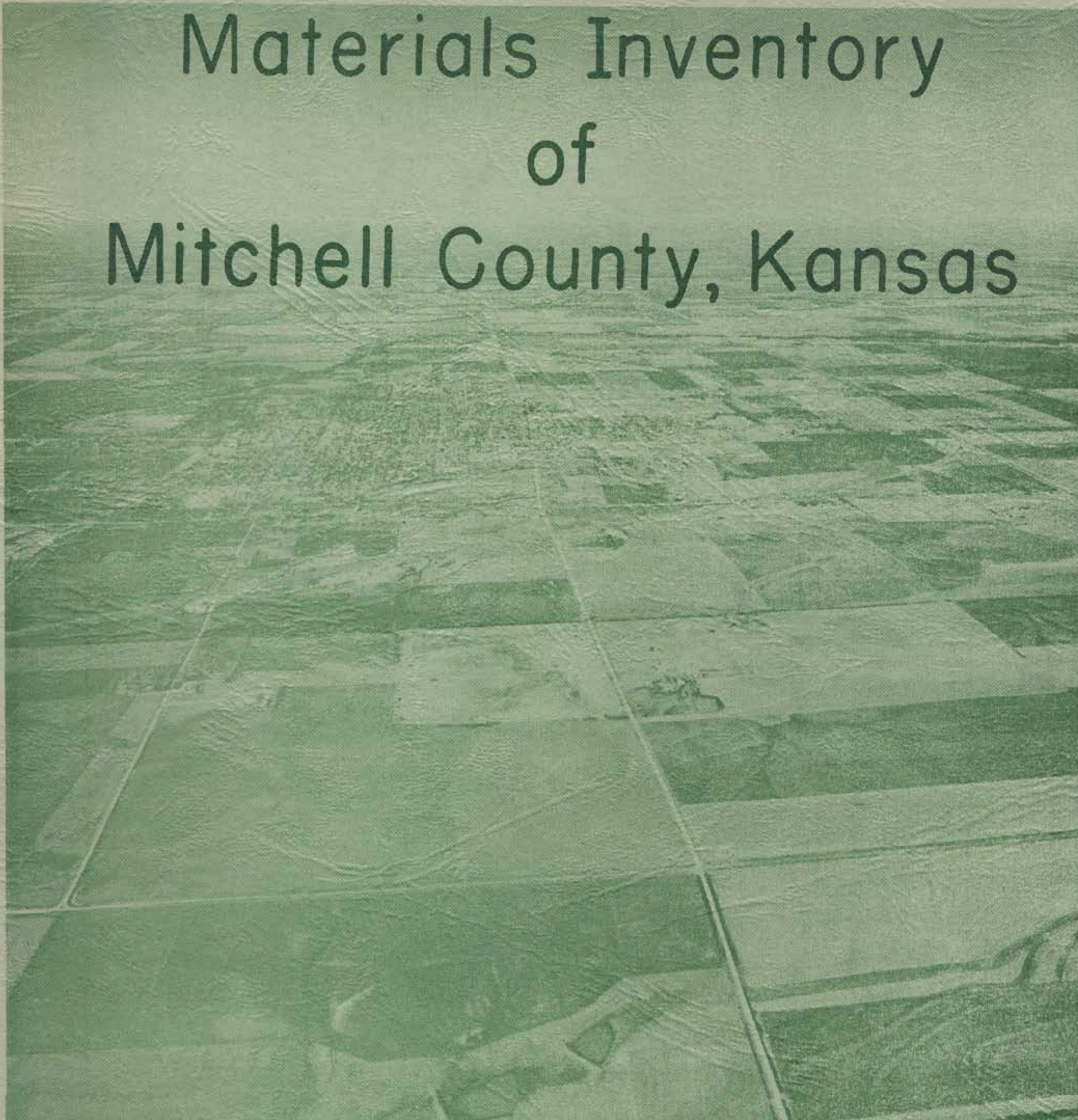
# Materials Inventory of Mitchell County, Kansas



prepared by

**The State Highway Commission of Kansas**

in cooperation with

**The U.S. Department of Commerce**

**Bureau of Public Roads**

State Highway Commission of Kansas
Research Department - Photronics Department

# MATERIALS INVENTORY OF MITCHELL COUNTY, KANSAS

BY

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Prepared in Cooperation with
U. S. Department of Commerce
Bureau of Public Roads

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Materials Inventory Report No. 3

## SUGGESTED USE OF THE REPORT

The Materials Inventory of Mitchell County is the third report of a series of county materials inventories prepared by the State Highway Commission of Kansas in cooperation with the Bureau of Public Roads. This report includes: 1. an introduction which describes the nature of the report and gives general information concerning Mitchell County; 2. an explanation of the procedures used in compiling information contained herein; 3. a brief explanation of the origin of the geologic units that are source beds for construction materials in the county, and a detailed description of the materials which has been produced from these units; 4. county materials maps (Plates I through VI) which show the geographic location of various source beds in the county along with the locations of all open and prospective materials sites; 5. appendixes I through IV which contain site data forms for each open and prospective materials site. Each form has a sketch showing the materials site and the surrounding landmarks, the name of the landowner, the name of the geologic source bed, and a resume' of all the test data available for that site.

When this report is used as a guide for planning an exploration program or making an assessment of the materials resources of Mitchell County, the reader may find the following suggestions helpful.

After becoming familiar with the nature of the report, the reader may wish to refer to the section "Construction Materials Resources of Mitchell County". In this portion of the report a geologic history of Mitchell County is presented which describes the geologic events which led to the deposition of the various source beds and sets forth the geologic nomenclature used throughout the report. A study of the Construction Materials Inventory will reveal the types of material available in the county, their geologic source beds, the localities where they are found, and a description of their engineering properties.

When the reader has determined which geologic bed may contain material that will meet his requirements, he should then refer to the county materials maps. From these maps he can find the areas in which this bed is present, the locations of the prospective materials sites in this source bed, and references to data forms for each open or prospective site.

For example, the reader determines from the study of Construction Materials Inventory that limestone gravel found in the Crete Formation fulfills the materials specifications for a project in the northwestern part of the county. The materials map (Plate II) shows several open pits in this formation. If the reader is interested in $\frac{\text{LG-51}}{\text{Qti}}$ he refers to Appendix II where detailed information is given on the site data form. This information enables him to plan his exploration in an orderly fashion.

## PREFACE

This is one of a series of county construction materials reports compiled as a product of the Highway Planning and Research Program, Project 64-6, "Materials Inventory by Photo Interpretation," a cooperative effort between the Bureau of Public Roads and the State Highway Commission of Kansas financed by Highway Planning and Research funds. The materials inventory program was initiated to provide a survey of all existing construction materials in Kansas on a county basis to help meet the demands of present and future construction needs.

The objectives of the program are to map and describe all material source beds in the respective counties and to correlate geologic nomenclature with these source beds for classification purposes. The program does not propose to eliminate field investigations, but it should substantially reduce and help to organize field work.

Several geologists have published reports that refer to the county either directly or in a general way, including two detailed reports, "Geology and Ground-Water Resources of Mitchell County, Kansas" (1959) by W. G. Hodson, and "Geologic Construction-Material Resources of Mitchell County, Kansas" (1951) by F. E. Byrne and others. In addition, several preliminary soil surveys have been made and centerline geological profiles prepared for road design purposes by the State Highway Commission of Kansas along the major highways that traverse Mitchell County; however, very little current information on materials suitable for construction purposes is available.

Aggregate quality test results, pertinent information pertaining to materials produced, and geologic data on Mitchell County used in this report were supplied by the Materials Department and the Geology Section of the Design Department. The report was prepared under the guidance of J. D. McNeal, Engineer of Planning and Research; R. R. Biege, Jr., Engineer of Aerial Surveys and Photogrammetry; and A. H. Stallard, of the Photogrammetry Section. Appreciation is extended to D. L. Jarboe, Second Division Materials Engineer, and F. S. Williamson, Mitchell County Engineer, for verbal information on Construction Materials in the area.

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ABSTRACT

The construction material resources of Mitchell County are restricted to Cretaceous bedrock and unconsolidated terrace deposits which are found throughout the county.

Iron cemented sandstone zones in the Dakota Formation have been the source of a very limited amount of surfacing material for township roads in the southeastern portion of Mitchell County; however, material from this source has proven to be generally unsatisfactory for this purpose because it is easily pulverized by traffic and eroded away by wind and water. Through experience, it has been found quite difficult to maintain a smooth riding surface where this material is used.

Chalky shale and limestone from the Greenhorn Limestone Formation have been used for surfacing lightly traveled rural roads throughout the county. This material is not entirely satisfactory for road surfacing because it is readily pulverized by traffic and, subsequently, eroded away by wind and water. Maintaining a smooth riding surface with this material has also proven to be very difficult because partially embedded pieces of limestone are left exposed when the softer chalky shale is eroded away. Normal maintenance operations dislodge and leave these pieces of limestone scattered over the road surface.

Chalky limestone from the Fort Hays Limestone Member of the Niobrara Formation could provide a source of surfacing material for lightly traveled rural roads in the southwestern portion of the county. This material is subject to wind erosion during periods of dry weather, but it becomes stable and provides a suitable all-weather surface during wet conditions.

The Crete Formation is the most important source of construction material in Mitchell County. This unit is composed mainly of limestone gravel with varying amounts of siliceous sand and gravel. Clay, which is commonly associated with these deposits, generally causes the material to have a high plastic index; therefore, it would be necessary to process material from this source before using it in bituminous or concrete construction.

Wisconsinan Terrace Deposits and Recent Alluvium located in the Solomon River valley are composed of coarse sand and gravel which grades upward into fine sand and silt. These deposits have provided limited quantities of sand and gravel for bituminous highway construction purposes. Tests indicate that some of the silt in these deposits is suitable for use as mineral filler.

Geo-engineering in Mitchell County merits some attention in this materials inventory with respect to: 1. material usage considerations, 2. pollution of water resources, and 3. possible hydrology problems in road construction. Of particular importance from the material usage aspect is the high swell and shrinkage characteristic of the plastic shales found in the Dakota Formation, Graneros Shale Formation, and the Blue Hills Member of the Carlile Shale Formation inasmuch as they are undesirable for use as embankment material. Polluted water, high in sulfates and chlorides,

is undesirable for use in concrete mixes. Because such contaminated water is known to exist in the Dakota Formation, Greenhorn Formation, and the Wisconsinan Terrace Deposits and Recent Alluvium, care should be exercised when use of water from these units is a consideration for concrete construction purposes. Hydrology problems in road construction may exist, under adverse climatic conditions, from water seeping through the various geologic units into the highway subgrade resulting in subsequent failure.

# INTRODUCTION

## Purpose of the Investigation

The purpose of this report is to present information pertaining to the availability, location, and nature of deposits of material for use in highway construction and similar projects in Mitchell County, and to provide a guide for materials prospecting in the county.

## Scope

This investigation includes all of Mitchell County. All geologic units which are considered a construction material source are mapped and described. Construction material, as used in this report, includes soft limestone which can be crushed and used as surfacing material on lightly traveled rural roads as well as granular material suitable for road construction purposes. Mineral filler of high quality is included in this term. General information concerning significant geo-engineering problems is included in this report.

## Nature of the Report

Because all construction material source beds are the product of geological agents, the materials inventory is based largely on the geology of the county. This enables one to ascertain the general engineering properties of the material source unit and to identify and classify each bed according to current geologic nomenclature. By adopting this nomenclature to materials inventories, a uniform system of material source bed classification is established. It should be noted that the quality of material which can be produced from a given source bed may vary from one part of the county to another, especially when dealing with unconsolidated deposits. Generally, the geologic name attached to unconsolidated sediments denotes age and not material type; therefore, two deposits may have the same geologic name but vary in composition because of different parent material. Consolidated geologic units such as limestone and shale usually have more uniform engineering qualities throughout a given area; however, some changes occur due to variations in depositional environment and weathering conditions.

In essence, the geology of the county provides a basis for mapping material source beds and criteria for evaluating the general quality of the material.

The mapping of the various geologic units is accomplished by using aerial photography of the county. Because of their continuous nature, most consolidated units can be mapped with a minimum amount of field checking. Unconsolidated deposits, such as sand and gravel, are less extensive and more erratic; however, they can be located by having a knowledge of the geology of the county and by interpreting significant terrane features that are discernible on aerial photography.

Geologic units included in the materials inventory were selected on the basis of past and present use of the material which they contain. Results of quality tests and field observations on the individual source beds were important in determining the possible uses of the material.

## General Information

Mitchell County has an area of 720 square miles and, according to the 1960 census, a population of 8,885. The county lies within the Smoky Hills physiographic division of Kansas and is bounded by parallels $39^{o}$ 13' and $39^{o}$ 34' north latitude and meridians $97^{o}$ 56' and $98^{o}$ 30' west longitude. It is bounded on the north by Jewell County, on the east by Cloud and Ottawa Counties, on the south by Lincoln County, and on the west by Osborne County. Figure 1 is a state map of Kansas showing the location of Mitchell County and other counties currently included in the materials inventory program.

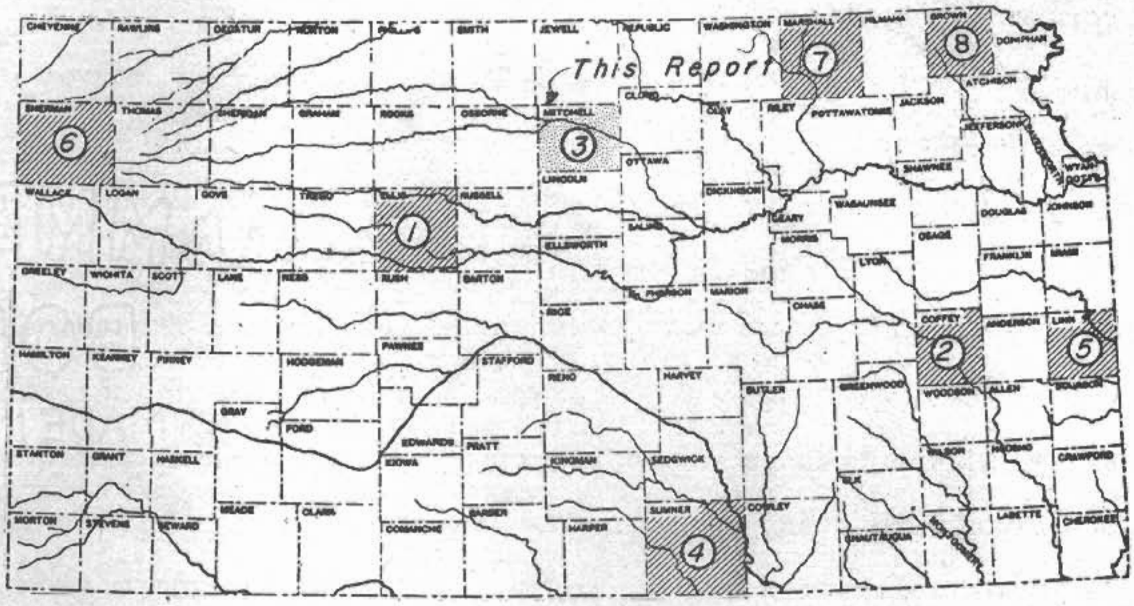



*Figure 1. Index map of Kansas showing the location of Mitchell County along with the report number and location of counties for which reports are published or are being prepared.*

The surface drainage in Mitchell County is controlled chiefly by the Solomon River and its tributaries. The south-central and southeastern portion of the county is drained by Salt Creek and its tributaries. Salt Creek flows eastward out of the county to a confluence with the Solomon River in Ottawa County. The extreme southwestern corner of Mitchell County is drained by tributaries of the Saline River which flows eastward across Lincoln County. Near the western boundry of the county the

Solomon River breaks into its two headwater components, the North and South Forks of the Solomon River.

Mitchell County is served by a line of the Missouri Pacific Railroad which runs in an east-west direction across the county. A branch of the Union Pacific Railroad extends southeast from Beloit, and a line of the Atchison, Topeka, and Santa Fe Railroad Company runs through Tipton and Hunter in the southwestern corner of the county.

The northern two-thirds of Mitchell County is served by a well developed system of roads; however, due to rough topography, the road network in the southern portion of the county is poorly developed. From the west county line, U. S. Highway 24 and State Highway K-9 extend eastwardly along the Solomon valley through Cawker City to just north of Beloit where the two highways take separate routes. U. S. Highway 24 trends southeastwardly and crosses the eastern boundry of the county 1½ miles north of Simpson, while K-9 extends due east from Beloit across the county line. Kansas Highway K-14 which serves the city of Beloit, runs north-south through the county. Highway K-128 extends north from U. S. Highway 24, at a point near Glen Elder, to the county line, and highway K-181 extends through the southwestern corner of the county serving the towns of Hunter and Tipton. State highways K-124, K-129, K-193, and K-194 also serve the county.

## PROCEDURES

The procedure followed in completing this report is divided into the following four phases: 1. research and review of existing publications, maps, and other data; 2. aerial

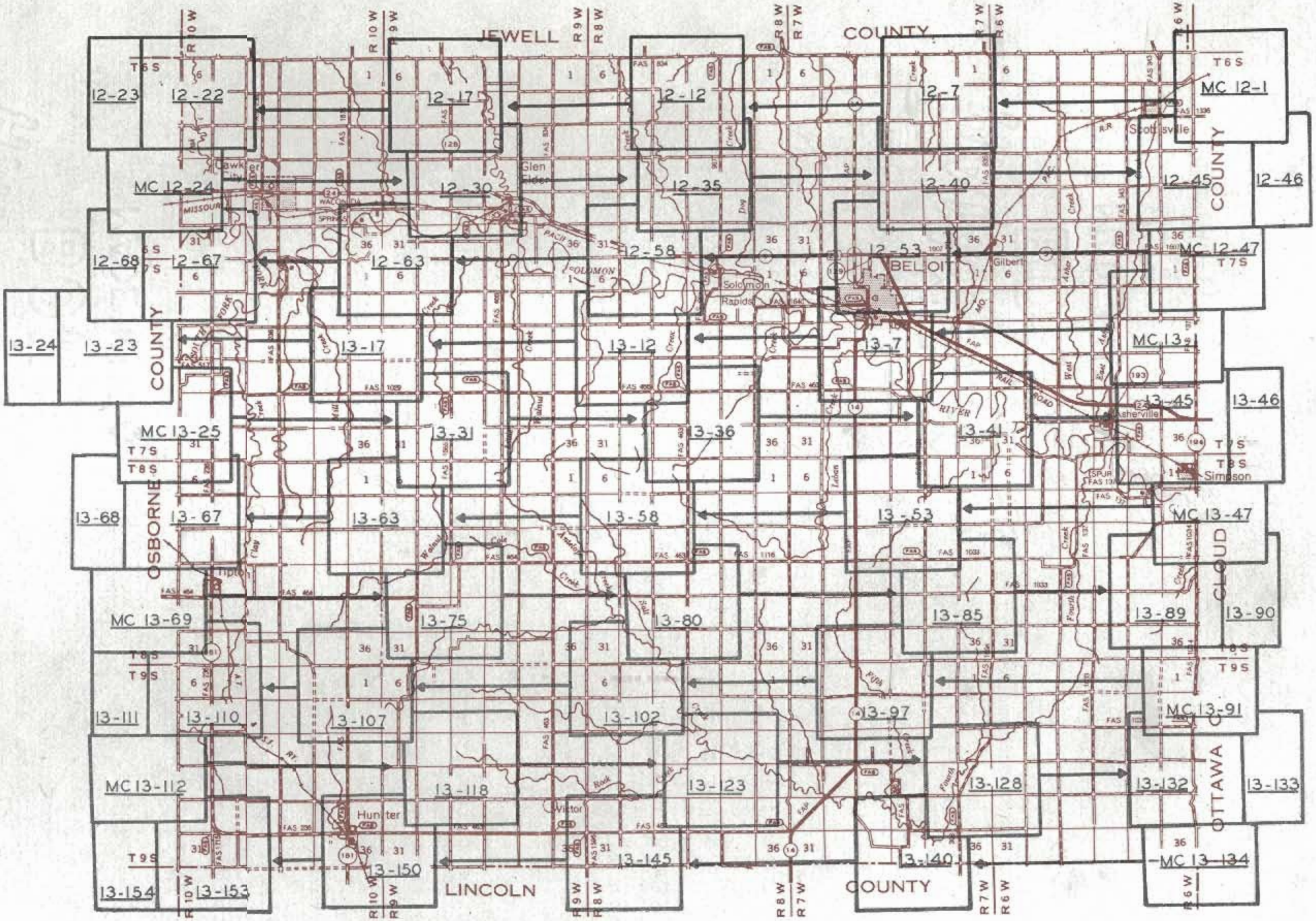



**Figure 2. Aerial photographic coverage map for Mitchell County.** *The numbers which are underlined indicate print numbers of aerial photography obtained by the Photogrammetry Section, State Highway Commission of Kansas. Aerial photographs are on file in the Photogrammetry Laboratory, State Office Building, Topeka, Kansas.*

photographic interpretation on a county wide basis; 3. field reconnaissance survey; and 4. report writing and completion of the illustrations. With the exception of the first, the phases of this investigation were not handled as separate operations, but were completed contemporaneously as each section of the report required. A detailed discussion of the steps followed in each phase is included in this section of the report.

*Phase I* Research of Available Information

All available information pertaining to the geology, soils, and construction materials resources of Mitchell County was reviewed, and the general geology of the county, relative to construction materials, was determined. The results of quality tests already completed on samples taken in Mitchell County were correlated with the various geologic units and deposits in the county.

*Phase II* Aerial Photographic Interpretation

The aerial photography used in this investigation was taken by the State Highway Commission of Kansas, April 5 and June 13, 1963, at a scale of 1:24,000 (one inch represents 2,000) feet). Figure 2, page 5, is a photographic coverage map of Mitchell County.

Initially, the entire county was studied on aerial photographs. The locations of all open material sites which had been sampled and tested were located on the photographs and plotted on a cronar base map of the county. The locations of all open material sites which had not been sampled or reported were also transferred to the base map. All material sites were then correlated with the geology of the county, and the source beds that were discernible on aerial photography were mapped and classified. Figure 3, page 8, illustrates the photo interpretation procedure.

The aerial photograph shown in Figure 3 shows a portion of the Solomon River and its associated terrace deposits. When this area is viewed stereoscopically, the boundaries between the different deposits can be delineated. A distinct break in the terrace marks the division between the Recent Alluvium and the Wisconsinan Terrace Deposits. The break between the Wisconsinan Terrace Deposits and the Crete Formation (upper right corner of the photograph) is much less conspicuous; however, the presence of sand and gravel pits in the upland area attests to the existence of the Crete Formation at this location. The upland area shown in the lower portion of the photograph can be distinguished from the Wisconsinan Terrace Deposits by the prominent bedrock exposure pattern.

After the source beds were tentatively mapped and classified on the aerial photographs, the geology of the county was checked in the field. Subsequently, the final mapping process was completed and a more detailed description of the geological source units was written. The quality of material that might be produced from a particular source bed was, in most instances, ascertained by correlating the results of quality tests with the geological unit from which the test samples were obtained and by field study of the producing unit.

*Phase III* Field Reconnaissance

A field reconnaissance of the county was conducted after


*Figure 3. Three cycles of deposition in the Solomon River valley; Crete Formation, Wisconsinan Terrace Deposits, and Recent Alluvium. Sand and gravel pits in the Crete Formation and the Recent Alluvium are easily distinguished.*

the first study of the aerial photographs had been completed. This enabled the photo interpreter to examine the material with which he was working, to verify doubtful mapping situations, and to acquaint himself better with the geology of the county. All open sites were inspected to verify the geologic classification. During a second field reconnaissance, a representative number of the prospective sites were field checked.

*Phase IV* Map Compilation and Report Writing

The fourth phase of the procedure consisted of correlating all new information gathered during the investigation with previously existing data, writing the report, completing the site data forms, and producing the construction materials map.

The Mitchell County materials map is divided into six sections approximately equal in area (Plates I through VI), with each designated plate representing a specific portion of the county.

Only geologic units or deposits that contribute to the construction materials resources of Mitchell County were mapped. The map units representing material source beds are based primarily on geologic age. In general, the engineering characteristics of material laid down during any given depositional period are fairly consistent throughout the county; however, the gradation of granular material is extremely variable because of its alluvial form of deposition.

All existing and prospective sites are identified on the county materials map by appropriate designations and symbols. The site symbol indicates the status of the materials site; that is, whether it is prospective or open and whether it has been sampled or not. The site designation will convey to the reader, the type of material which can be found at the location, the estimated quantity available, the number of the corresponding data form for that site, and the geologic classification of the source bed.

The map legend explains all letter and map symbols used in the site designations.

To furnish the user of the report with all available information, a data form was completed for each site depicted on the materials map. The site data forms are included in this report as Appendixes I through IV. Appendix I contains data forms for all sites depicted on the Mitchell County materials map that are open, but have not been tested by the State Highway Commission of Kansas. Appendix II contains forms for all sites shown on the materials map as "Open site; sampled." Test data are presented on each data form included in this appendix. Appendix III contains a site data form for each location depicted on the materials map as a "Prospective site; sampled." Test data are presented on each form included in this appendix. Appendix IV contains site data forms for all sites which are shown on the materials map as "Prospective site; not sampled."

Geologic information is presented on each data form to facilitate future correlation. The type of material which can be anticipated in unsampled sites can be determined by referring to nearby tested locations in the same source bed.

A sketch of each site was drawn to illustrate major cultural and natural features of the immediate area which may be helpful in establishing the exact location in the field.

Landowner information is presented for each materials site as it is recorded in the Mitchell County Register of Deeds Office.

The text of the report was completed by presenting a generalized geologic history of the county, by describing and presenting available quality data on geologic units which have produced or are considered possible producers of construction material, and by describing, briefly, certain geologic engineering problems which are considered pertinent in road construction.

## CONSTRUCTION MATERIALS RESOURCES OF MITCHELL COUNTY

### Geologic History of Mitchell County

This portion of the report is intended to provide the layman with a general knowledge of the geologic history of Mitchell County. The information contained in this section is general, and for the geologist, probably inadequate.

The study of geology revolutionized ordinary notions of time. We tend to think of earliest human records as very ancient, but in a geologic sense, the first appearance of man, several thousand years ago is a very recent event. In the years that have elapsed since the appearance of man, the earth's landscape has remained essentially unchanged; however, from the much longer geologic record, geologists know that before man appeared, mountain ranges were born and worn away by the same forces that are at work today. The time element for such a transformation is inconceivably great.

The age of the earth is estimated to exceed three billion years. Geologic time, as other histories, is divided into major segments. The longest divisions are termed eras, and these have been subdivided into units called periods. It should be noted that most periods represent several million years.

Figure 4, page 13, is a geologic timetable reproduced with the permission of the State Geological Survey of Kansas, which shows the general breakdown of geologic time along with the approximate number of of years represented by each period. The rock units formed during any given period are subdivided into series, stages, formations, and members.

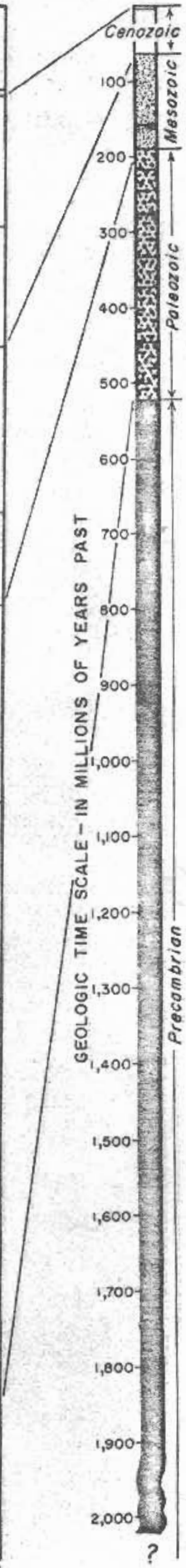
Mitchell County, like the remainder of Kansas, is underlain by a "basement complex" of Pre-Cambrian igneous and metamorphic rock (i.e. granite, gneiss, and schist). The area which includes Mitchell County was invaded by the sea in early Paleozic time and remained a sea, except for short periods of emergence, throughout most of this era. Merriam (1963) indicated that rocks representing all the periods of the Paleozoic Era should be found in the subsurface of Mitchell County. Some folding began in the Mississippian Period and continued through the Pennsylvanian and into the Permian Period. This resulted in the formation of the Nemaha Anticline to the east of Mitchell County. The accompanying downwarp associated with the Nemaha Anticline formed the Salina Basin in the area which includes Mitchell County. During most of the Pennsylvanian and early Permian, the Salina Basin was a sea in which alternate beds of limestone and shale were deposited. In later Permian time, widespread emergence produced shallow basins and low plains in which red silty shale (redbeds) and evaporites (i.e. salt and gypsum) were deposited.

The Mesozoic Era was ushered in by widespread emergence and complete withdrawal of all seas. During the Triassic, Jurassic, and early Cretaceous Periods, the Mitchell County area, as well as most of Kansas was subjected to erosion. In the Cretaceous Period the sea advanced over most or all of Kansas, resulting in the dep-

| ERAS | PERIODS | ESTIMATED LENGTH IN YEARS* | TYPE OF ROCK IN KANSAS | PRINCIPAL MINERAL RESOURCES |
|---|---|---|---|---|
| CENOZOIC | QUATERNARY (PLEISTOCENE) | 1,000,000 | *Glacial drift; river silt, sand, and gravel; dune sand; wind-blown silt (loess); volcanic ash.* | Water, agricultural soils, sand and gravel, volcanic ash. |
| CENOZOIC | TERTIARY | 59,000,000 | *River silt, sand, and gravel; fresh-water limestone; volcanic ash; bentonite; diatomaceous marl; opaline sandstone.* | Water, sand and gravel, volcanic ash, diatomaceous marl. |
| MESOZOIC | CRETACEOUS | 70,000,000 | *Chalk, chalky shale, dark shale, vari-colored clay, sandstone, conglomerate. Outcropping igneous rock.* | Ceramic materials; building stone, concrete aggregate, and other construction rock; water. |
| MESOZOIC | JURASSIC | 25,000,000 | *Sandstones and shales, chiefly subsurface.* | |
| MESOZOIC | TRIASSIC | 30,000,000 | | |
| PALEOZOIC | PERMIAN | 25,000,000 | *Limestone; shale; evaporites (salt, gypsum, anhydrite); red sandstone and siltstone; chert; some dolomite.* | Natural gas; salt; gypsum; building stone, concrete aggregate, and other construction materials; water. |
| PALEOZOIC | PENNSYLVANIAN | 25,000,000 | *Alternating marine and non-marine shale, limestone, and sandstone; coal; chert.* | Oil, coal, limestone and shale for cement manufacture, ceramic materials, construction rock, agricultural lime, gas, water. |
| PALEOZOIC | MISSISSIPPIAN | 30,000,000 | *Mostly limestone, predominantly cherty.* | Oil, zinc, lead, gas, chat and other construction materials. |
| PALEOZOIC | DEVONIAN | 55,000,000 | *Subsurface only. Limestone, black shale.* | Oil |
| PALEOZOIC | SILURIAN | 40,000,000 | *Subsurface only. Limestone.* | Oil |
| PALEOZOIC | ORDOVICIAN | 80,000,000 | *Subsurface only. Limestone, dolomite, sandstone, shale.* | Oil, gas, water. |
| PALEOZOIC | CAMBRIAN | 80,000,000 | *Subsurface only. Dolomite, sandstone.* | Oil |
| PRE-CAMBRIAN | (Including PROTEROZOIC and ARCHEOZOIC ERAS) | 1,600,000,000 + | *Subsurface only. Granite, other igneous rocks, and metamorphic rocks.* | Oil and gas. |

(Not scaled for geologic time or thickness of deposits)

*Committee on Measurement of Geologic Time, National Research Council




*State Geological Survey of Kansas*

*Figure 4. Geologic timetable*

osition of sandstone at the sea's margin and shales, chalky shales, and chalky limestone in the deeper areas. Deposits associated with this late Cretaceous sea represent the surface exposures of bedrock in Mitchell County. The oldest exposed unit in Mitchell County is the clay shale and sandstone of the Dakota Formation, which is a marginal sea or delta type deposit. The younger exposed bedrock units, which include the Graneros Shale Formation, Greenhorn Limestone Formation, Carlile Shale Formation, and the Fort Hays Limestone Member of the Niobrara Formation are deeper marine deposits.

The rise of the present day Rocky Mountains ended the Mesozoic Era and gave birth to the Cenozoic Era. During the early part of the Cenozoic (Tertiary Period), eastward flowing streams from the newly formed Rocky Mountains eroded considerable quantities of Cretaceous bedrock in western and central Kansas. During late Tertiary time, a reversal from stream erosion to deposition occurred causing the land surface of western and central Kansas to be covered by alluvial silt, sand, and gravel from the Rocky Mountains. This material, which composed the Ogallala Formation in western Kansas, has been removed from Mitchell County by subsequent erosion.

The present topography of Mitchell County was formed during the Quaternary Period of geologic time. The glaciation which occurred during this period played a controlling role in the development of the nomenclature and in the classification of deposits laid down during this time. Although glaciers did not extend into Mitchell County, deposits in the county have been classified according to time periods based on glacial events.

Figure 5 shows the divisions of the Quaternary Period (Pleistocene Epoch) along with the approximate number of years represented by each.

| Divisions of the Quaternary Period | | | | |
|---|---|---|---|---|
| Period | Epoch | Age | Estimated length of age duration in years | Estimated time in years elapsed to present |
| Quaternary | Pleistocene | Recent | | 10,000 |
| | | Wisconsinan Glacial | 45,000 | 55,000 |
| | | Sangamonian Interglacial | 135,000 | 190,000 |
| | | Illinoisan Glacial | 100,000 | 290,000 |
| | | Yarmouthian Interglacial | 310,000 | 600,000 |
| | | Kansan Glacial | 100,000 | 700,000 |
| | | Aftonian Interglacial | 200,000 | 900,000 |
| | | Nebraskan Glacial | 100,000 | 1,000,000 |

*Figure 5. Geologic timetable of the Quaternary Period*

Geologic events which took place during Pleistocene time were responsible for the deposition of the best construction material found in Mitchell County. Depositional cycles which occurred during the various ages of the Pleistocene Epoch resulted in the formation of terraces which contain material composed of varying amounts of clay, silt, sand, and gravel.

The main channels of the Solomon River and Salt Creek were developed during the Pleistocene Epoch. During the early portion of this time these two streams were probably flowing at nearly the same location as they are today, but they were probably not major streams because their headwater channels were not far west of Mitchell County.

No deposits of Nebraskan or Kansan age have been found in Mitchell County. Shortly after the beginning of Pleistocene time there was an uplift or climatic change which caused the streams to entrench their channels into older deposits (Hodson, 1959, p. 22). In Nebraskan time these streams presumably deepened their channels and only a minor amount of alluvial material was deposited, later to be removed by erosion. By Kansan time, the Solomon River had become a trunk stream and the modern drainage was developed. Late in the Kansan Age, the streams in Mitchell County became overloaded with sediments and began to aggrade their channels. Sand and gravel deposits forming high terraces upstream along the North Fork of the Solomon River near Cedar in Smith County and Portis in Osborne County have been dated as Kansan in age (Hodson, 1959, p.23); however, these deposits do not extend into Mitchell County.

In Illinoisan time a depositional phase of stream activity took place which consisted of aggrading the earlier channels with material composed mainly of chalky limestone fragments. These gravel deposits of early Illinoisan age have been termed the Crete Formation. Although most of the material in the Crete Formation is limestone gravel of local origin, minor amounts of sand and gravel along with silt and clay indicates that the Solomon River was carrying erosional products from the west (mostly the Ogallala Formation) during Illinoisan time.

Contemporary with and following the Illinoisan fluvial cycle was the deposition of the Loveland Formation. Aggrading valleys and their resultant flood plains were probably the source of the wind deposited silt composing this unit. During the interglacial age (between the Illinoisan and Wisconsinan), a period of stability occurred, at which time the Sangamon Buried Soil was formed.

In Wisconsinan time, valleys deepened and most of the earlier Illinoisan channel deposits were removed. The Solomon River cut a channel in Mitchell County which is estimated to be 100 feet below the Crete Formation (Hodson, 1959, p.24). The last period of degradation was followed by rapid aggradation in late Wisconsinan time which extended into the Recent. This cycle of alluviation resulted in the Solomon River valley being filled with silt, sand, and gravel. Leonard (1952) referred to these Wisconsinan deposits, which may be 40 to 60 feet thick in the deeper portions of the stream valleys, as the Kirwin Terrace.

During early Wisconsinan time, wind blown silt, presumably from the broad flood plains of the Platte and Republican River valleys, was deposited in Mitchell County. This silt is termed the Peoria Formation.

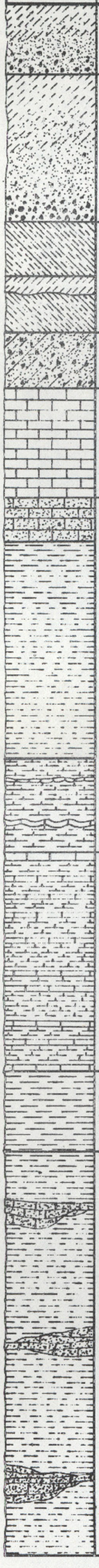
According to Hodson (1959), the Solomon River was rejuvenated and began to cut into late Wisconsinan alluvial fill in early Recent time. At present this river has entrenched its channel well into the older alluvial deposits, cutting both vertically and laterally. Aggradation which occurs during flood stage results in a deposit of fine sediment over the modern flood plain.

## Construction Materials Inventory

Although several formations and members are exposed or near the surface in Mitchell County, only a few are significant as material sources. Figure 6 gives a resume' of the major material bearing beds, the type of material which can be produced from each, the general area where a particular type of material is found, and the page in this report upon which the units are described. In planning an exploration program the general de-

| Material Type | Geologic Source | Page Described | Locality Where Available |
|---|---|---|---|
| Sandstone | Dakota Formation | 20 | Southeastern portion of the county. |
| Limestone | Greenhorn Limestone Formation | 21 | Along the margins of the drainage systems throughout most of the county. |
| | Fort Hays Limestone Member, Niobrara Formation | 23 | Southwestern one fourth of the county. |
| Sand & Gravel | Crete Formation | 26 | High terraces along the Solomon River and its major tributaries, Salt Creek, and in the high area in the southwestern portion of the county. |
| | *Wisconsinan* Terrace Deposits & Recent Alluvium | 27 | Solomon River Valley |
| Mineral Filler | Wisconsinan Terrace Deposits | 27 | Solomon River Valley. |

*Figure 6. A recapitulation of the construction material types and their availability in Mitchell County.*



| Graphic Legend | Thickness | System | Ser. | Formations and Members | Generalized Description | Construction Materials |
|---|---|---|---|---|---|---|
| | 0' to 30' | Quaternary | Pleistocene | Alluvium | Gravel and coarse sand grading upward into fine sand and silt. | Road Surfacing Material, Aggregate |
| | 0' to 60' | Quaternary | Pleistocene | Wisconsinan Terrace Deposits | Gravel and coarse sand grading upward into fine sand and silt. | Road Surfacing Material Aggregate Mineral Filler |
| | 0' to 40' | Quaternary | Pleistocene | Peoria Formation | Massive tan to gray-buff calcareous eolian clayey silt. | |
| | | Quaternary | Pleistocene | Loveland Formation | Reddish-tan clayey silt, in part eolian, with the buried Sangamon soil at the top. | |
| | 0' to 20' | Quaternary | Pleistocene | Crete Formation | Stream deposited clay, silt, sand, and gravel. | Road Surfacing Material, Aggregate |
| | 0' to 45' | Cretaceous | Upper Cretaceous | Niobrara Formation: Fort Hays Limestone Member | Massive cream to buff limestone separated by thin shale partings. | Road Surfacing Material |
| | 0' to 400' | Cretaceous | Upper Cretaceous | Carlile Shale Formation: Codell Sandstone Member | Yellow-brown fine grained sandstone | |
| | | Cretaceous | Upper Cretaceous | Carlile Shale Formation: Blue Hill Shale Member | Gray to blue-black clayey shale with some calcareous concretions. | |
| | | Cretaceous | Upper Cretaceous | Carlile Shale Formation: Fairport Chalk Member | Gray calcareous shale and thin nodular chalky limestone, weathers buff. | |
| | 0' to 87' | Cretaceous | Upper Cretaceous | Greenhorn Limestone Formation: Pfeifer Shale Member | Gray chalky shales and thin chalky limestone zones, weathers buff. | Road Surfacing Material |
| | | Cretaceous | Upper Cretaceous | Greenhorn Limestone Formation: Jetmore Chalk Member | Gray chalky shales and thin chalky limestone zones, weathers buff. | |
| | | Cretaceous | Upper Cretaceous | Greenhorn Limestone Formation: Hartland Shale Member | Gray chalky shales and thin chalky limestone zones, weathers buff. | |
| | | Cretaceous | Upper Cretaceous | Greenhorn Limestone Formation: Lincoln Limestone Member | Gray chalky shales and crystalline limestone zones, weathers buff. | |
| | 0' to 30' | Cretaceous | Upper Cretaceous | Graneros Shale Formation | Dark blue-gray clayey shale which weathers gray and tan. | |
| | 350± | Cretaceous | Lower (?) Cretaceous | Dakota Formation | Gray and varicolored shale with lenses of sandstone. | Road Surfacing Material |

*Figure 7. A generalized geologic column of the surface geology in Mitchell County.*

scription of the material can be used as a guide in selecting geologic units for production purposes. A sampling and testing program should be conducted if detailed information is desired on a particular materials site.

Figure 7, page 19, is a generalized geologic column of the surface geology in Mitchell County which illustrates the relative stratigraphic position of each geologic source bed.

## Cretaceous System

### *Dakota Formation*

The oldest geological unit exposed in Mitchell County is in the Dakota Formation. The exposures of this formation are limited mostly to the southeastern portion of the county where the Solomon River and Salt Creek drainage systems have cut through overlying sediments. In Mitchell County the full thickness of the formation is approximately 350 feet, most of which is in the subsurface. It has been estimated that the Dakota is composed of approximately 80 percent clay shale and 20 percent sandstone. The sandstone, being more resistant to erosional processes, developes a more conspicuous exposure than the shale. Figure 8, page 21, is a view of some iron cemented sandstone in the Dakota Formation.

A small amount of iron cemented sandstone has been used to surface lightly traveled rural roads; however, this material has proven to be unsatisfactory for this purpose because it is easily pulverized by traffic and eroded away by wind and water. Experience has also shown that it is extremely difficult to maintain a smooth riding surface with this material. Due to its limited use, the Dakota has not been mapped in this inventory. No quality tests are available which may have been performed on material

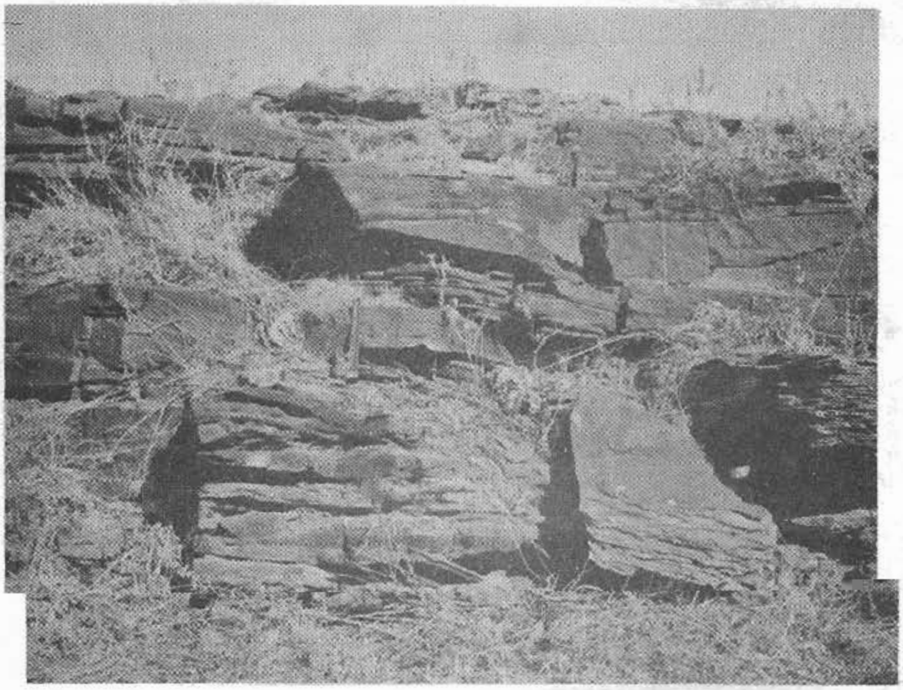


*Figure 8. Iron cemented sandstone in the Dakota Formation, SW¼, Sec. 28, T9S, R7W.*

from the Dakota Formation in Mitchell County.

*Greenhorn Limestone Formation*

Exposures of the Greenhorn Limestone Formation are readily found in the county along the margins of the drainage systems. It is composed of approximately 87 feet of chalky shales and limestones. Figure 9, page 22, illustrates a good exposure of a portion of the Greenhorn located within the city of Glen Elder. The top of the formation is marked by the prominent Fencepost limestone zone which was extensively used a few decades ago for building stone and fencing posts. Figure 10, page 23, is a ground view of this zone in an abandoned Fencepost limestone quarry.

The Greenhorn Limestone Formation is included in the Mitchell

County materials inventory and is shown on the material map (Plates I through VI). The map symbol generally represents

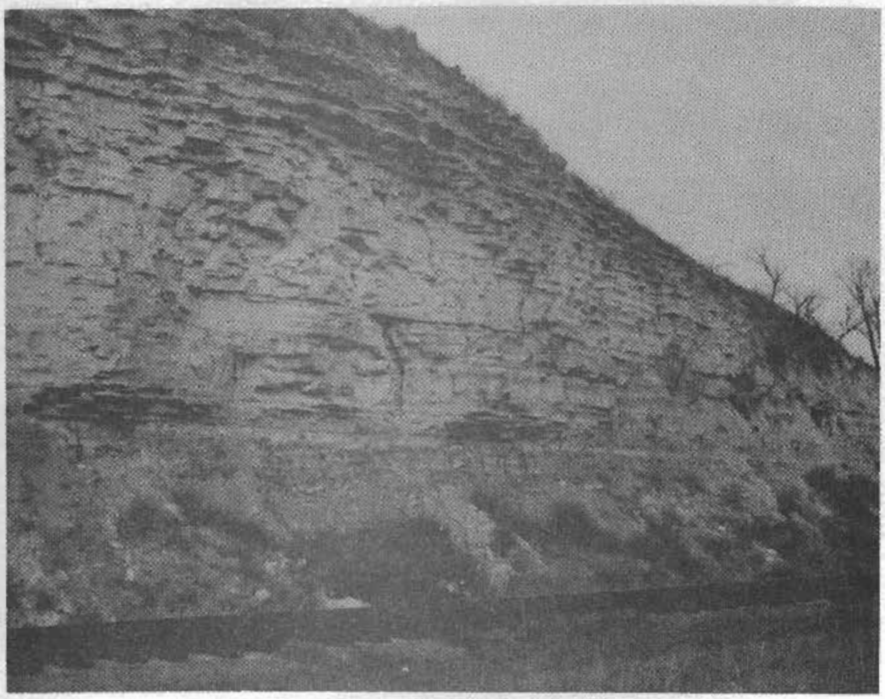


*Figure 9. An exposure of the Greenhorn Limestone Formation, SW¼, Sec. 27, T6S, R9W.*

an exposure of the limy zones which are easily traced on aerial photography.

Some lightly traveled rural roads in Mitchell County have been surfaced with chalky shale and limestone from this formation. The material has not proven to be entirely satisfactory for this purpose because of its rapid disintegration and erosional tendencies. Because the chalky shale constituents erode more rapidly than the limestone, roads surfaced with this material soon become rough and are difficult to maintain.

In the past, the material utilized from the Greenhorn has been obtained generally from the Jetmore Chalk Member of the Formation because of the relatively high percentage of limestone found in this particular member. Figure 11, page 24, includes

*Figure 10. Fencepost limestone zone in an abandoned quarry, SE¼, Sec. 24, T8S, R6W.*

the results of a test performed on a sample of the material. These results illustrate the high absorption and wear properties associated with the Greenhorn. Material from this source is used for surfacing by the county and townships because a more satisfactory type is not available within a feasible hauling distance.

*Fort Hays Limestone Member, Niobrara Formation*

The youngest unit of the Cretaceous System found in Mitchell County is the Fort Hays Limestone Member of the Niobrara Formation. The unit is composed of cream to buff colored limestone separated by thin shale partings. Exposures of the Fort Hays are limited to the southwestern one fourth of the county (Figure 12, p. 25).

| Location | Material Type | 1 1/2 | 1 | 3/4 | 3/8 | 4 | 8 | 16 | 30 | 50 | 100 | Wash | G.F. | P.I. | L.L. | Sp.Gr. | Wt./Cu.Ft. | Wear | Soundness | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOURCE OF MATERIAL: Recent Alluvium | | | | | | | | | | | | | | | | | | | | |
| SE 1/4, Sec. 34, T6S, R10W | Sand & Gravel | - | - | - | 4 | 19 | 49 | 92 | 99 | 100 | 100 | 0 | 4.63 | - | - | - | - | - | - | 1 quality sample |
| SE 1/4, Sec. 8, T7S, R7W | Sand & Gravel | - | - | - | 3 | 5 | 8 | 38 | 76 | 87 | 87 | 11 | 3.03 | - | - | 2.59 | 100.3 | 32.7 | 0.93 | 1 quality sample |
| SOURCE OF MATERIAL: Wisconsinan Terrace Deposits | | | | | | | | | | | | | | | | | | | | |
| SW 1/4, Sec. 28, T6S, R9W | Mineral Filler | - | - | - | - | - | - | - | - | 1 | 6 | 84 | - | 4 | 26 | - | - | - | - | Average of 2 samples |
| SE 1/4, Sec. 26, T6S, R9W | Sand & Gravel | - | - | 1 | 1 | 3 | 5 | 10 | 21 | 71 | 91 | 7. | 2.03 | 2 | 16 | - | - | - | - | Average of 16 test holes |
| SOURCE OF MATERIAL: Crete Formation | | | | | | | | | | | | | | | | | | | | |
| SE 1/4, Sec. 29, T6S, R8W | Limestone Gravel | - | - | - | 2 | 5 | 9 | 23 | 59 | 88 | 95 | 4 | 2.81 | - | - | 2.59 | 105.8 | 36.6 | 0.86 | 1 quality sample |
| NW 1/4, Sec. 10, T7S, R7W | Sand & Gravel | - | - | 2 | 6 | 14 | 23 | 38 | 60 | 77 | 82 | 16 | 3.02 | - | - | 2.56 | 101.9 | 38.3 | 0.94 | 1 quality sample |
| NW 1/4, Sec. 10, T7S, R7W | Sand & Gravel | 2 | 4 | 5 | 9 | 16 | 24 | 40 | 74 | 93 | 96 | 3 | 3.63 | - | - | 2.60 | 106.6 | 41.0 | 0.89 | 1 quality sample |
| S 29, T8S, R10W | Sand & Gravel | - | - | 1 | 5 | 41 | 65 | 74 | 81 | 84 | 87 | 11 | 4.38 | - | - | 2.50 | 100.1 | 23.7 | 0.95 | 1 quality sample |
| NW 1/4, Sec. 3, T7S, R7W | Sand & Gravel | - | - | 1 | 4 | 8 | 14 | 26 | 53 | 80 | 88 | 11 | 2.74 | - | - | 2.55 | 105.2 | 36.9 | 0.95 | 1 quality sample |
| SW 1/4, Sec. 29, T6S, R8W | Limestone Gravel | - | - | 1 | 4 | 7 | 13 | 31 | 71 | 91 | 93 | 6 | 3.11 | - | - | - | - | - | - | Average of 10 test reports for Subgrade Modification projects |
| SE 1/4, Sec. 8, T7S, R10W | Sand & Gravel | - | - | 2 | 7 | 23 | 52 | 89 | 97 | 98 | 98 | 1 | 4.66 | - | - | - | - | - | - | 1 quality sample |
| SE 1/4, Sec. 31, T6S, R9W | Sand | - | - | - | - | - | - | 3 | 30 | 78 | 94 | 5 | 2.05 | 1 | 17 | - | - | - | - | Average of 12 samples |
| SW 1/4, Sec. 33, T8S, R8W | Limestone Gravel | - | - | 2 | 6 | 19 | 37 | 58 | 78 | 86 | 89 | 9 | 3.73 | - | - | - | - | - | - | 1 quality sample |
| SE 1/4, Sec. 10, T7S, R7W | Sand & Gravel | - | - | 3 | 12 | 22 | 31 | 43 | 63 | 78 | 82 | 16 | 3.34 | - | - | 2.35 | - | 36.6 | 0.86 | 2 quality samples |
| SOURCE OF MATERIAL: Fort Hays Limestone Member, Niobrara Formation | | | | | | | | | | | | | | | | | | | | |
| SE 1/4, Sec. 11, T9S, R10W | Limestone | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1.79 | - | 61.4 | 0.34 | Absorption 17.81 |
| SOURCE OF MATERIAL: Jetmore Chalk Member, Greenhorn Limestone Formation | | | | | | | | | | | | | | | | | | | | |
| NW 1/4, Sec. 23, T7S, R6W | Limestone | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2.06 | 133 | 55.8 | 0.84 | Absorption 9.06 |

*Figure 11.* Results of tests completed on samples of material from several geologic source beds in Mitchell County.

The limestone, which may be as much as 45 feet thick, has not been used in Mitchell County for materials purposes; however, in other counties it has been used as surfacing material on lightly traveled rural roads. When so used, the limestone from the Fort Hays is readily pulverized by traffic and is subject to severe wind erosion in periods of dry weather, but it does provide a stable roadbed during wet seasons.

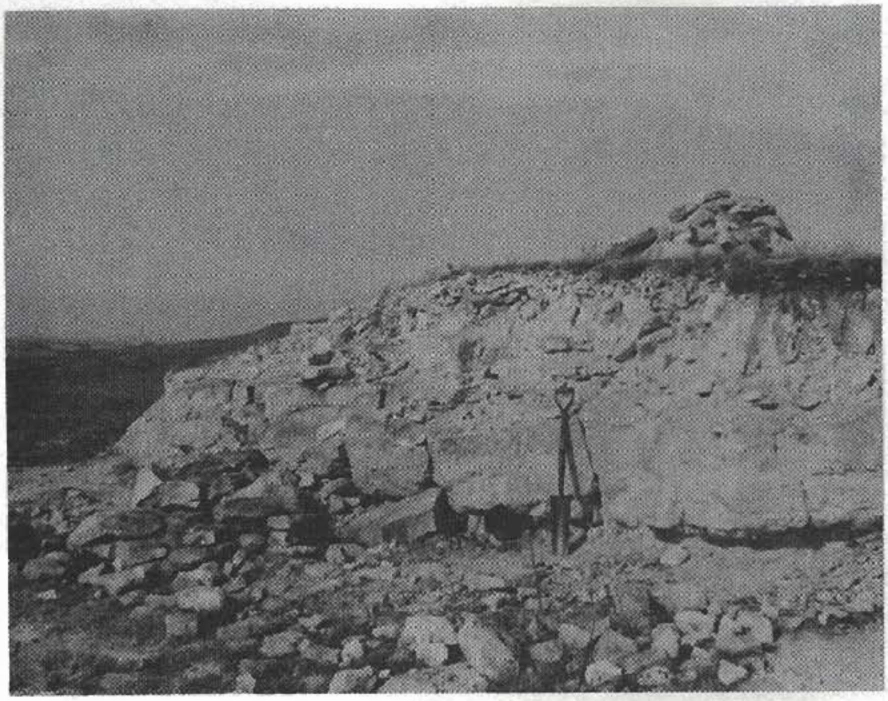


*Figure 12. Fort Hays Limestone exposure, SW¼, Sec. 17, T9S, R9W.*

Figure 11, page 24, shows the results of one quality test which was performed on a sample of Fort Hays Limestone from Mitchell County. Mr. F. S. Williamson, Mitchell County Engineer, stated that the limestone has too high an absorption and percent of wear to be used in concrete or bituminous construction (personal communication). This fact has been verified by the results of quality tests.

Quaternary System
*Crete Formation*

Stream deposited clay, silt, sand, and gravel, overlying Cretaceous bedrock and forming high terraces along the Solomon River and its larger tributaries in Mitchell County, represent the Crete Formation. The unit usually does not exceed 20 feet in thickness and is composed, mainly, of limestone gravel with varying amounts of siliceous sand and gravel. There are many Crete terraces along the north side of the Solomon valley lying close to the valley wall and extending well into some of the major tributaries. Crete terraces are less numerous along the south wall of the Solomon River valley; however, they are abundant in the upland area south and east of Tipton and along Salt Creek.

It is probable that two different cycles of deposition are represented by the Crete Formation in Mitchell County. Higher terraces may represent the original Crete Formation, and the lower elevation terraces may represent, at least in part, a reworked product of the original Crete. It was noted that the lower (younger) terraces, located along the Solomon River and its major tributaries, are characterized by a greater percentage of siliceous material than the higher (older) deposits; therefore, a better quality material can usually be produced from the former.

A good example of the younger Crete sand and gravel may be viewed in an open pit on U. S. Highway 24 just east of Beloit. This material is erratically bedded which is characteristic of alluvial deposits. Clay balls, which are common in this unit (Figure 13, page 27), generally result in the material having a high plastic index.

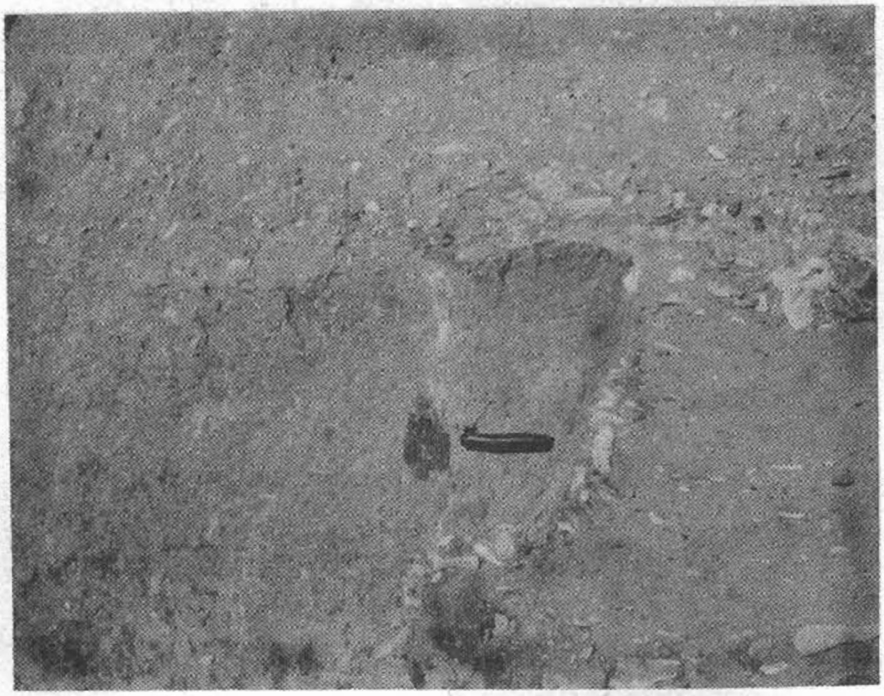


*Figure 13. Clay ball in a Crete gravel pit, NW¼, Sec. 1, T7S, R7W.*

The Crete Formation is the most important source of construction material in Mitchell County. The primary use of the material is for surfacing rural roads; however, material produced from some locations may be processed and used in bituminous and concrete construction. Several quality tests, the results of which are shown in Figure 11, page 24, have been performed on samples taken from this formation.

*Wisconsinan Terrace Deposits and Recent Alluvium*

The Wisconsinan Terrace Deposits (Figure 14, page 28) and Recent Alluvium along the major streams in Mitchell County are composed of coarse sand and gravel grading upward into fine sand and silt. Although these deposits are present along all of the major streams in the county, only the Solomon River valley (where these deposits have a maximun thickness of 60 feet) contains a sufficient quantity of coarse material to be considered as a source of aggregate for highway construction. One should note that even in this valley, a sizeable percentage of the material is fine, necessitating a considerable amount of screening to produce material which will meet most gradation specifications. At all existing pit locations, production has been by pumping operations because the coarse fraction of the material lies below the water table.

*Figure 14. A view looking across the broad, flat, Wisconsinan terrace plain of the Solomon River, Sec. 25, T7S, R.[illegible]W.*

Mineral filler has been produced from at least one location in the Wisconsinan Terrace Deposits of the Solomon River valley. Only two prospective sites, wnere the silt in the terrace may be suitable for use as mineral filler, have been shown on the materials map (Plates I and II), but extensive field investigation will probably lead to the discovery of other sites from which similar material could be produced.

Figure 11, page 24, includes a resume' of the results of tests performed on material taken from the Wisconsinan Terrace Deposits and the Recent Alluvium.

## Geo-Engineering

### Material Usage Considerations

Nearly all of the geological units exposed in Mitchell County have been used in construction of embankment or subgrades; however, many of these, such as the Graneros Shale and some of the highly plastic soils, are not recommended for subgrade or shoulder construction due to their shrinkage and and swell characteristics. A highly plastic material may be useful if slope protection is desired because of its resistance to erosional processes; but if development of a turf is desired its use should be avoided.

In Mitchell County the Dakota Formation, Graneros Shale Formation, and the Blue Hills Member of the Carlile Shale Formation have undesirable engineering properties which are considered especially pertinent in this materials inventory. The following discussion is a resume' of these units and their characteristics.

Some of the clay shales from the above mentioned three formations have the capacity to absorb water readily and swell or increase in volume. Because of this high swell characteristic, roadbeds constructed on fill composed of these materials will frequently fail, and slides often occur in cuts where these units are present. These shales are also a problem when conducting bridge foundation investigations. Due to the variable penetration of pile into this type of material, pile tip elevations are often hard to predict accurately.

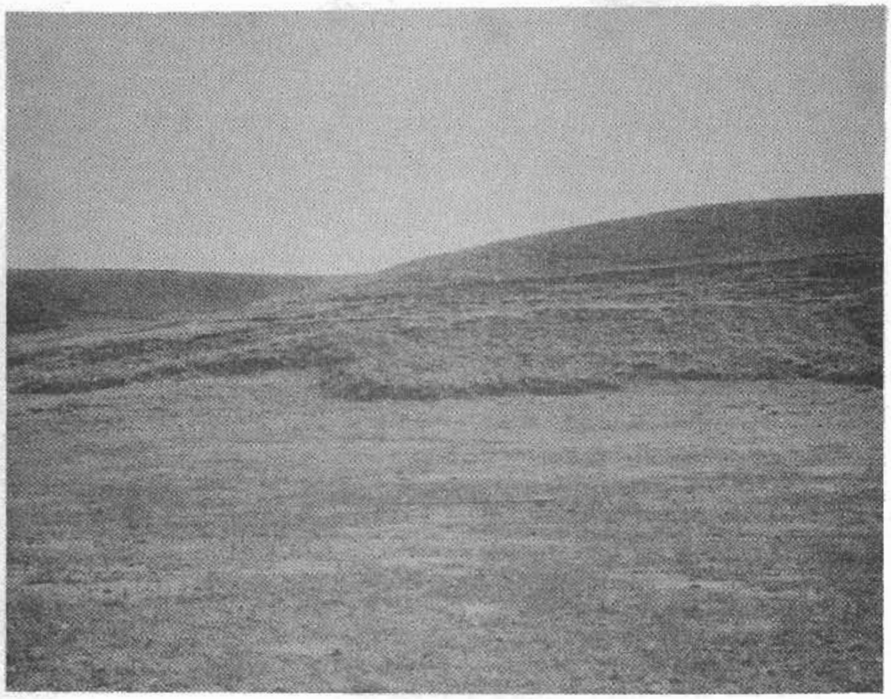


*Figure 15. Typical slide in the Graneros Shale Formation, NW¼, Sec. 28, T9S, R7W.*

Of all the consolidated geologic units found in Kansas, the Graneros Shale has probably caused more problems than any other because of its unsound engineering properties. Lithologically, the Graneros is a dark gray, clay shale which varies from 20 to 30 feet in thickness. It is characterized by slides which frequently occur where the unit is exposed or nearly exposed on steep hillsides. Figure 15 is a ground view of a slide in the Graneros shale. These slides commonly displace fences, roadways, and other cultural features. Because of the severe engineering problems encountered in this unit, proposed highways may be realigned to avoid traversing this unit. When a proposed highway crosses a hillside which contains the Graneros Shale, berming down to unweathered or more stable material is often recommended to insure highway stability. The shale which is removed by berming is generally wasted because of the undesirability of the material for embankment purposes.

Pollution of Water Resources

The following discussion is based on the information presented by Hodson (1959) on the geology and groundwater resources of Mitchell County, and is intended to acquaint the reader with the water bearing geological units and the purity of the water produced. The mineral content should be considered when selecting a source of concrete mix water, especially if sulfates or chlorides are known to contaminate local supplies.

*Dakota Formation*

The Dakota Formation contains lenticular sand pockets which yield moderate amounts of water. In eastern and southeastern Mitchell County, the water from this unit is relatively pure, but in the remainder of the county the yield from the Dakota is moderately to highly mineralized. In some areas, saline water under artesian pressure from the Dakota Formation has been reported to have contaminated the water in alluvial terrace deposits (i.e. in the area around Waconda Springs and in the Solomon River valley near Beloit).

*Greenhorn Limestone Formation*

The Greenhorn Limestone yields small quantities of water most of which is seasonal (during seasons of heavy rainfall). Tests indicate that some of the water from the Greenhorn Limestone Formation is also highly mineralized.

*Wisconsinan Terrace Deposits and Recent Alluvium*

Wisconsinan Terrace Deposits and Recent Alluvium provide the principle sources of groundwater in Mitchell County. Chemical tests completed on samples of water from these deposits indicate that the degree of mineralization varies throughout the county. Some mineralized water, high in sulfate and chloride content, found in localized areas along the Solomon River valley, has resulted from fluid infilteration under artesian pressure from the Dakota Formation. As a precautionary measure, the water which is to be used in concrete mixes should be tested for mineralization to help insure high quality concrete.

Possible Hydrology Problems in Road Construction

Most of the geologic units exposed in Mitchell County have properties which could contribute to ground water problems in road construction under adverse climatic conditions. Specific recommendations concerning these situations are beyond the scope of this report; however, some factors are briefly discussed to familiarize the reader with their existence.

Sandstone zones in the Dakota Formation that are known aquifers have, under given circumstances, contributed to failure in subgrades; however, such zones are local in nature because of the erratic bedding planes in the formation. Detailed field investigation on proposed projects should be conducted to determine the extent of these beds, and consideration should be given to the problems associated with their occurrence.

The limestone zones and bentonite layers in the Greenhorn Limestone Formation are known to carry some water; however, major hydrology problems in road construction are not numerous.

The water table in the Wisconsinan Terrace Deposits and Recent Alluvium is frequently found near the surface. Inasmuch as these deposits form a broad flat plain very few cut sections are necessary in road construction; however, some instability, due to the high water table, may be found to exist when fills are constructed across such deposits.

## GLOSSARY OF SIGNIFICANT TERMS

Absorption: Determined by tests performed in accordance with A.A.S.H.O. Designation T85.

Aggradation: The natural filling up of a stream channel by deposition of sediments.

Consolidated geologic unit: Usually older bedrock units (older than Pleistocene age) where individual grains of the material have been cemented together. Examples of consolidated geologic units include limestone, sandstone, and shale.

Degradation: The natural scouring out of sediments in a stream channel by running water.

Exposure pattern: Topographic feature formed on the land surface by the exposure of geologic units.

Fluvial cycle: Term applied to the stream action cycle involving periods of deposition, erosion, and return to deposition.

Geologic process: Term pertaining to erosion, deposition, and diastrophic methods by which the earth's surface has been shaped.

Gradation factor: The value obtained by adding the percentages of material retained on the 1½", 3/4", 3/8",4,8,16,30,50 and 100 sieves respectively and dividing the sum by 100.

Headwater components: Term applied to the major channels of a trunk stream in the upstream portion of the drainage area.

Liquid limits: Determined by tests performed in accordance with Section Y-4 of the State Highway Commission of Kansas Standard Specification, 1960.

Los Angeles Wear: Determined by tests performed in accordance with A.A.S.H.O. Designation T96 as modified by Section Y-14 of the State Highway Commission of Kansas Standard Specifications, 1960.

Open materials site: A pit or quarry which has produced or is producing materials suitable for some phase or phases of road construction.

Physiographic division: A divison of the state based on general geologic and (or) geographic features.

Plastic index: Determined by tests performed in accordance with Y-4 of the State Highway Commission of Kansas Standard Specifications, 1960.

Soundness: Determined by tests performed in accordance with Section Y-15 of the State Highway Commission of Kansas Standard Specifications, 1960.

Specific gravity: Determined by tests performed in accordance with A.A.S.H.O. Designation T84 for sand and gravel and A.A.S.H.O. Designation T85 for crushed stone.

Strength ratio: Determined by tests performed in accordance with A.A.S.H.O. Designation T71.

Trunk stream: A major drainage channel in a given area.

Unconsolidated deposits: Usually refers to deposits not older than Pleistocene age where individual grains of material have not been cemented together. Examples are clay, silt, sand and gravel.

Wash: (Material passing the No. 200 sieve) Determined by tests performed in accordance with A.A.S.H.O. Designation T11.

Weathering: The disintergration or decomposition of rock in the place where it was deposited.

Weight per cubic foot: Determined by tests performed in accordance with A.A.S.H.O. Designation T19-45.

SELECTED REFERENCES


1. American Association of State Highway Officials,(1961) Standard specifications for highway materials and methods of sampling and testing pt. 1, 8th ed., pp. 1-401.

2. American Association of State Highway Officials,(1961) Standard specifications for highway materials and methods of sampling and testing, pt. II, 8th ed., pp. 1-616.

3. Byrne, F. E., Johnson, W. B., and Bergman, D. W. (1951) Geologic construction-material resources of Mitchell County, Kansas: U. S. Geol. Survey Circ. 106, pp. 1-21.

4. Dunbar, C. O. (1952) Historical geology, pp. 1-31, John Wiley and Sons, Inc. New York.

5. Frye, J. C. and Leonard, A. B. (1952) Pleistocene geology of Kansas: Kansas Geol. Survey Bull. 99, pp. 1-230.

6. Hodson, W. G. (1959) Geology and ground-water resources of Mitchell County, Kansas: Kansas Geol. Survey Bull. 140, pp. 1-130.

7. Leonard, A. R. (1952) Geology and ground-water resources of the North Fork Solomon River in Mitchell, Osborne, Smith, and Phillips Counties, Kansas: Kansas Geol. Survey Bull. 98, pp. 1-150.

8. Merriam, D. F. (1963) The geologic history of Kansas: Kansas Geol. Survey Bull. 162, pp. 13-254.

9. State Highway Commission of Kansas (1955) Standard specifications for state road and bridge construction, pp. 391-574.

10. Thornbury, W. D. (1956) Principles of geomorphology, pp. 276-315, John Wiley and Sons, Inc. New York.

11. Tolsted, L. L. and Swineford, Ada (1952) Kansas rocks and minerals: Kansas Geol. Survey, pp. 3-10.