite; light gray, weathers orange gray	.1
Shale, very thin bedded; black, weathers gray	1.5
Bentonite; light gray, weathers orange gray	.4
Shale, noncalcareous, very thin bedded; black, weathers gray	13.0
Base covered.	17.1

Thickness.--The total thickness of the Graneros shale in Jewell County is thought to be about 20 feet, but individual outcrops are thinner. A test hole drilled a short distance southeast of Jewell in 1948 by the Kansas Geological Survey penetrated 23 feet of rock identified as this formation. 8/

Construction materials.--No use of material from the Graneros shale was observed in engineering structures in Jewell County. Material from this formation might be used in fills and embankments, but because of the high content of clay the shoulder slopes should be flat.

Greenhorn limestone

Areal distribution.--Outcrops of the Greenhorn limestone of Upper Cretaceous age (see fig. 2) occur in the southeast quarter of Jewell County. This formation is divided into four members: (1) the Lincoln limestone (the oldest and stratigraphically the lowest), (2) the Hartland shale, (3) the Jetmore chalk, and (4) the Pfeifer shale (the youngest and stratigraphically the highest); but the first two members, the Lincoln limestone and the Hartland shale, are not differentiated in this county. The formation is mapped as a single stratigraphic unit on plate 1, although descriptions of the several members will be given to aid in field recognition.

The formation crops out most extensively along the valley walls of Buffalo Creek from Randall east to the county line and in the valleys of tributaries to this stream. (See pl. 1.) A second important area of outcrop is that at the heads of some of the tributaries to Marsh Creek along the east border of the county. Isolated from these two areas is an outcrop of the upper part of the formation along the west wall of the valley of Limestone Creek in secs. 32 and 33, T. 5 S., R. 9 W. This formation underlies most of the county but is concealed beneath younger stratigraphic units for the most part.

[8] Walters, K. L., geologist, Kansas Geol. Survey, personal communication.

General description.--The Greenhorn limestone, a marine deposit, conformably overlies the Graneros shale and is overlain similarly by the Carlile shale. An intervening erosional break (unconformity) separates it from still younger stratigraphic units, Sanborn formation and terrace deposits, that may overlie it in some localities.

The undifferentiated Lincoln limestone and Hartland shale members consist of beds of shale interbedded with numerous thin layers of limestone and seams of bentonite. The shale layers are calcareous, laminated, and gray or dark gray. They weather to light gray or blue gray. The shales generally are composed of clay-size particles but are silty in some zones. The thin limestones are crystalline, hard, and rather massive. Their color varies from buff through light gray to dark gray, and they weather to light gray or buff. These limestone layers are less fossiliferous than those in the upper part of the formation but locally may contain numerous shark teeth and some fossilized vertebrae of bony fish.

There are many thin but persistent interbedded seams or layers of bentonite in the undifferentiated Lincoln-Hartland members. The bentonite is light gray or white when unweathered but weathers to orange gray. The swelling phenomenon often associated with bentonite is only poorly developed in the bentonites of this unit.

Generally this part of the Greenhorn limestone crops out in rather steep sided banks from which some of the thicker and more massive crystalline limestones project as fairly conspicuous ledges. The most conspicuous of these is a layer 0.6 foot thick in the basal part of the unit. It forms a minor terrace in the valley of Buffalo Creek above the one formed by the Dakota sandstone.

The Jetmore chalk member is perhaps distinguished most readily from the undifferentiated Lincoln limestone-Hartland shale members by its limestone beds which are characteristically chalky in contrast to the harder, more crystalline limestones of the underlying unit. The bulk of the Jetmore chalk member is composed of beds of blue-gray, laminated or very thin bedded calcareous shale. They weather to dark gray.

The limestone layers in the Jetmore chalk are thinner than the shales with which they are interbedded. The limestones are usually chalky and only occasionally crystalline; they are rather hard and gray, cream, or tan in color. Most of the limestones and some of the shales contain numerous shells of Inoceramus, a fossil clam.

The top of the Jetmore chalk member is marked by a conspicuous, buff-gray, chalky limestone, usually about a foot thick, in which there is an abundance of shells. For this reason, the bed is known throughout north central Kansas as "shell rock." The unweathered limestone is quite soft but case-hardens upon weathering. It forms rounded hillside terraces.

The top of the Greenhorn limestone and its uppermost member, the Pfeifer shale, is arbitrarily defined as the top of the "Fencepost" limestone bed. This layer ranges from 0.8 foot to 1.3 feet thick and is tan or buff gray, abundantly fossiliferous, and marked by a typical rust-colored band in its middle part.

The "Fencepost" limestone forms a conspicuous shoulder on many of the hills in the southeastern part of the county. It has been used extensively as structural stone throughout the area of its outcrop. Other limestone layers in the Pfeifer shale member are quite thin, orange to gray, and chalky; they contain numerous shells of Inoceramus and other fossil invertebrates. Limestone beds in the upper part of the member tend to be concretionary. The interbedded layers of calcareous, fossiliferous shale generally are thicker than the chalky limestones. The shales vary from tan to gray, are chalky, and usually are very thin bedded or platy. Thin seams of orange-gray bentonite occur within the shales, and thin layers of gray, crystalline limestone were noted in the basal part of the member.

Representative measured sections.--The following measured sections show the characteristics of the several members of the Greenhorn limestone as they crop out in Jewell County:

(1) A bank along a tributary to Marsh Creek in the NW¼SW¼ sec. 23, T. 4 S., R. 6 W., shows the following section of the undifferentiated Lincoln limestone and Hartland shale members:

	Feet
Sanborn formation	5.0+
Undifferentiated Lincoln limestone and Hartland shale members of Greenhorn limestone:	
Limestone, hard; light gray, weathers orange buff; limonite-streaked; numerous fossil fragments	0.4
Shale, laminate; buff	1.2
Limestone, hard; light gray, weathers buff; limonite-streaked; Inoceramus	.2
Shale, laminated; gray, weathers buff; thin interbedded calcareous layers	2.2
Shale, calcareous, platy; light gray, weathers orange gray	.9
Bentonite; orange	.3
Shale, flaky; gray, weathers light gray; interbedded thin siltstone layers; Inoceramus, shark teeth	4.3
Bentonite; light gray, weathers orange gray	.2
Shale, calcareous, flaky; gray, weathers light blue gray; interbedded thin siltstone layers	4.2
Bentonite; tan gray, weathers orange gray; thickens and thins laterally	.2
Limestone, platy; thin crystalline layer at top; dark gray, weathers light gray	.6
Shale, laminated; limonite-streaked; dark gray, weathers light gray	.2
Bentonite; light gray, weathers orange gray	.1

Undifferentiated Lincoln limestone and Hartland shale members of Greenhorn limestone--Continued.

	Feet
Shale, flaky; gray, weathers light gray; interbedded thin siltstone layers; Inoceramus, shark teeth	.8
Bentonite; light gray, weathers orange gray	.2
Shale, laminated; buff gray	1.7
Bentonite; orange gray	.4
Limestone, chalky, platy; white, weathers light gray	.2
Shale, laminated and platy; buff, weathers orange gray	.6
Limestone, hard, massive; buff, weathers light gray	.4
Shale, laminated; orange gray, weathers buff	1.2
Bentonite; light gray, weathers orange gray	.3
Shale, calcareous, flaky; gray, weathers buff; Inoceramus	.9
Shale, calcareous, flaky; dark gray, weathers light blue gray	1.5
Limestone, hard, somewhat crystalline; gray, weathers light gray	.2
Bentonite; orange gray	.1
Shale, flaky; thin layers of crystalline limestone; buff gray	3.1
Shale, platy; dark gray, weathers light blue gray; interbedded thin seams of bentonite; Inoceramus	6.3
Shale, laminated; black, weathers light gray	.3
Limestone, hard, crystalline; dark gray, weathers light gray	.15
Underlain by Graneros shale.	33.35

(2) The following section was measured in a bank along a tributary to Marsh Creek in the SW¼SW¼ sec. 35, T. 3 S., R. 6 W. The bank includes the uppermost part of the Hartland shale member and the full thickness of the Jetmore chalk and Pfeifer shale members.

	Feet
Carlile shale	6.0+
Pfeifer shale member of Greenhorn limestone:	
"Fencepost" limestone bed, chalky, massive; tan gray with rust-brown band in middle part; weathered surfaces hard; occasional shell fragments	1.1
Shale, chalky, very thin bedded; tan, weathers buff; some calcareous concretions; thin bentonite layer in upper part; Inoceramus	2.0
Limestone, platy, somewhat crystalline; orange gray	.1

Pfeifer shale member--Continued.	Feet
Shale, chalky, very thin bedded; buff gray	.8
Limestone, somewhat crystalline; gray, weathers buff	.1
Shale, very thin bedded; tan gray, weathers buff gray; thin bentonite in lower part	.9
Limestone, chalky, fresh surfaces soft, weathered surfaces hard; orange gray; *Inoceramus*, *Prinotropsis* (fossil cephalopod)	.2
Alternating crystalline limestones and limy shales; gray tan; *Inoceramus* abundant	9.8
Total thickness.	15.0

Jetmore chalk member of Greenhorn limestone:	Feet
"Shell rock" limestone bed, chalky; unweathered surfaces soft, weathered surfaces hard; lower part somewhat platy; buff gray; *Inoceramus* very abundant	1.1
Shale, chalky, laminated; light gray, weathers buff; interbedded thin beds of fossiliferous limestone	1.8
Limestone, hard, dense; gray, weathers buff; *Inoceramus*	.3
Shale, very thin bedded; dark gray; interbedded thin, irregular layer of fossiliferous limestone	.8
Limestone, hard, dense, crystalline; gray, weathers buff; *Inoceramus*	.3
Shale, calcareous, platy; gray; *Inoceramus*	.9
Limestone, hard, dense, crystalline; gray, weathers buff; *Inoceramus*	.4
Shale, laminated to very thin bedded; blue gray; *Inoceramus*	.6
Limestone, hard, dense, crystalline; limonite-streaked in middle part; gray; *Inoceramus*	.3
Shale, calcareous, very thin bedded to platy; blue gray; *Inoceramus*	.5
Limestone, chalky, hard; tan, weathers buff gray	.3
Shale, very thin bedded; blue gray; *Inoceramus*	.4
Limestone, chalky, hard; cream color, weathers buff; limonite-streaked; thickens and thins laterally	.2
Shale, very thin bedded to laminated; buff to blue gray, weathers blue gray; *Inoceramus* abundant in basal part	.9
Limestone, hard; cream tan, weathers buff; fossil fragments	.5

Jetmore chalk member of Greenhorn limestone--Continued.	Feet
Shale, laminated to platy; blue gray, weathers light blue gray	.5
buff gray; *Inoceramus*	.1
Shale, very thin bedded to laminated; blue gray; fossil fragments	.4
Limestone, hard; blue gray, weathers buff; fossil fragments	.1
Shale, laminated to very thin bedded; blue gray; fossil fragments	.4
Limestone, somewhat chalky, hard; gray, weathers buff; thickens and thins laterally; fossil fragments	.2
Shale, very thin bedded; blue gray; fossil fragments	.5
Limestone, somewhat chalky, hard; thickens and thins laterally; gray, weathers buff; fossil fragments	.1
Shale, very thin bedded; very thin limestone layer in basal part; blue gray; fossil fragments	.6
Limestone, hard, dense, crystalline; buff gray; limonite-streaked; fossil fragments	.3
Underlain by Hartland shale member.	12.5

Thickness.--The total thickness of the Greenhorn limestone in Jewell County is thought to be between 60 and 70 feet. The full thickness of the Pfeifer shale member is 15 feet, that of the Jetmore chalk member is 12.5 feet, and the combined thickness of the Hartland shale and Lincoln limestone members is probably a little more than 35 feet. Individual outcrops of this formation are seldom more than 15 feet thick. The formation appears to thicken toward the southwest.

Construction materials.--
Structural stone.
Road metal.

Carlile shale

Areal distribution.--The Carlile shale of Upper Cretaceous age (see fig. 2) consists of three members: (1) the Fairport chalky shale (the oldest), (2) the Blue Hill shale, and (3) the Codell sandstone (the youngest). The three members crop out in Jewell County and are mapped on plate 1 as a single stratigraphic unit, the Carlile shale, because no one of them is especially significant as a source of engineering construction materials. As aids to field recognition, however, general descriptions and representative measured sections of the members will be given.

The Carlile shale crops out extensively in all but the northwestern part and the northern border area of Jewell County, although there are several small outcrops along the south wall of the valley of the Republican River in the northern border area. The formation is exposed below the Fort Hays limestone member of the Niobrara formation in almost every place where the Fort Hays member crops out. Other exposures occur along the valley walls of tributary streams in the southeastern part of the county and in the southern border area. The Carlile shale has been eroded completely from the eastern parts of the valleys of Buffalo and Marsh Creeks. It generally is concealed beneath younger formations in the northern and northwestern parts of the county.

General description.--The lowest member of the Carlile shale, the Fairport chalky shale, generally is orange brown or yellow brown, calcareous, and characterized by numerous thin beds of soft, clayey chalk in the basal part. It overlies the Greenhorn limestone conformably and is separated and arbitrarily distinguished from it by the "Fencepost" limestone bed at the top of the older unit. The Fairport usually is concealed by a younger, overlying formation, the Sanborn, and exposures therefore are limited in extent in Jewell County. It erodes to form a relatively flat plain overlain by a thin veneer of silt of the Sanborn formation.

The Blue Hill shale member is far more conspicuous in this county than the Fairport chalky shale. It is composed principally of clay-size particles and is essentially noncalcareous. Its color, typically, is blue gray, but many zones have been conspicuously stained by limonite and are rust-colored. Septarian concretions, some of which are 2 feet or more in diameter, are present at various levels within the member. Thin zones of crystals of a variety of gypsum (selenite) are reported to occur in the Blue Hill shale but were not observed by the field party.

The soft clay shales weather and erode to form a badland type of topography. Such badland areas are found only near outcrops of the overlying Fort Hays limestone member of the Niobrara formation, but similar areas concealed by the Sanborn formation undoubtedly occur in the southern and eastern portions of the county.

The Codell sandstone, the uppermost member of the Carlile shale, is a thin, buff to brown, limonite-stained, sandy siltstone. It grades into the underlying Blue Hill shale member and, to a lesser extent, into the overlying Fort Hays limestone member of the Niobrara formation. It is usually concealed, except along cut banks, by the overlying Fort Hays limestone.

As originally defined by Bass,9/ the Codell sandstone member includes two sandstones separated by a shale. The lower sandstone appears to be absent in Jewell County, and the shale is indistinguishable from those that compose the Blue Hill shale member. For these reasons, the Codell sandstone member, as the term is used in this report, is restricted to the siltstone immediately below the Fort Hays limestone member of the Niobrara formation.

Representative measured sections.--

(1) A cut bank in the NE¼SW¼ sec. 14, T. 4 S., R. 9 W., shows the following section of the upper part of the Carlile shale:

	Feet
Fort Hays limestone member of Niobrara formation	10.0+
Codell sandstone member of Carlile shale:	
Siltstone, noncalcareous, soft; rust-colored	1.5
Siltstone, noncalcareous, soft; gray with rust-colored streaks	.8
Blue Hill shale member of Carlile shale:	
Shale, clay, noncalcareous, blocky; blue gray	2.0
Shale, clay, noncalcareous, very thin bedded; dark blue with numerous rust-colored limonite streaks; septarian concretions scattered throughout basal 40 feet	85.7
Base covered.	90.0

(2) The basal member of the Carlile shale crops out in the SE¼NE¼ sec. 14, T. 3 S., R. 6 W., as follows:

	Feet
Sanborn formation: Silt	3.0+
Fairport chalky shale member of Carlile shale:	
Shale, chalky; mottled gray and orange color, weathers gray	2.5
Chalk, clay; alternating gray and orange-brown bands; weathers orange	2.5
Base covered.	5.0

Thickness.--The total thickness of the Carlile shale in Jewell County is estimated to be between 250 and 300 feet. The Fairport chalky shale member is estimated to be more than 80 feet thick, although individual outcrops generally are less than 10 feet thick. The Blue Hill shale member forms thicker outcrops, some of them 25 or more feet thick, and its total thickness is estimated to be about 175 feet. The thickness of the Codell sandstone member is somewhat variable but averages about a foot.

Construction materials.--No materials of especial value in engineering construction were found in this formation. The shales probably would be satisfactory as material for fills and embankments, but the shoulder slopes should be flat wherever these shales are so used because of the high percentage of clay in the formation. The clay content and the consequent low bearing strength indicate that this material probably would be unsatisfactory for use in earthern dams.

Fort Hays limestone member of Niobrara formation

Areal distribution.--The Fort Hays limestone and the Smoky Hill chalk members compose the Niobrara formation of Upper Cretaceous age (see fig. 2). The two members are mapped as individual units on plate 1 and will be described separately because the Fort

9 Bass, N. W., Geologic investigations in western Kansas, pt. 1, Geology of Ellis County: Kansas Geol. Survey Bull. 11, p. 28, 1926.

Hays limestone is more important than the Smoky Hill chalk as a source of construction materials.

The Fort Hays limestone member crops out in a wide belt extending from White Rock Creek at the east border toward the southwest corner of the county. This member at one time undoubtedly underlay the entire county but subsequently has been eroded from most of the southeastern part and along some of the stream courses in the remainder of the county. The Fort Hays limestone member is concealed by younger formations in the northwestern part of the county.

General description.--The Fort Hays limestone was deposited in marine waters and is conformable with the overlying Smoky Hill chalk member of the same formation and the underlying Codell sandstone member of the Carlile shale. The limestone beds average about 3 feet in thickness and are chalky, soft, massive, and cream to white in color. They alternate with thin layers, usually about 0.2 foot thick, of chalky, buff to blue-gray shale. This member contains fossilized shells of Inoceramus and a fossil oyster (Ostrea) in considerable numbers; it is reported to contain fossilized skeletons of vertebrates, although none was found by the field party. The Fort Hays limestone forms bluffs 20 to 30 feet high, and small streams cutting into the limestone have incised steep-sided valleys. The part of the member that immediately underlies the land surface exhibits a tendency to "shatter"--that is, to break into flattish fragments 1 inch or 2 inches thick and 4 or 5 inches long.

Numerous small secondary structures were observed in the Fort Hays limestone and other rocks formed during the Cretaceous period (see fig. 2) but are not mapped on plate 1 because they are not important in a survey of construction materials. A small overthrust of the Smoky Hill chalk onto the Fort Hays limestone was observed in the NW¼SW¼ sec. 1, T. 2 S., R. 9 W. A small fold (monocline) is visible in a road cut in the SW¼SW¼ sec. 23, T. 3 S., R. 8 W, the Fort Hays limestone here dipping at an angle of approximately 30°. In addition, a normal fault was encountered in surveying the cross section shown in figure 3. The displacement along this fault plane appears to be between 35 and 40 feet.

The stratigraphic units of Cretaceous age dip generally toward the northwest at the rate of about 10 feet per mile. As a result of this regional dip and a general rise in the land surface toward the west and northwest, the oldest Cretaceous units crop out in the southeastern part of the county, and belts of successively younger units occur toward the northwest.

Representative measured section.--The following section of the Fort Hays limestone member was measured in a quarry in the SW¼NW¼ sec. 10, T. 2 S., R. 8 W.:

	Feet
Smoky Hill chalk member of Niobrara formation	8.2
Fort Hays limestone member of Niobrara formation:	
Limestone, chalky, massive; light tan, weathers buff; limonite-stained	1.6
Fort Hays limestone member of Niobrara formation--Continued.	
Shale, chalky	.2
Limestone, chalky, soft, blocky; buff gray; Inoceramus, Ostrea	.7
Shale, chalky, platy; light blue gray	.2
Limestone, chalky, soft, massive; buff gray; limonite-stained; Inoceramus, Ostrea	3.0
Covered	3.5
Limestone, chalky, massive; cream, weathers buff	3.5
Shale, chalky	.2
Limestone, chalky, massive; cream brown, weathers buff; limonite-stained	1.8
Shale, chalky	.4
Limestone, chalky, massive, numerous limonite nodules; cream brown, weathers buff	2.7
Shale, chalky	0.1
Limestone, chalky, massive; light brown; limonite-stained; Inoceramus, Ostrea	2.7
Shale, chalky	.1
Limestone, chalky, massive; cream, weathers buff	.6
Shale, chalky	.2
Limestone, chalky, massive; cream brown, weathers buff; Inoceramus, Ostrea	3.3
Underlain by Carlile shale.	25.5

Thickness.--The thickness of the Fort Hays limestone member varies somewhat in Jewell County. The representative measured section indicates a total thickness of about 25 feet, but the outcrops along the line of the cross section (see fig. 3) indicate a total thickness of about 35 feet. This member undoubtedly thickens toward the west and southwest, because outcrops more than 50 feet thick have been measured in Ellis and Trego Counties, Kans.

Construction materials.--The Fort Hays limestone has been used as riprap on earthern dams but is unsatisfactory. Numerous such dams have been observed in the field, and in every one the Fort Hays limestone had so deteriorated, presumably through slaking, freeze-and-thaw, or both, that it served no valuable purpose. The uses for which the Fort Hays limestone member is considered adequate are:

Structural stone.
Calcareous binder.
Road metal.

Smoky Hill chalk member of Niobrara formation

Areal distribution.--The Smoky Hill chalk, the upper member of the Niobrara formation (see fig. 2), crops out extensively over a wide area in Jewell County and is absent only in the southeastern part and the eastern and southern border areas. (See pl. 1.) The most conspicuous outcrops are along White Rock Creek and its tributaries. Less extensive outcrops occur in the headward areas of the smaller tributaries to Marsh, Buffalo, and Limestone Creeks. The member is present under most of the divides in the northwest half of the county but is obscured by the younger Ogallala and Sanborn formations.

General description.--The Smoky Hill chalk member conformably overlies the Fort Hays limestone but is overlain unconformably by the Ogallala and Sanborn formations. This is the youngest local stratigraphic unit deposited in marine waters. It consists of layers of laminated or platy, chalky shales, blue gray in the lower part of the member but becoming orange gray in the upper part, and interbedded thin layers of massive or blocky chalk. The chalk beds vary from white through cream to blue gray and are quite soft. Fossilized shells of Inoceramus and Ostrea are quite abundant in the member, and fossilized skeletons of marine vertebrates have been reported in it.

The soft beds that compose the Smoky Hill are easily eroded and form areas of badland topography.

Representative measured section.--A road cut in the SE¼SE¼ sec. 31, T. 1 S., R. 8 W., exhibits the following section:

	Feet
Sanborn formation: Silt	3.0±
Smoky Hill chalk member of Niobrara formation:	
Chalk, soft, platy; white, weathers buff	.8
Shale; cream, weathers buff	.5
Chalk, soft, platy to blocky; white, weathers buff; Ostrea	.9
Shale, chalky, soft, platy; cream, weathers buff	1.1
Chalk, blocky to massive; cream color, weathers buff; Ostrea	1.9
Shale, laminated; buff; Ostrea	3.0
Shale, chalky, platy; blue gray; limonite-stained	1.7
Shale, laminated; buff; fragments of fossil wood	.9
Chalk, platy to blocky, soft; brown gray, weathers light gray	.3
Chalk, platy, soft; cream color, weathers buff	1.8
Shale, chalky, soft, platy; blue gray, weathers light blue gray; Ostrea, Inoceramus	6.6
Covered	4.0
Shale, chalky, platy, soft; brown gray, weathers buff; Ostrea	8.2
Chalk, platy to blocky, soft; blue gray, weathers light blue gray	2.9
Shale, laminated, soft; brown gray with orange streaks, weathers buff; Inoceramus, Ostrea	4.9
Chalk, platy to blocky, soft; blue to buff gray, weathers light blue gray; Ostrea, Inoceramus	2.4
Base covered.	41.9

Thickness.--Individual outcrops of the Smoky Hill chalk member range from several feet to as much as 50 feet in thickness. The total thickness of this member in Jewell County is estimated to be about 200 feet. This is only about the basal third of the full thickness of the formation as it is developed farther west in Kansas.

Construction materials.--
- Road metal.
- Calcareous binder.

Ogallala formation

Three deposits classified as belonging to the Ogallala formation crop out near the crests of some of the divides in the southwest corner of the county (secs. 16 and 34, T. 4 S., R. 10 W., and secs. 11 and 14, T. 5 S., R. 10 W.). Questionable deposits of this age crop out most widely in the area a short distance north and northeast of Mankato, but there are several smaller outcrops south and southwest of the city.

Areal distribution.--The Ogallala formation of Tertiary age (see fig. 2) is not typically developed in Jewell County. Some materials that crop out near the tops of divides can be assigned definitely to this formation, but on other divides very thin layers of apparently similar material can only questionably be assigned to this unit. A distinction was made between these two phases of the Ogallala formation in the field mapping. Outcrops of undoubted Ogallala formation are shown on plate 1, whereas the areas in which the questionable material was found are shown in figure 4. No exhaustive attempt was made to solve this problem because its solution would contribute nothing of value to a survey of construction materials; the Ogallala formation in Jewell County is only a minor source of construction materials at best.

General description.--In the counties west and southwest of Jewell County, the Ogallala formation is a deposit of sand and gravel laid down principally by streams draining eastward from the Rocky Mountains. In Jewell County, however, this characteristic phase of the formation is poorly developed. An outcrop of typical Ogallala material was found in the NE¼SW¼ sec. 16, T. 2 S., R. 8 W. The deposit is a fine sand in which pebble-size fragments of igneous rocks are intermixed. Only one outcrop of a typical mortar bed of the Ogallala was found in Jewell County by the field party, although somewhat similar material was observed at other places in the same vicinity. The bed crops out in the SW¼SW¼ sec. 16, T. 2 S., R. 8 W., and is a hard, light-gray, lime-cemented, fine-grained sand about a foot thick. Mortar beds are much more conspicuous in the counties toward the west.

As usually developed in this county, the Ogallala formation caps some of the high divides and consists of a veneer of dense, hard, calcareous material that averages less than 2 feet in thickness. It is white to gray in color, and there are occasional sand grains scattered through it. There is a similar hard, dense limestone near the top of the Ogallala formation in many other areas of western Kansas, and the correlation of this material in Jewell County with the Ogallala formation seems acceptable. The part of the Ogallala formation mapped in figure 4, however, generally is only several inches thick as exposed on or near the tops of hills. It too is a hard, dense limestone with occasional sand grains scattered through it. The material obviously is not a part of the Smoky Hill chalk member of the Niobrara, which

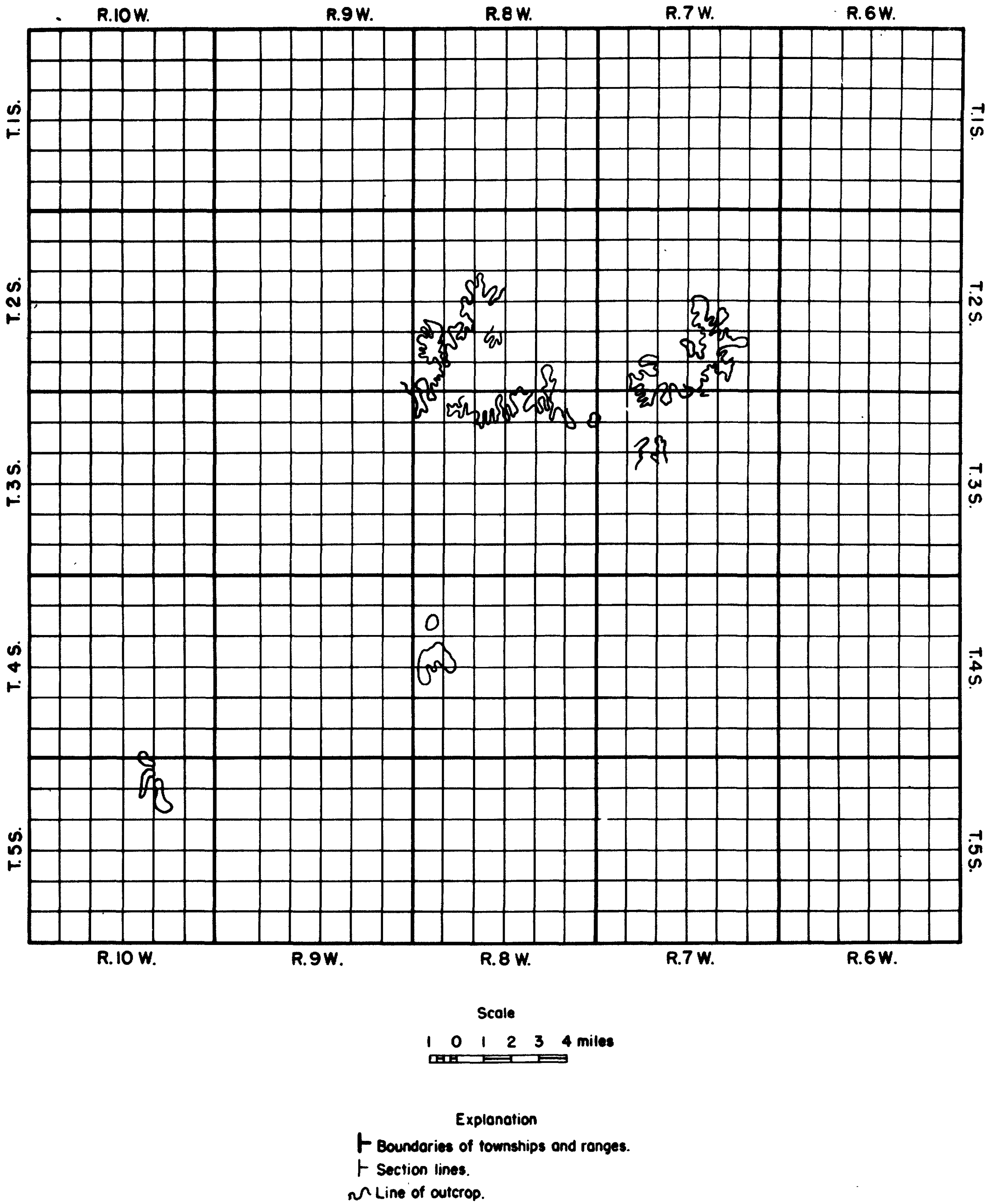


Figure 4.—Map showing outcrops of rocks tentatively assigned to the Ogallala formation.

always underlies the Ogallala formation in Jewell County, and is in no way similar to any other local material of younger than Tertiary age.

Representative measured section.--No representative section of the Ogallala formation sufficiently thick to be measured was found in Jewell County.

Thickness.--The thickness of the Ogallala formation in Jewell County varies from less than a foot to a maximum of about 4 feet. The average thickness is probably less than 2 feet.

Construction materials.--This formation is so thin and poorly developed in Jewell County that it has little of the construction materials value associated with it in other counties of western Kansas. Certainly the material is so limited in quantity that economical exploitation is not likely.

Belleville formation

Areal distribution.--The Belleville formation of Pleistocene age crops out only in the northeastern part of the county along the south wall of the valley of the Republican River. (See pl. 1 and fig. 2.) Its full extent can be determined only by test drilling because it is so generally concealed by the overlying Sanborn formation.

General description.--The Belleville formation was named by Wing 10/ 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 11/ and others indicates quite conclusively that its age is early Pleistocene.

The Belleville formation consists predominantly of lenses of cross-bedded sand, composed of quartz and feldspar grains, and igneous-rock gravel. 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 generally is tan or gray. Fragments of fossilized vertebrate skeletons are reported to be fairly common.

Mineral analyses (see table 1) show that the sands and gravels of the Belleville formation are composed predominantly of quartz and feldspar particles. There are minor quantities of igneous rock fragments, generally of gravel size, and occasional fragments of quartzite were noted in the samples analyzed. Fishel and Lohman 12/ believe that the Belleville formation was deposited as the result of the damming of the Republican River during early Pleistocene times and the consequent diversion of the river from its preglacial course toward the northeast to its present course south into Kansas. Most of the material in the Belleville formation seems to have been eroded originally from rocks that crop out far to the west and to have been transported by the Republican River to this point. The presence of red and purple quartzite pebbles indicates that some of the material was brought in by the outwash from Pleistocene glaciers lying north and northeast of this area. The upper part of the formation tends to become finer-grained and may be silty enough locally that it grades into the overlying Sanborn formation without a discernible break.

Representative measured section.--The sediments composing the Belleville formation are so homogeneous that it was not thought necessary to measure a section of the formation.

Thickness.--The full thickness of this stratigraphic unit could have been determined only by test drilling. Many exposures of the formation are 20 to 30 feet thick. Fishel and Lohman 13/ believe that the total thickness may be as much as 120 feet in some places.

Construction materials. --
Mixed aggregate.
Road metal.

Sanborn formation

Areal distribution.--The Sanborn formation of Pleistocene and Recent (?) age is the most widely distributed stratigraphic unit cropping out in Jewell County. (See pl. 1 and fig. 2.) The formation at one time undoubtedly extended over most of the county, but subsequently it has been eroded from the courses of many of the streams. Its most extensive phase is that which caps the tops of the divides as a blanket of silt of variable thickness. A second phase is that found part way up the walls of some of the larger stream valleys in the county, as along the south wall of the valley of White Rock Creek east of Reubens. Outcrops of this second phase are relatively thin and discontinuous. Both phases, because of their similar lithologies, are mapped as a single stratigraphic unit.

General description.--The Sanborn formation is composed of materials deposited by streams, slope wash, wind, and the action of gravity. Frye and Fent 14/ 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. Such mapping would have required a greatly expanded field program, including test drilling. The treatment of the Sanborn formation as an undivided unit seems adequate for the purposes of an inventory of construction materials.

The formation is composed predominantly of silt, but the basal part may contain lenses of sand and gravel. The particles composing the gravels are largely of local origin. The color of the formation varies from buff tan to gray brown.

[10] Wing, J. E., Geology of Cloud and Republic Counties, Kans.: Kansas Geol. Survey Bull. 15, pp. 19-21, 1930.
[11] Fishel, V. C., and Lohman, S. W., Geology and ground-water resources of Republic County and northern Cloud County, Kans.: Kansas Geol. Survey Bull. (in press).
[12] Fishel, V. C., and Lohman, S. W., op. cit.
[13] Fishel, V. C., and Lohman, S. W., op. cit.
[14] 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 15/ have reported a buried soil zone. The A zone of the soil profile characteristically is rather thin, ranging from 0.5 foot to 1.5 feet thick, and is underlain by a much thicker B zone. The B zone is characterized by the secondary deposition of calcium carbonate by downward-percolating waters. The calcium carbonate may be disseminated throughout the zone or locally concentrated within the zone in the form of nodular or pipelike concretionary masses. A crude columnar structure, the result of the intersection of irregular joint planes, is very often developed, especially in the B zone.

That phase of the Sanborn formation present on the tops of the divides in Jewell County probably is to be correlated with "Terrace No. 6" as defined in Nebraska by Condra, Reed, and Gordon, 16/ whereas that part of the formation visible on the valley walls probably is to be correlated with their "Terrace No. 5."

Generally the Sanborn formation erodes to form a gently undulating surface. The headward parts of stream valleys that have been cut into it often exhibit a phenomenon known as "catstep erosion," which probably is the result of the sliding of water-saturated silt, through gravity, down toward the streams. The catsteps are bounded by scarps a foot or two high and slump blocks from several feet to about 20 feet wide developed along gently sloping valley walls.

Numerous lenses of volcanic ash are present in the basal part of the Sanborn formation in the northern part of the county. The ash is composed of glasslike shards ejected during the explosive phase of a volcanic eruption. Most of the ash beds found in Jewell County are relatively pure--that is, there is little silt, clay, or sand and gravel intermixed with them. The color is white or light gray.

Shells of fossil snails (gastropods) are fairly numerous in the Sanborn formation. Fragments of fossilized vertebrate skeletons are reported but were not found by the field party in Jewell County.

A small deposit of sand and gravel occurs in the SW¼SW¼ sec. 16, T. 3 S., R. 8 W., a short distance west of Mankato. The sand grades upward into typical silt of the Sanborn formation with no indication of an intervening unconformity, but a mineral analysis (see table 1, fa 3) shows that the sand is similar to sand found in the Ogallala and Belleville formations. It is possible that this isolated sand and gravel deposit is an erosional remnant of the Belleville formation and that the Belleville formation was once far more extensive than its present distribution indicates.

15/ 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.

16/ Condra, C. E., Reed, E. D., and Gordon, E. D., Correlation of the Pleistocene deposits of Nebraska: Nebraska Geol. Survey Bull. 15, pp. 48-49, 1947.

On the other hand, the sand may be a channel deposit in the Ogallala formation similar to deposits found in Smith County, Kans., adjoining Jewell County on the west. The exact age of this deposit can be determined only by more intensive field exploration than it was possible for this reconnaissance-type survey to allot to the problem, but assignment of the deposit to the Sanborn formation seems justified by the field evidence now available.

Representative measured section.--The following section of the Sanborn formation was measured in a road cut in the SW¼SE¼ sec. 2, T. 1 S., R. 10 W.:

	Feet
Soil, silty	1.0
Sanborn formation:	
Silt; nodules and pipelake concretions of calcium carbonate; buff gray; stands in a vertical bank	7.8
Silt; streaks of calcium carbonate throughout; gray, weathers light gray	3.0
Silt; calcium carbonate disseminated throughout or in the form of large nodules; dark buff gray	7.0
Base covered.	17.8

Thickness.--Individual exposures of the Sanborn formation generally range between 5 and 20 feet thick. The maximum thickness of this unit occurs in the northwestern part of Jewell County and is estimated to be about 100 feet.

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

Terrace deposits

Areal distribution.--Terrace deposits of Recent age are conspicuous in the valleys of Buffalo, Limestone, Marsh, and White Rock Creeks. (See pl. 1 and fig. 2.) Narrow extensions of the terraces project into the valleys of the larger tributaries. The terrace deposits along the Republican River are discontinuous, although a single deposit may cover an area of several square miles. The average width of the terrace deposits in the valley of White Rock Creek is about a mile, and those of Marsh, Buffalo, and Limestone Creeks average about 0.5 mile in width. Two or more terraces are present but are mapped on plate 1 as a single stratigraphic unit 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 their earlier gradational cycles. The upper part of the terrace deposits is a brown to brown-gray silt.

A soil profile is developed in the upper part of the formation, and there may be a buried soil zone at a variable depth below the top. A thick B zone occurs below the thin, dark-brown to black A zone of the profile. Fossilized shells of gastropods are occasionally found. The deposits usually become coarser with increasing depth and, in the basal part, grade into sand and fine gravel. The sands and the gravels are lenticular and are no more than a few feet thick. Most of the sediments composing the terrace deposits are material from the older, locally outcropping formations that has been reworked by streams in later gradational cycles.

Representative measured section.--The 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 have a maximum thickness of about 45 feet, and that those of Buffalo, Marsh, and Limestone Creeks are no more than 30 or 35 feet thick.

Construction materials. --
Mineral filler.
Road metal.

Alluvium

Areal distribution.--The deposits (see fig. 2) formed by streams in their present gradational cycles are mapped as alluvium on plate 1. They, with the dune sands that locally overlie them, constitute the most recent stratigraphic units in Jewell County. Alluvium is defined in this report as the material underlying the present flood plain of a stream, the flood plain being 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, Marsh, and Buffalo 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 scaled to 1 inch equals 1 mile. The alluvium in the valley of the Republican River averages considerably more than a mile in width, but similar deposits in the valleys of White Rock and Buffalo Creeks have an average width of less than 0.2 mile.

General description.--The alluvium of the Republican River Valley is predominantly silt, but many lenses of sand and occasional lenses of gravel are included. Flood waters in fairly recent times have spread sand widely over the flood plain surface where, locally, the wind has reworked it into dunes. The dune areas, however, are not sufficiently extensive that they can be mapped with any accuracy; hence the dunes are not distinguished as a separate stratigraphic unit. The alluvial deposits of the other streams in the county also are composed predominantly of silt but contain occasional lenses of sand in which there may be intermixed local rock fragments of gravel size.

White Rock Creek is rather unusual in that, in its present-day gradational cycle, it has incised its valley 25 to 30 feet below its previous gradational level. Throughout most of the length of this stream in Jewell County, the present-day valley is very narrow, but it tends to expand somewhat in the eastern border area of the county.

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 thickness could not be made in the absence of test-hole data. It is estimated that the alluvial deposits of the Republican River may reach a maximum thickness of 50 feet and that the alluvial deposits of the other streams in the county are less than 25 feet thick.

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

INVENTORY OF CONSTRUCTION MATERIALS

General

The objectives of this inventory of construction materials in Jewell 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 17/ and the American Association of State Highway Officials. 18/

[17] State Highway Commission of Kansas, Standard specifications for State road and bridge construction, 512 pp., 1945.

Gradation factor, p. 16.

Sieve analysis, pp. 333-334.

Soundness, pp. 335-336.

[18] American Association of State Highway Officials, Standard specifications for highway materials and methods of sampling and testing, pt. 2, 5th ed., 361 pp., 1947.

Absorption, pp. 251-252.

Compressive strength, pp. 257-258.

Deval abrasion, pp. 235-236.

Liquid limit, pp. 198-201.

Los Angeles abrasion, pp. 237-239.

Plasticity index, pp. 202-204

Specific gravity, pp. 249-250.

Toughness, pp. 240-241.

Weight per cubic foot, pp. 253-254.

Table 1.—Summary of materials tests

(Blank spaces indicate data nct available)

Classification of the material	Number on Plate 1	Location: Fraction of 1/4 section	Location: 1/4 section	Location: Section	Location: Township (S)	Location: Range (W)	Estimated quantity of material (in cubic yards)	Average thickness: Material (in feet)	Average thickness: Overburden (in feet)	Accessibility	Geologic formation or member	Authority for test data[1]	Date of test	Sieve analysis: Percent on 3/4 inch	Percent on 3/8 inch	Percent on No. 4	Percent on No. 6	Percent on No. 100	Percent passed No. 200 (wash)
Fine aggregate	fa1		N 1/2	4	1	6	150,000	5	0	Good	Alluvium	SHCK USGS	11-47				0	69	17.6
	fa2	SE	NE	2	1	7	10,000	10	0-1	do	Dune sand	do	do				0	68	13.0
	fa3	SW	SW	16	3	8	5,000	4	2-6	do	Sanborn	do	do			0	12	95	3.9
Mixed aggregate	ma1		NE	9	1	6	20,000	12	0-6	do	Belleville	do	do	1	2	13	64	99	0.84
	ma2	SE	NW	9	1	6	25,000	12	0-5	do	do	do	do	0	2	12	55	98	1.34
	ma3	SE	NW	10	1	6	150,000	20	1-5	Fair	do	do	do	0	2	7	39	98	1.3
	ma4		NE	11	1	6	150,000	25	0-4	Good	do	SHCK	12-46	0	6	27	84	99	0.3
	ma5	C	SW	16	1	6	5,000	15	4	Fair	do	SHCK USGS	9-47	16	23	29	46	88	9.1
	ma6	SW	NW	11	1	7	150,000	30	0-3	Good	do	SHCK	1-41	0	2	11	75	97	2.0
	ma7	NE	NE	28	2	8	10,000	10	2-4	do	Sanborn	SHCK USGS	9-47	4	6	9	15	86	12.0
Limestone gravel	lg1	SE	SW	28	1	7	5,000	4	0-2	do	do	do	do	4	19	38	59	89	9.0
	lg2	NW	NW	36	1	7	5,000	5	4	do	do	do	do	1	16	37	58	95	4.1
	lg3	NE	NE	1	2	8	5,000	5	0-5	do	do	do	8-47	18	38	50	62	78	20.2
	lg4	SE	SE	27	2	10	3,000	5	0-2	do	do	do	11-47	0	4	18	58	90	7.6
	lg5		C	8	3	6	5,000	10	0-3	Fair	do	do	do	21	36	51	70	81	17.0
	lg6	SE	NW	6	4	6	4,000	4	3-5	Good	do	SHCK	1-46	8	25	42		75	23
	lg7	C	NE	4	4	8	3,000	3	0-3	do	do	SHCK USGS	11-47	3	22	42	67	84	14.9
	lg8	SE	SE	19	4	9	3,000	5	2-4	do	do	do	do	1	10	30	68	91	7.8
	lg9	SW	SE	20	4	10	5,000	5	1-3	do	do	do	do	1	10	27	66	92	7.4
	lg10	SE	SW	4	5	8	10,000	4	0-5	do	do	SHCK	1-46	1	9	29		75	24
	lg11	NW	NW	7	5	9	10,000	5-7	0-2	do	do	SHCK USGS	11-47	8	23	42	64	72	25.6
	lg12	NW	NW	9	5	10	5,000	4	0-3	do	do	do	do	4	19	38	66	81	17.6
Mineral filler	mf1	SW	NW	19	1	6	150,000	10	1-3	do	do	do	do				0	4	81.4
	mf2	SW	SE	24	1	10	150,000	15	1-3	do	do	do	8-47			0	3	15	81.0
Volcanic ash	va1	NW	NE	16	1	6	20,000	15	0-5	Poor	do	do	11-47				0	13	49.6
	va2	NW	SW	16	1	6	7,000	4	0-4	Good	do	do	8-47				0	2	87.8
	va3	SE	NW	32	1	9	5,000	13	0-10	Poor	do	do	11-47				0	11	64.0
	va4	SE	SW	33	1	9	5,000	3-4	0-4	Good	do	do	8-47				0	10	68.6
	va5	SE	NW	5	2	9	6,000	10	0-4	Fair	do	SHCK	1-46				0	6	69
Limestone	l1	SW	NW	10	2	8	10,000	10	0-3	Good	Fort Hays	SHCK USGS	9-47						
	l2	SE	NE	35	3	6	3,000	1	0-6	do	Greenhorn	SHCK	7-35						
	l3		NE	24	3	8	150,000			do	Fort Hays	CE	7-46	Chemical composition: SiO_2, 4.64%; Al_2O_3, 2.61%; Fe_2O_3, 3.89%; CaO, 50.70%; MgO, 0.63%; SO_3, 0.17%; Na_2O+K_2O, 0.25%; undetermined, 0.26%; soluble in HCl, 94.57%.					
	l4	SW	SW	33	3	9	10,000	10	0-4	do	do	SHCK	1-46						
	l5	E 1/2	NW	2	4	6	3,000	1	0-6	do	Greenhorn	do	7-35						
	l6	NW	SW	7	5	6	3,000	1	0-4	do	do	do	9-34						
Quartzite	q1	SE	SW	12	5	6	3,000	1-2	0-4	do	Dakota	SHCK USGS	11-47						
Sandstone	ss1	NW	NW	13	5	6	4,000	6	0-4	do	do	do	do						

Number on Plate 1	Description of the material[2]: Fraction	Quartz	Feldspars	Acid igneous rocks	Basic igneous rocks	Mortar bed	Carbonate minerals	Chalk	Silicified chalk	Quartzite	Chert and/or chalcedony	Limonite nodules	Laboratory test data: Weight per cubic foot (dry)	Specific gravity (saturated)	Gradation factor	Compressive strength ratio: 1 day	Compressive strength ratio: 3 days	Los Angeles loss (%)	Soundness[3] ratio (25 cycles)	Toughness	Cementation	Absorption	Liquid limit	Plasticity index	Remarks
fa1	C F	 85	 15										98.7	2.57	0.80										High percentage of wash.
fa2	C F	 75	 20		 5								105.5	2.59	0.96										2 percent ferromagnesian minerals; overburden is silty soil; high percentage of wash.
fa3	C F	75 80	20 20		5 tr					tr tr			102.4	2.59	2.23	1.00	1.18								Numerous mica flakes retained on No. 16 sieve; clear in color test; formation might be Ogallala with Sanborn overburden.
ma1	C F	60 70	40 30		 tr					 tr			114.8	2.61	3.91	2.02	1.45		0.99						Clear in color test.
ma2	C F	45 70	45 25		6 tr					4 5			114.7	2.61	3.62	1.99	1.48								Clear in color test.
ma3	C F	55 60	40 40		5 tr						tr 		113.1	2.62	3.20	1.40	1.37								Clear in color test.
ma4													111	2.62				31.8	0.98						
ma5	C F	65 85	30 10		tr tr			5 5		tr 		tr 		2.54	3.94	1.09	1.19								Overburden is Sanborn formation; high percentage of wash; coarse particles lime-coated; light straw in color test.
ma6	Granitic sand with limestone pebbles.												110	2.60	4.09	1.36	1.08								0.48 percent of clay balls.
ma7	C F	15 70	3 10		tr tr	tr 	2 	80 20		tr 			99.8	2.56		0.82	1.00								High percentages of wash and chalk fragments; 1 percent of clay balls; straw in color test.
lg1															4.17								26	14	
lg2															4.26								17	6	
lg3															4.63								31	15	
lg4															3.76								45	27	
lg5															4.81								37	22	
lg6																									
lg7															4.29								32	18	
lg8															4.25								26	12	
lg9															4.11								28	14	
lg10																									
lg11															4.03								32	18	Overburden is soil zone; high cementation factor.
lg12															4.15								28	14	Overburden is soil zone.
mf1	Buff, calcareous silt and clay.												86.0	2.65							100				
mf2	Tan sand and silt; some intermixed volcanic ash.												77.7	2.56							8				
va1	Light-gray volcanic ash; some intermixed fine sand. and silt.												54.6	2.36							1				
va2	White and light-gray volcanic ash; interbedded thin layers of silt.												55.6	2.35							1				
va3	Light-tan, powdery volcanic ash; some intermixed silt and fine sand.												59.3	2.45							2				
va4	White, powdery volcanic ash; minor amount of fine sand.												61.1	2.38							1				
va5	Light-tan to white volcanic ash; interbedded thin layers of fine sand.												58												
l1	Soft, white and light-yellow, chalky limestone.													2.11				52.4	0.59			16.3			
l2	Soft, light-yellow to brown limestone.													2.25					Unsound			17.05			Deval abrasion loss, 15.25 percent.
l3														2.08				48.6				15.5			Location described as junction of Highways US 36 and K14, 3 to 5 miles east of Mankato.
l4	Light-yellow, chalky limestone.													2.04				66.7	0.45			19.4			
l5	Light-brown limestone.													2.32					Sound	4		6.6			Deval abrasion loss, 7.1 percent.
l6	Brown fossiliferous limestone.													2.46					Sound			3.9			Deval abrasion loss, 7.48 percent.
q1	Hard, massive, fine-grained, gray to brown, quartzitic sandstone.													2.53				44.1	0.96			1.65			
ss1	Fine-grained, lime cemented, light-tan to rust-brown sandstone; thin quartzitic zone at top.													2.39				81.9	0.75			5.99			

1. SHCK, State Highway Commission of Kansas. SHCK and USGS, sieve analysis and laboratory tests by State Highway Commission of Kansas; sample collection and description of material by U.S. Geological Survey. CE, Corps of Engineers, U.S. Army.
2. C, coarse fraction, retained on No. 4 sieve; F, fine fraction, passed through No. 4 sieve; Tr, trace.
3. Loss ratio.

It is expected that the 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 Jewell County and to establish the geologic pattern required for the location and development of materials which future 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 aggregate 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 usually are not included because of the added expense in removing the material, nor are relatively inaccessible 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 Jewell County:

(1) Belleville formation. Six samples (ma 1 to ma 6) of mixed aggregate were taken from the Belleville formation and are mapped on plate 1; their test characteristics are given in table 1. This formation is the most important potential source of aggregate for concrete in Jewell County. All samples were sufficiently coarse that they were classified as mixed rather than fine aggregate. The mineral and rock fragments composing aggregates of the Belleville formation are predominantly quartz and feldspar particles with only minor quantities of fragments of basic igneous rock and quartzite. No one of these materials is considered to be chemically deleterious. The laboratory test data indicate that the material is acceptable as concrete aggregate, but its performance is reported by the county engineer to be inferior. The average specific gravity of the samples tested is about 2.6, the gradation factor is about 3.7, the compression ratio in all samples is well above 1, and the material probably is sound because two samples tested (ma 1 and ma 4) developed soundness ratios of 0.99 and 0.98, respectively. The quantity of material available in the Belleville formation is essentially unlimited, but the supply is localized to the northeastern part of the county.

(2) Sanborn formation. One sample classified as fine aggregate (fa 3) is mapped as from the Sanborn formation but might possibly belong to the Belleville or the Ogallala. The question of its geologic age has been discussed under the Sanborn formation. Laboratory test data indicate that the material is acceptable as fine aggregate.

In addition to the sample of doubtful age (fa 3), only one other aggregate sample was taken from the Sanborn formation. The source of the sample (ma 7) is mapped on plate 1, and its mineral and test characteristics are given in table 1. The mineral analysis indicates that material from the Sanborn formation probably will contain an excessive percentage of soft chalk fragments of local origin.

Undoubtedly there are other potential sources of aggregate material in the basal part of the Sanborn formation. Intensive exploration of the basal part, exposed where streams have cut into older, underlying formations, probably would be profitable. Because the deposits are channel fills of sand and gravel, it is likely that all of them will be limited in quantity.

Recent studies by Plummer and Hladik 19/ suggest that the wind-deposited silts and clays in the Sanborn formation may be manufactured into a "ceramic slag" that is suitable for use as concrete aggregate.

(3) Alluvium. One sample of fine aggregate (fa 1) was secured from the alluvium of the Republican River. The material is a very fine sand composed predominantly of fragments of quartz, but minor amounts of feldspar particles are present. Fine aggregate from the alluvium probably is obtainable only from the flood plain of the Republican River, where it exists in almost unlimited quantities. The alluvial deposits of other streams are predominantly silt.

[19] 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, pp. 87-89, 95, 1948.

Alluvial sands of the Republican River Valley have been reworked by the wind into small, discontinuous dunes covering very limited areas. The construction materials characteristics of the dune sand (fa 2, table 1 and pl. 1) essentially duplicate those of the sample of alluvium (fa 1).

Road metal

Engineering and geologic characteristics. --Road metal, known also as surfacing material, crushed stone, and aggregate, is defined in this report as any material that may be applied to a road to improve the performance characteristics of that road. Many geologic materials fulfill this requirement, and the list of such materials will vary from one area to another.

The following materials have been used in Jewell County 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, especially on secondary roads.

(3) Crushed rock. Indurated rocks are available in Jewell County for use as crushed stone in road construction or railway ballast, and some of them have been so used. The rocks are limestone, a compact, massive layer of calcareous material, variable in its hardness; quartzite, a massive, compact, hard rock in which sand and/or gravel have been firmly silica-cemented by the action of percolating ground water; and 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 more specifically listed in table 1 and mapped on plate 1 as 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. The materials listed in the section on aggregate for concrete have been used in the base course of bituminous-mat roads, as loose road metal on many light-traffic roads within the county, and in other types of road construction. Most of the aggregate now being used in road construction is taken from pits in the Belleville formation. Previously, however, deposits of sand and gravel in the Sanborn formation in the southern part of the county had been utilized, as well as material shipped in from nearby Kansas counties or from Nebraska.

(2) Limestone gravel. Twelve sources of material classified as limestone gravel are mapped on plate 1, and the test data of the material are given in table 1 (lg 1 to lg 12). The Sanborn formation was the source of all the samples. The limestone gravels occur as channel deposits in the basal part of the Sanborn formation, usually where that formation unconformably overlies the Carlile shale. The limestone particles appear to have been eroded from nearby outcrops of the Niobrara formation, and the quantity of material contained in any one of the deposits is relatively limited. The material is acceptable as road metal for light-traffic roads, although in some samples tested, such as lg 5 and lg 6 (table 1), the plasticity index may be too high. Additional deposits of limestone gravel undoubtedly occur in the parts of the county east and south of the escarpment formed by the Fort Hays limestone.

(3) Crushed rock.

(a) Dakota sandstone. The Dakota sandstone is a potential source of material for use in road construction. The sandstone might be crushed, if necessary, and used in base-course construction for roads of a bituminous-mat type. The test characteristics of one sample analyzed (ss 1, table 1) indicate that it is satisfactory for this use.

The quartzitic zones in the Dakota sandstone might also be used in road construction. The quartzite, if crushed and applied to the road in particles less than 0.5 inch in maximum dimension, might serve adequately as loose road metal. This use of quartzite from 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 uses.

The fact that the Dakota sandstone crops out only in a limited area restricts its usefulness; furthermore, the quantities of quartzite and sandstone available in the Dakota sandstone in Jewell County also are limited.

(b) Greenhorn limestone. The Greenhorn limestone has been used as road metal throughout most of the area of its outcrop. The usual practice is to quarry the thicker limestones near the top of the formation, such as those in the Jetmore chalk and Pfeifer shale members, and stock-pile the cobble-size fragments of chalky limestone. Weathering by slaking and freeze-and-thaw causes the surficial portion of each fragment to slough off. The remainder is then crushed, mixed with shales from the same formation, and applied to the road. The material tends to self-cement and to form a traffic-bound macadam. Its wet-weather characteristics are good and, unlike traffic-bound macadam constructed of chalky limestone from the Niobrara formation, it shows little tendency toward dry-weather dusting. The part of a county road extending 3 miles south of Randall has been metaled with crushed Greenhorn limestone. Numerous quarries are mapped on plate 1, and additional sources of material from this formation can be located throughout most of the area of its outcrop.

(c) Fort Hays limestone member of Niobrara formation. The two members of the Niobrara formation, the Fort Hays limestone and Smoky Hill chalk, have been used extensively throughout north central Kansas as road metal. It has been the practice to use the Fort Hays limestone in preference to the Smoky Hill chalk wherever material from both of the members is available. In either case the rock is quarried, crushed, watered down, and rolled. Traffic causes it to self-cement to form a macadam that needs to be maintained only by blading. The wet-weather characteristics of the road generally are quite good if the macadam is 8 inches or more thick, but excessive saturation may develop a gumbolike quality in the road structure. In dry weather each passing vehicle stirs up a cloud of fine white dust. Efforts have been made to control the dusting tendency of the macadam roads constructed of rock from the Niobrara formation, but none has been entirely successful. If a bituminous-mat wearing course is applied directly to the chalky limestone macadam, moisture accumulates at the top of the limestone base course and causes it to soften, with the result that the road fails. It is possible that a seal coat applied to the macadam would prove satisfactory inasmuch as such a coat would permit the evaporation of moisture from the limestone, apparently a necessary condition if road failure is to be avoided. Calcium chloride might be applied to such roads but is not effective as an antidusting agent unless the humidity is 50 percent or higher, a condition rather unusual in most parts of Kansas.

Field observation indicates that the best results are obtained when a course 8 inches or more thick is used. If the thickness is less than 8 inches, the road tends to fail by excessive thinning in critical spots. An essentially unlimited quantity of chalky limestone is available in the Fort Hays member. The county highway extending from east to west through Burr Oak is only one example of a road in Jewell County constructed of Fort Hays limestone. Numerous operated and prospect quarries are mapped on plate 1, but additional quarries could be opened at any convenient site within the area of outcrop.

(d) Smoky Hill chalk member of Niobrara formation. Some use of the Smoky Hill chalk member as material for roads of the traffic-bound macadam type has been observed in other counties in north central Kansas. There is no indication, however, that material from this source has been so used in Jewell County. The more massive chalk beds in this member have about the same characteristics as the chalk beds in the Fort Hays limestone member but are not so thick. The chalky shales are used together with the crushed chalky limestones. Field observation indicates that traffic-bound macadam roads constructed of material from the Smoky Hill chalk member are fairly satisfactory. They do not stand up quite so well in wet weather as macadam roads constructed of the Fort Hays limestone but show less of the dry-weather dusting tendency characteristic of Fort Hays limestone. There is an almost unlimited quantity of Smoky Hill chalk available throughout the area of its outcrop mapped on plate 1, and quarries could be opened at any convenient site within that area.

(e) Ogallala formation. The hard, dense, nodular limestone, the characteristic expression of the Ogallala formation in Jewell County, has been used in other north central Kansas counties as loose road metal. The material is quarried, crushed, and applied to the road in the same way as crushed quartzite. The limestone bed is so thin in Jewell County, however, that it is doubtful whether it would be economical to develop it for use in road construction.

The lenses of sand and gravel characteristic of the Ogallala formation in the counties to the west and southwest are almost entirely lacking in Jewell County. The one deposit noted in the field is so small that its development would not be economical.

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 states [20]/ 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 mf 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. One of these samples (mf 1) apparently was taken from the B zone of the soil profile, because the cementation factor (100) probably is excessive. The other sample (mf 2) was taken from below the B zone, and the cementation factor is within acceptable limits. The Sanborn formation is the most widespread source of mineral filler in Jewell 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 development of a site, the material be laboratory-tested and its cementation factor determined. Although silt in the deeper zones of the Sanborn formation is less firmly cemented, the overburden might prove too thick for economical development.

(2) Terrace deposits. No samples of terrace deposits were tested in the laboratory, but this stratigraphic unit is a potential source of mineral filler and has been used in other counties of the State for that purpose. Because of its lithologic similarity to the Sanborn formation, it is probable that the test characteristics of the terrace deposits are similar. A sample should be laboratory-tested to determine the cementation factor prior to the development of a site.

Volcanic ash

Engineering and geologic characteristics. -- 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

[20] Horner, S. E., chief geologist, letter dated Jan. 4, 1947.

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 and sand.

Stratigraphic source and performance characteristics. --The Sanborn formation is the only source of volcanic ash found by the field party in Jewell County. Test data for five samples (va 1 to va 5) are given in table 1, and the locations from which the samples were taken are mapped on plate 1. Individual deposits of volcanic ash are limited in quantity because the material was deposited in lenses. Sieve analyses indicate that there might be a minor percentage of silt and fine sand intermixed with the ash. The test characteristics show that the samples reported in table 1 are satisfactory for use in engineering construction.

Numerous lenses of volcanic ash, in addition to those sampled, were found by the field party and are mapped on plate 1. Intensive exploration of the basal part of the Sanborn formation, particularly in the northern half of the county, undoubtedly will bring to light other sources of this material.

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 test characteristics of the rock in the quartzitic zones of the Dakota sandstone (q 1, table 1) indicate that this material is adequate for use as riprap on earthen dams. Its specific gravity is sufficiently high, it is sound, and the abrasion loss is not excessive. Unfortunately, however, the amount of quartzite in the Dakota sandstone of Jewell County is so limited that this formation cannot be considered an adequate source of riprap.

(2) Greenhorn limestone and Niobrara formation. Several small dams riprapped with chalky limestone from the Greenhorn limestone and the Niobrara formation were observed in Jewell County. In each case the riprap had deteriorated completely and, after only a short interval, had lost its protective value. The chalky limestones from both of these units are unsound in any water-saturated environment and soon deteriorate by slaking, freeze-and-thaw, or a combination of both. The exploitation of either of these stratigraphic units as a source of riprap is highly inadvisable.

(3) Ogallala formation. The hard, dense limestone near the top of the Ogallala formation is a possible source of riprap in Jewell County, but because of the limited quantity of material available it is not a significant source.

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 Greenhorn limestone and in the Fort Hays limestone member of the Niobrara formation.

Stratigraphic sources and performance characteristics. --

(1) Greenhorn limestone. The "Fencepost" limestone bed at the top of the Pfeifer shale member of the Greenhorn limestone is used extensively as structural stone throughout a wide area in north central Kansas, even to a considerable distance from the area of its outcrop. So many quarries have been opened in this bed in Jewell County that only a few of them are mapped on plate 1. Additional quarries could be opened at any convenient site within the area of outcrop. Typically the rock is quarried only when the overburden is less than 2 or 3 feet thick. When heavy overburden is encountered, the usual practice is to abandon the site and move to another place where the overburden is thinner.

The test characteristics of stone from this bed (ls 2, ls 5, and ls 6) are given in table 1. Field observation indicates that the limestone is entirely suitable as a structural stone in this area because structures built of it stand up very well in the relatively dry climate that prevails in north central Kansas. The rust-colored band in the center of the bed gives the stone a pleasing appearance that may be enhanced further by polishing the external surfaces, as was done in the construction of the Jewell County courthouse.

The "shell rock" bed at the top of the Jetmore chalk member of the Greenhorn limestone is used as structural stone within the area of its outcrop. The stone, however, is not so pleasing in its finished appearance as the "Fencepost" limestone, and it is not so widely used. No structures built of this stone were observed in Jewell County.

(2) Fort Hays limestone member of Niobrara formation. Several samples of the Fort Hays limestone (ls 1, ls 3, and ls 4) have been tested; the data are given in table 1. The test characteristics of this material indicate that it is slightly inferior to the "Fencepost" limestone for use as structural stone; however, ledges of this member are many times thicker than the "Fencepost" limestone bed, and there is a far greater quantity of stone available. Some of

the smaller buildings in Jewell County have been constructed of Fort Hays limestone, although it weathers in a less pleasing fashion than the "Fencepost" limestone. Because there are so many outcrops of the Fort Hays limestone member in Jewell County, it was not thought necessary to map more than a few of the many operated quarries or to locate more than occasional prospective quarry sites.

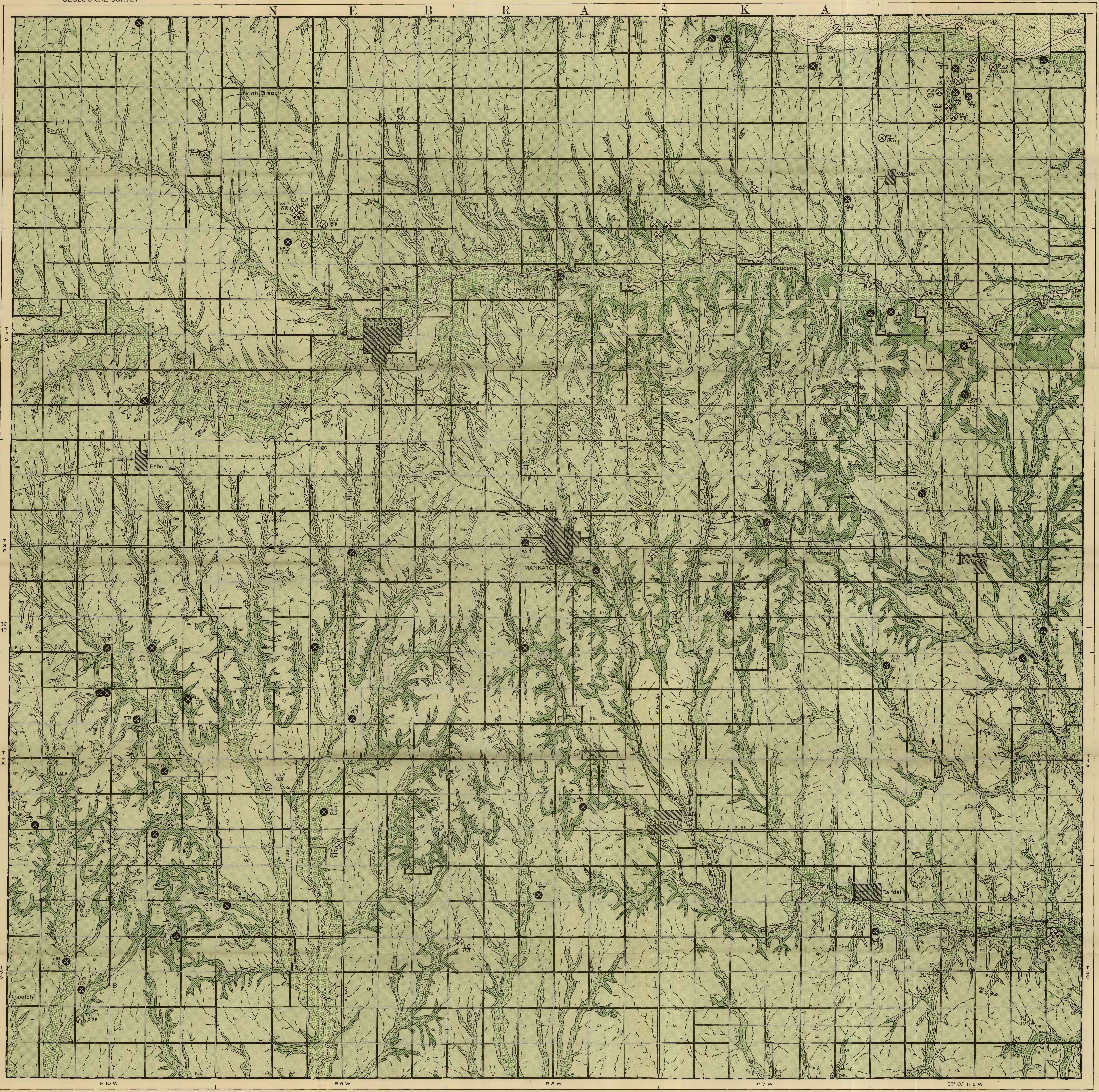
Calcareous binder

Engineering and geologic characteristics. --To be classified as calcareous binder, the material must be composed essentially of calcium carbonate and must be soft and easily pulverized. A variety of geologic materials is included in this classification.

Stratigraphic sources and performance characteristics. --The Fort Hays limestone and the Smoky Hill chalk members of the Niobrara formation have been accepted by the State Highway Commission as sources of material suitable for use as calcareous binder. Both members contain numerous beds of chalky limestones which are soft, easily pulverized, and free from deleterious substances. This material can be obtained from all the outcrop areas of the Niobrara formation in Jewell County mapped on plate 1.

PLATE 1

MAP SHOWING CONSTRUCTION MATERIALS AND GEOLOGY OF JEWELL COUNTY, KANSAS 1949



Base adapted from map provided by Soil Conservation Service, United States Department of Agriculture.

MAP SHOWING CONSTRUCTION MATERIALS AND GEOLOGY OF JEWELL COUNTY, KANSAS

Scale 1 0 1 2 3 4 Miles

1949

Geology by M. S. Houston and M. R. Mudge

EXPLANATION

QUATERNARY — Pleistocene and Recent

Qal — Alluvium
(Predominantly light-brown silt with numerous sand lenses and some gravel lenses interbedded. Source or potential source of: aggregate, road metal)

Qt — Terrace deposits
(Upper part, brown to brown-gray silt locally with buried soil zone; basal part, silt with thin lenses of sand and fine gravel. Source or potential source of: mineral filler, road metal)

Qs — Sanborn formation
(Upper part, gray-brown silt locally with buried soil zone; lower part, buff or tan silt and interbedded lenses of sand and gravel; numerous lenses of white or light-gray volcanic ash in basal part. Source or potential source of: mineral filler, volcanic ash, aggregate, road metal)

Qb — Belleville formation
(Cross-bedded, tan-gray sand and gravel composed principally of quartz, feldspar, and igneous rock particles; occasional lenses of silt and clay. Source or potential source of: aggregate, road metal)

TERTIARY — Pilocene

To — Ogallala formation
(Light-gray limestone; some sand, gravel, and mortar bed)

CRETACEOUS — Upper Cretaceous

Kns, Knf — Niobrara formation
(Kns; *Smoky Hill chalk member*)
(Blue-gray and orange-gray chalky shales interbedded with white or blue-gray massive or blocky chalks, forms badlands. Source or potential source of: road metal, calcareous binder)
(Knf; *Fort Hays limestone member*)
(Massive, soft, cream to white chalky limestones alternating with thin layers of chalky shale. Source or potential source of: structural stone, calcareous binder, road metal)

Kc — Carlile shale
(Thin sandy siltstone at top; upper part, blue-gray, thin-bedded clay shale; lower part, orange-brown chalky shales and thin chalks)

Kg — Greenhorn limestone
(Tan and gray shales interbedded with thin, tan-gray, chalky limestones and very thin bentonites. Source or potential source of: structural stone, road metal)

Kgs — Graneros shale
(Dark-gray or black noncalcareous clay shale; thin bentonites interbedded)

Kd — Dakota sandstone
(Brown to tan sandstone, locally quartzitic; thin clay lenses interbedded. Source or potential source of: road metal, riprap)

Geologic boundary

Operated pit or quarry

Prospect pit or quarry

L — Limestone

SS — Sandstone

Q — Quartzite

FA — Fine aggregate

MA — Mixed aggregate

LG — Limestone gravel

VA — Volcanic ash

MF — Mineral filler

MA — Inclined letters indicate materials not tested

MA 2 — Vertical letters indicate materials listed in Table I and their sample numbers.

1.0 — Quantity of material available (in units of 10,000 cubic yards)

Federal (U S) Highway

Other roads, all classes

Railway

City

Section line

Township corner

Stream, permanent

Stream, intermittent

A —— B
Line of cross-section, Figure 3 (along the line between sections 27 and 28, T. 4 S., R. 10 W. and sections 21 and 22, T. 5 S., R. 10 W.)

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1947