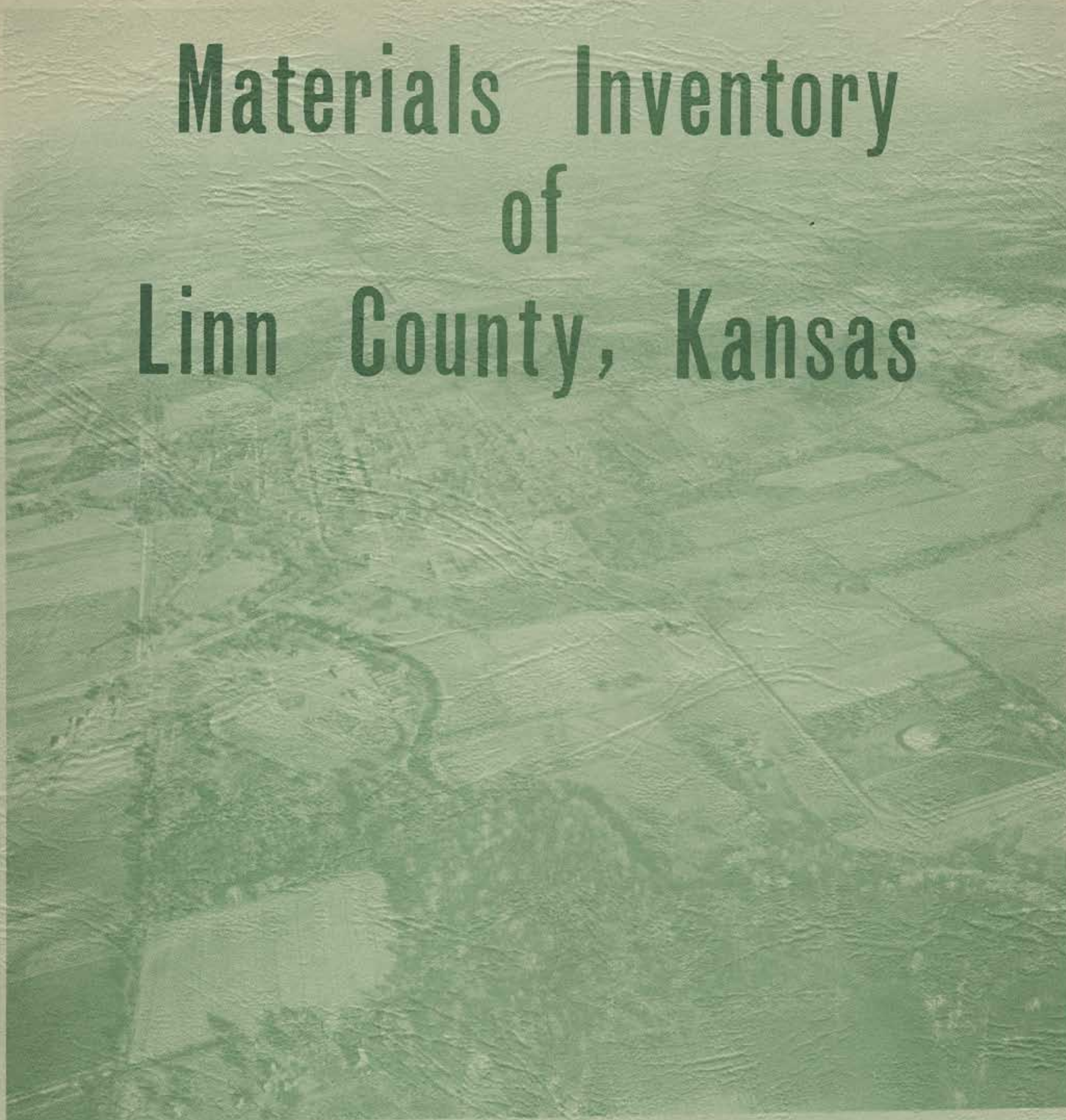
# Materials Inventory of Linn County, Kansas



prepared by the

State Highway Commission of Kansas

in cooperation with the

U. S. Department of Transportation

Federal Highway Administration

Bureau of Public Roads

State Highway Commission of Kansas
Planning and Research Department - Photronics Department

# MATERIALS INVENTORY OF LINN COUNTY, KANSAS

BY

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Prepared in Cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

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Materials Inventory Report No. 5

## SUGGESTED USE OF THE REPORT

The Materials Inventory of Linn County is the fifth of a series of county materials inventories prepared by the State Highway Commission of Kansas in cooperation with the Bureau of Public Roads. The report includes: 1. an introduction which describes the nature of the report and gives general information concerning Linn County; 2. an explanation of the procedures used in compiling the information contained herein; 3. a brief explanation of the origin of the geologic units that are source beds for construction materials, and a detailed description of the materials which have been produced from these units; 4. a geo-engineering section to acquaint the engineer with geologic problems which may be encountered in highway construction; 5. county materials maps (Plates I through VI) which show the geographic locations where various source beds can be found in the county, along with the locations of all open materials sites; and 6. appendices I and II which contain a site data form for each open materials site. Each site data form has a sketch showing the material site and surrounding landmark, the name of the landowner, the name of the geologic source bed, and a resume' of all test data available for the site.

When this report is used as a guide for planning an exploration program or making an assessment of the materials resources of Linn 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 Linn County." In this portion of the report a geologic history of Linn County is presented which describes the events that led to the deposition of the various source beds and sets forth the geologic nomenclature used throughout the report. The construction materials resources of Linn County are also inventoried in this portion of the report. A study of this information 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 is interested in material in a given portion of the county, he should determine from Figure 7 (Page 18), which source beds are present in that area. He should study the description of these beds to determine their physical characteristics, and then refer to the county materials maps to determine where these units are exposed or near the surface, the locations of sites which have produced material from this source and references to data forms for all open sites.

For example, when searching for material in northwestern Linn County, the reader will find that the Argentine Limestone and the Raytown Limestone are both found in this locality. A study of the report will show the Argentine to be a good quarry limestone but that it thins rapidly to the south. If he is interested in this unit he will note that site $\frac{LS+18}{\mathbb{P}a}$ is producing material from this source. Reference may be made to the data form for this site for more detailed information concerning location and engineering properties. The reader will find that the Raytown has not been tested, but it covers a more extensive area than the Argentine. The choice between these two units may be determined by conducting a field check and utilizing information contained in this report.

## 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 wide 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 correlate them with geologic nomenclature for classification purposes. The program does not propose to eliminate field investigations, but it should substantially reduce and help to organize field work.

Previous to this time, no extensive or county-wide materials investigation had been completed in Linn County; however, several geologists have published reports that refer to the county in a general way. Access to some unpublished field information compiled by W. J. Seevers (State Geological Survey of Kansas) during preparation of the forthcoming bulletin, "Geology and Ground-water Resources of Linn County, Kansas," was especially helpful in preparing this report. 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 Linn County; however, available information on materials suitable for construction purposes has been very meager.

Aggregate quality test results, pertinent information pertaining to materials produced, and geologic data on Linn 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; the project leader, R. R. Biege, Jr., Engineer of Aerial Surveys and Photogrammetry; and A. H. Stallard of the Photogrammetry Section. Appreciation is extended to J. L. Farrell, Fourth Division Materials Engineer, for constructive criticism on this report.

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ABSTRACT

The construction materials resources of Linn County consist of a rather limited supply of chert gravel suitable for use as light type surfacing material and an abundant supply of limestone suitable for the production of crushed limestone aggregate.

The Laberdie, Bethany Falls, Winterset, Raytown and Argentine Limestone Members have been quarried in the county and are considered to be the primary source of construction materials. Test results which are available for all of these units except the Raytown Limestone, indicate that material suitable for use in all phases of road construction can be produced from these units. The selection of a limestone for quarrying purposes is usually based on the proximity of a source bed to the project.

The Kansan Terrace Deposits are composed of clay bound chert gravel which has been used extensively in the eastern part of the county for surfacing county roads; however, the abundance of high quality limestone in this area and the high cost of processing gravel from these terraces has precluded the use of material from this source in the construction of bituminous and concrete road surfaces.

Much of the material encountered on road construction projects in the county has properties which make it undesirable for use in embankment and subgrade construction. These include high plastic indices, high liquid limits, low stability values and high swell characteristics. The Mulberry Coal Zone, Fontana Shale and Thayer Coal Zone are of major concern with respect to stability problems. When these zones are encountered, care should be exercised when selecting material for this phase of road construction.

Many of the geologic units in Linn County have been known to be sources of ground-water problems in road construction. Hydrology problems have been encountered on road construction projects in Linn and other eastern Kansas counties at the base of limestones and within sandstone and coal zones. It is recommended that a detailed field investigation be conducted prior to the construction of any project to ascertain the extent and severity of these problems. General recommendations are made in this report concerning possible remedies for certain types of situations which may be encountered in Linn County.

Some of the water supplies in Linn County are too highly mineralized for use in concrete. In general, wells which obtain water from black shales, coal zones, or from depths in excess of 100 feet, produce mineralized water. Good quality water can usually be obtained from the alluvial deposits in the major stream valleys, but some contamination may be found in local areas within the county. Coal mines in the eastern part of the county contain water which may be very highly mineralized.

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The construction materials resources of Linn County consist of a rather limited supply of chert gravel suitable for use as light type surfacing material and an abundant supply of limestone suitable for the production of crushed limestone aggregate.

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# 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 suitable for use in highway construction and similar projects in Linn County, and to provide a guide for materials prospecting in the county.

This report is complete within itself with all available and pertinent laboratory and field data included in addition to information extracted from aerial photographs. Space is provided on the site data forms for detailed information which may be obtained during subsequent field investigations. Geological information is presented to aid in the development of existing materials sites and to aid in the detection of prospective sites.

## Scope

This investigation includes all of Linn County. All geological units which were considered pertinent with respect to materials were mapped and described.

The term "construction material," as used in this report, includes limestone suitable for the production of crushed aggregate and chert gravel which may be used as light type surfacing material for rural roads.

## Nature of the Report

Because all materials source beds are the product of geologic agents, the materials inventory is based largely on the geology of the county being investigated. By using geology as the basis of the materials inventory, one is able to ascertain the general engineering properties of a given unit and to identify and classify each source bed according to current geologic nomenclature. By adopting this nomenclature to materials inventories, a uniform system of materials source bed classification may be used. However, the quality of the material which may be obtained from a given source bed may vary from place to place, especially when one is dealing with unconsolidated deposits.

Generally, the name assigned to unconsolidated deposits denotes geologic age. Thus, two units composed of different material may have the same geologic name because of the age correlation. Consolidated units such as limestone and shale usually have more uniform engineering qualities throughout a given area; however, some changes occur due to variation in depositional environment and weathering conditions. In essence, the geology of the county provides a basis for mapping material source beds and a criterion for evaluating the general quality of the material.

Mapping of the significant geologic units is accomplished through the use of aerial photography of the county. Consolidated units usually form prominent ledges because of their resistance to erosional processes. Unconsolidated deposits such as sand and gravel are less extensive and more erratic, but they can be located, frequently, by having a knowledge of the geology of the county and by interpreting significant terrain features discernible on the photographs.

Geologic units included in the materials inventory were selected on the basis of their past and present use as a construction material. Quality tests on the individual source beds were important in determining the possible uses of the material.

General Information

Linn County has an area of approximately 614 square miles and a population of 8,520 according to the 1960 census. It lies within the Osage Cuestas physiographic division of Kansas and is bounded by parallels 38° 02' and 38° 23' north latitude and meridians 94° 37' and 95° 05' west longitude. Linn County is bounded on the north by Miami County, on the east by Bates and Vernon Counties in Missouri, on the south by Bourbon County, and on the west by Anderson County. Figure 1 is a state map of Kansas showing the location of Linn County and other counties currently included in the materials inventory program.

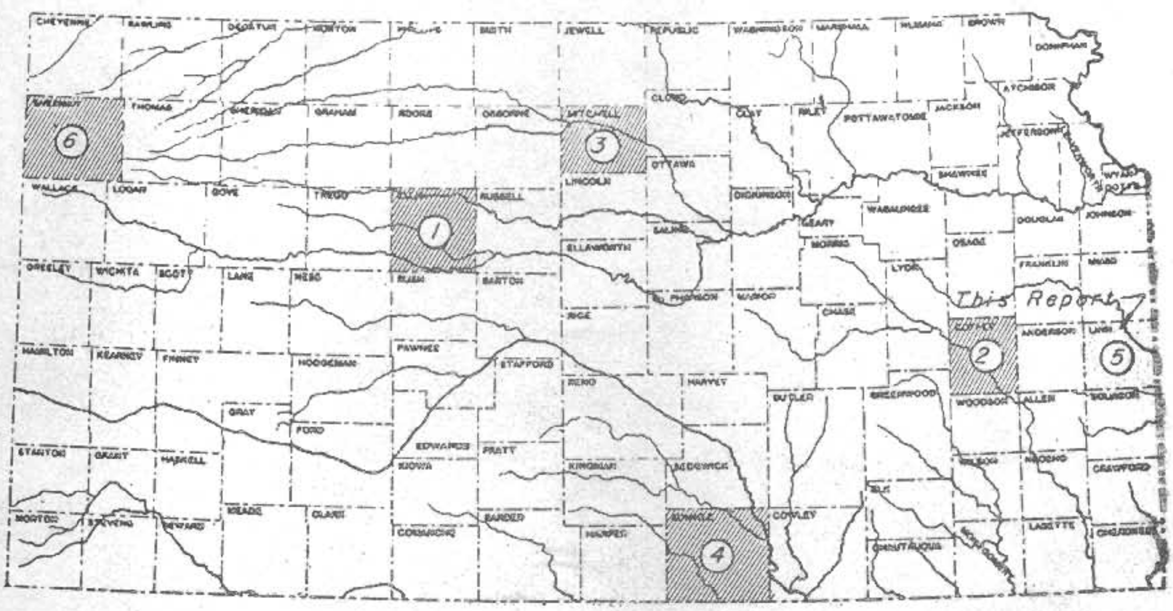


*Figure 1. Index map of Kansas showing the location of Linn County along with the report number and location of counties for which reports are published or are being prepared.*

The surface drainage in Linn County is controlled chiefly by the Marais des Cygnes River and its tributaries, the largest of which include Hushpuckney Creek, Elm Creek, Big Sugar Creek, Mine Creek, and Sugar Creek. Owl Creek, Lost Creek, Elk Creek, and Indian Creek drain the southern one-fifth of the county and are tributaries of the Little Osage River which traverses the northern portion of Bourbon County.

Mound City, with a population of 675, is the county seat of Linn County. Other towns in the county include Pleasanton, population 1,219; La Cygne, population 816; Blue Mound, population 339; Prescott, population 307; and Parker, population 180.

The Missouri, Kansas and Texas Railroad extends through the northwestern corner of the county and serves the communities of Parker, Goodrich, Dunlay, Centerville, and Vance, while the St. Louis and San Francisco Railroad serves the communities of La Cygne, Boicourt, Pleasanton, and Prescott.

U. S. Highway 69 traverses the county from south to north, serving the communities of Trading Post, Pleasanton, and Prescott. Kansas Highway K-135 extends from Highway 69 west through La Cygne and junctions with Highway K-7 at a point one mile south of Cadmus. Highway K-7 extends north-south through Cadmus, Farlinville, Mound City, and Mantly. Kansas Highway K-52 extends west from the east county line through Trading Post, thence south through Pleasanton, and then west through Mound City and Blue Mound. Kansas Highway K-31 extends north from the south county line and junctions with Highway K-52 at a point three miles southwest of Mound City, From this point it trends west through Blue Mound and across the west county line. Linn County is served by a moderately well developed system of county roads, most of which have all-weather surfacing. The eastern portion of the county is scarred by strip mines. Most of the mining operations in the county are no longer active due to economic reasons; however, several thousand acres are still leased for mining purposes.

## 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 photographic interpretation on a county wide basis; 3. field reconnaissance survey, and 4. report writing and compilation 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 Linn County geology, geography and construction materials resources was studied. The most important sources of geologic information were the State Geological Survey of Kansas and the Geology Section of the State Highway Commission of Kansas. Aggregate test results and other pertinent information on materials produced in the county were obtained from the Materials Department of the State Highway Commission of Kansas.

### *Phase II* Aerial Photographic Interpretation

Aerial photography of the county was flown by the State Highway Commission of Kansas on March 28, 1963 and February 14, 1964. The scale of the photography is 1:24,000 (1 inch represents 2,000 feet). Figure 2 (Page 6 ), is a photographic coverage map of Linn County.

Initially, the entire county was studied on aerial photographs. During this process, all open material sites, which had been sampled and tested, were located on the aerial photographs and plotted on a

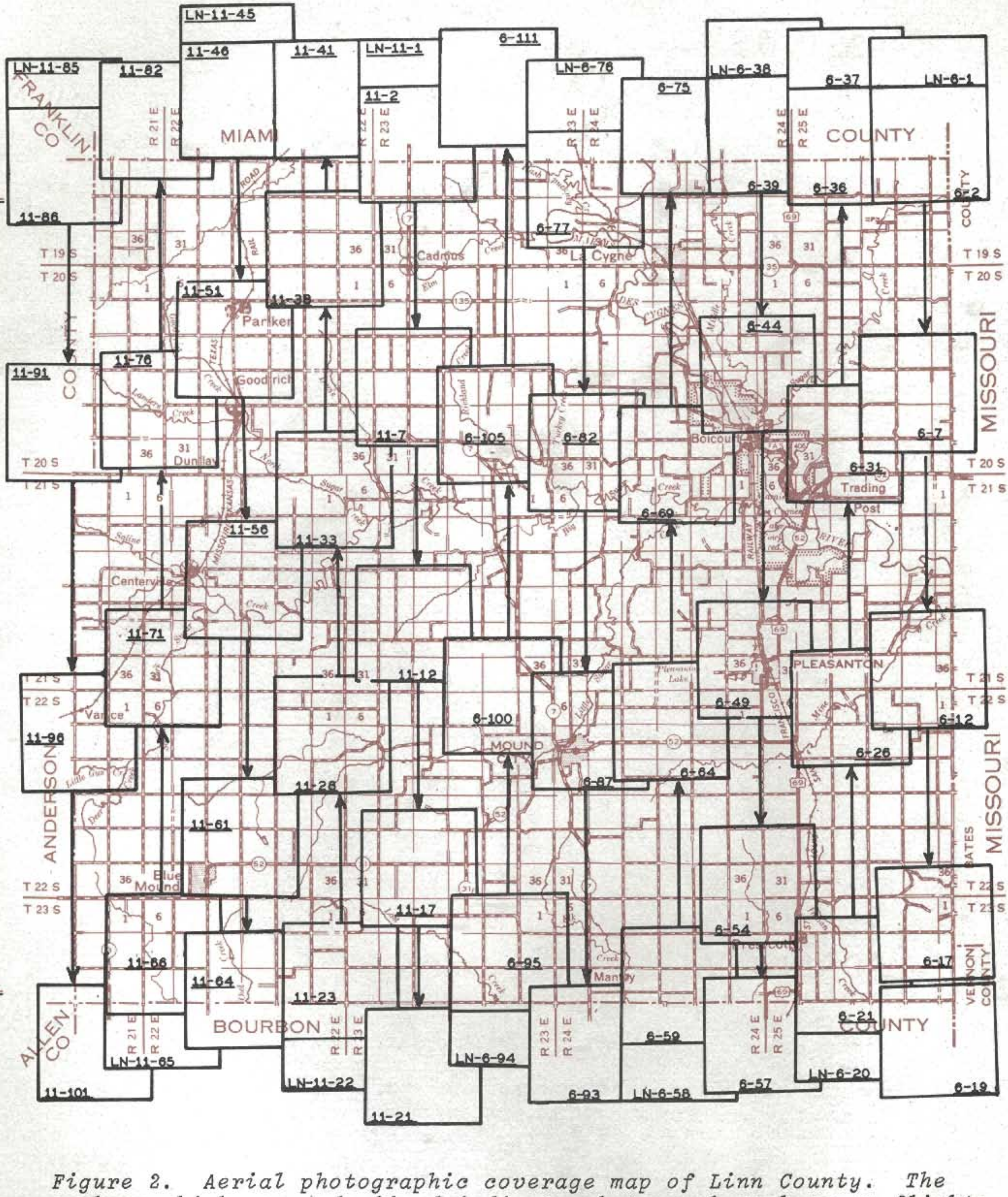


*Figure 2. Aerial photographic coverage map of Linn County. The numbers which are underlined indicate photograph numbers on flights taken by the Photogrammetry Section, State Highway Commission of Kansas, on March 28, 1963 and February 14, 1964 at a scale of 1:24,000. Aerial photographs are on file in the Photogrammetry Laboratory, State Office Building, Topeka, Kansas.*

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 photographs were mapped and classified. Figure 3 illustrates this procedure.

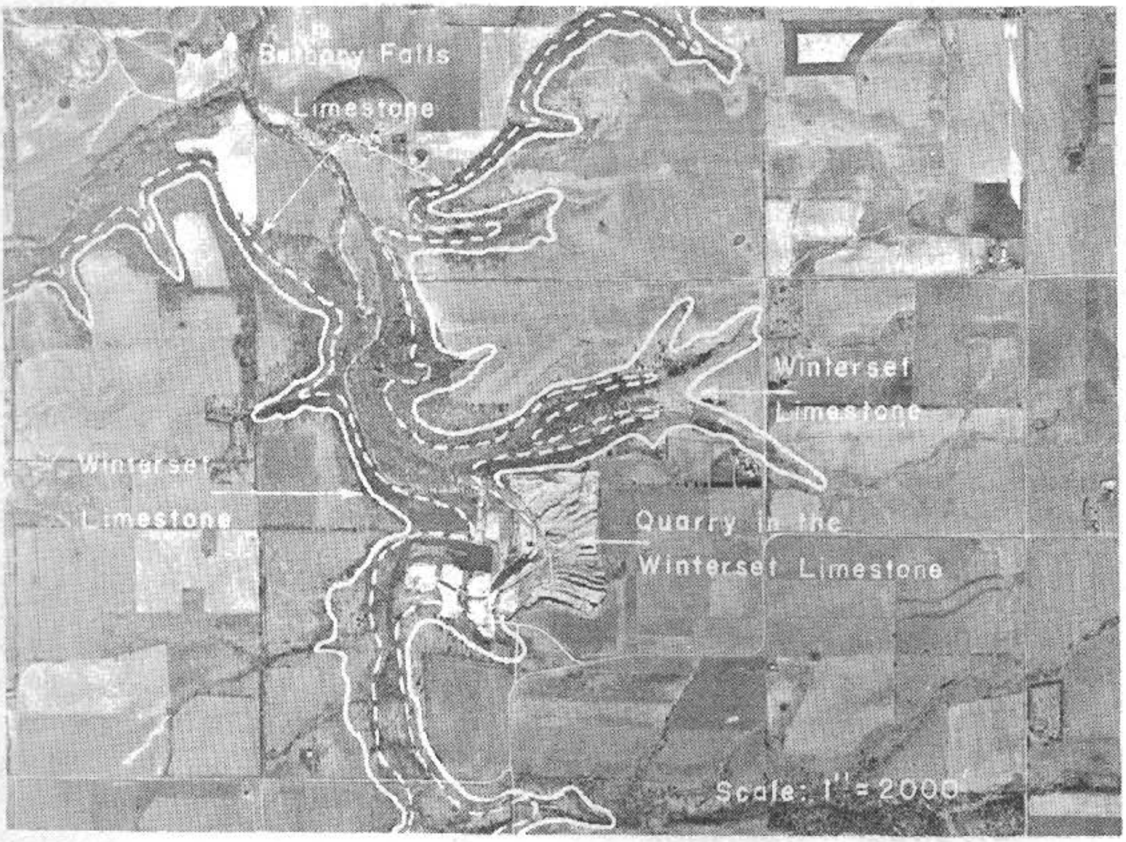


*Figure 3. A portion of an aerial photograph taken over west-central Linn County showing a quarry producing from the Winterset Limestone along with the outcrop pattern of the Winterset and underlying Bethany Falls Limestone in the area.*

Figure 3 shows a quarry which produces limestone from the Winterset Limestone Member of the Dennis Limestone Formation. When viewed stereoscopically, the outcrop of the Winterset can be recognized by a distinct break in the terrain. The underlying Bethany Falls Limestone Member of the Swope Limestone Formation is separated from the Winterset in this area by approximately ten feet of shale.

The exposure of this unit is marked by a band of lush vegetation which is a result of the discharge of ground-water from the base of this thick limestone. In this area the outcrop pattern of the Bethany Falls nearly parallels that of the Winterset.

*Phase III* Field Reconnaissance

Field reconnaissance was necessary in this matèrials investigation to verify situations which were doubtful in the mind of the interpreter. One trip was conducted early in the investigation to inspect the materials in the open pits and to further acquaint the photo interpreter with the geology of the county. A second survey was conducted when the photographic study was completed to check the accuracy of the interpretation and mapping procedures.

*Phase IV* Map Compilation and Report Writing

The final stage of the investigation involved the correlation of information extracted from aerial photographs with previously known data, preparation of the report, completing of site data forms, and production of the county construction materials map.

The Linn County materials map was divided into six sections, approximately equal in area (Plates I through VI). The map units representing material source beds are based primarily on geologic age. In general, the engineering characteristics of material, laid down during each cycle of deposition, are fairly consistent throughout the county. For example, aggregate produced from various quarries in the Winterset Limestone is fairly uniform in quality, but it has different properties than material produced from the Laberdie Limestone, which represents an earlier depositional cycle.

All existing pits and quarries are identified on the county materials map by appropriate designations and symbols. The site symbols indicate whether the site has been tested or not. The site designation will convey to the reader the type of material which can be found at the location, the estimated quantity of material, the number of the corresponding data form for that site, and the geologic name assigned to the source bed. The map legend associated with each plate also explains all letter and map symbols used in the site designations.

To furnish the user of the report with all available information, a site data form was compiled for each materials site shown on the materials map. The site data forms are included in this report as appendices I and II. Appendix I contains forms for all sites depicted on the materials map that are open, but which have not been sampled by the State Highway Commission of Kansas. Appendix II contains data forms for all open materials sites for which test information is available. Test results are presented on each site data form in this appendix. Geologic information is presented on each of the data forms to facilitate future correlation. Each form includes a sketch which shows the major cultural and natural features of the immediate area to help locate the materials site in the field. The name and address of each landowner, supplied by the Linn County Register of Deeds, is presented on the site data forms to expedite future field investigations.

The text of the report was completed by presenting the geologic history of the county as it pertained to the various material source beds, a general description of the available material, and a general description of the geologic units which in the past have displayed unsound engineering properties.

## CONSTRUCTION MATERIALS RESOURCES OF LINN COUNTY

### Geologic History of Linn County

This section of the report is included to provide the layman with a general knowledge of the geologic history of Linn County. This information, though admittedly general, will familiarize the reader with the sequence of events responsible for the deposition of the construction materials source beds that are found in the county.

Figure 4 (Page 11), is a geologic timetable reproduced with permission of the State Geological Survey of Kansas. One should note that according to this timetable the earth has existed for more than two billion years. It should also be noted that each geologic period (a division of geologic time), with the exception of the Quaternary, exceeds one million years in length.

The reader should realize that in the past, mountain ranges have been born, eroded down, and raised again. Seas have advanced over the land leaving layers of sand, mud, and lime carbonate, which over the years have been transformed into sandstone, shale, and limestone. None of these events occurred suddenly or miraculously, but they were the result of geologic agents (wind, water, and diastrophism) which are active in the world today.

The geologic history of this area, as it is discussed here, is based primarily on reports by Frye and Leonard (1952) and Merriam (1963).

The earliest record of the geologic history of Linn County is the erosional surface of Pre-Cambrian rocks which underlie Paleozoic sediments. It is believed that the Pre-Cambrian surface is composed chiefly of metamorphic and igneous rocks whose origin has not been accurately determined.

| 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*

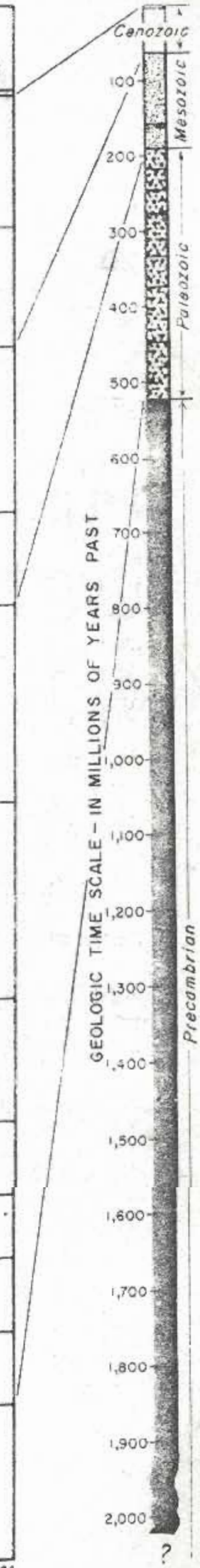


*Figure 4. Geologic timetable*

During the Cambrian Period this area was submerged below sea level and sediments consisting mostly of dolomite with minor amounts of sandstone were laid down. These sediments are represented in the subsurface of Linn County by the Arbuckle Group which is considered to be Cambrian and early Ordovician in age.

Erosion has removed any sediments from Linn County which may have been deposited in late Ordovician, Silurian, and Devonian time; therefore, no historical record exists for those periods. From evidence found in other parts of Kansas, it is believed that this area was alternately submerged and elevated during these periods.

Limestone of Mississippian age, found in the subsurface, is evidence that a prolonged cycle of submergence occurred during this period. Near the end of the Mississippian, this area was uplifted and subjected to erosion. This erosional cycle, which continued into the Pennsylvanian Period, stripped away varying amounts of Mississippian rocks.

During the Pennsylvanian Period, the sea invaded this area and covered the Mississippian erosional surface. Deposition of marine shale and limestone predominated in this sea; however, the presence of coal and sandstone deposits indicate that the area was periodically elevated above sea level. These periods of emergence are also demonstrated by the absence of some geologic units from local areas. The absence of these geologic units may result from either non-deposition or erosion which occurred after they were deposited and prior to the deposition of overlying beds. The Pennsylvanian rocks in this entire section of Kansas are frequently characterized by facies changes and by radical variations in thickness. These characteristics indicate that a highly variable depositional environment prevailed even during cycles of marine deposition. Various units present in one part of the county are absent from the geologic section in other parts, and the thickness of some of the units varies from a few inches at one exposure to several feet at another.

No deposits of Permian, Triassic, Jurassic, Cretaceous, or Tertiary age are found in this section of Kansas. If any sediments were laid down in this region during any of these periods, they have been removed by subsequent erosion.

The Quaternary Period represents a time of repeated glacial and interglacial cycles in North America. Glacial activity in Kansas was restricted to the extreme northeastern corner of the state; however, the sequence of glaciation, which occurred during this time, has played a controlling role in the development of Quaternary nomenclature. Figure 5 (Page 14), is a geologic timetable which shows the divisions of the Quaternary Period and the approximate length of each. The glacial ages (Nebraskan, Kansan, Illinoisan, and Wisconsinan) represent the advance of the glaciers, while the three interglacial ages (Aftonian, Yarmouthian and Sangamonian) represent periods of major glacial recession. The Recent Age represents the time which has elapsed since the last retreat of the Wisconsinan glacier.

According to Frye and Leonard (1952), the ancestral Marais des Cygnes River had established a course nearly parallel to that of the present day river by the time the Nebraskan glacier began to retreat. It is assumed that the river was downcutting during this time; however, the presence of one small gravel deposit in Linn County, which is thought to be Nebraskan in age, indicates that some deposition may have occurred. This deposit, consisting of round and sub-

| 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*

rounded coarse and medium chert gravel, is located approximately 100 feet above the present flood plain.

During Kansan time the Marais des Cygnes River established its present course and continued to degrade its channel. It is evident that this erosional process was interrupted by a depositional cycle because deposits found along the Marais des Cygnes in Linn County have been classified as Kansan in age. These deposits, composed of brown chert gravel imbedded in a matrix of red clay, are found approximately 40 to 50 feet above the present flood plain. The topographic position of these deposits indicate that the river degraded its channel in Linn County by as much as 60 feet between Nebraskan time and the end of Kansan time. It is probable that the Kansan deposits found today are

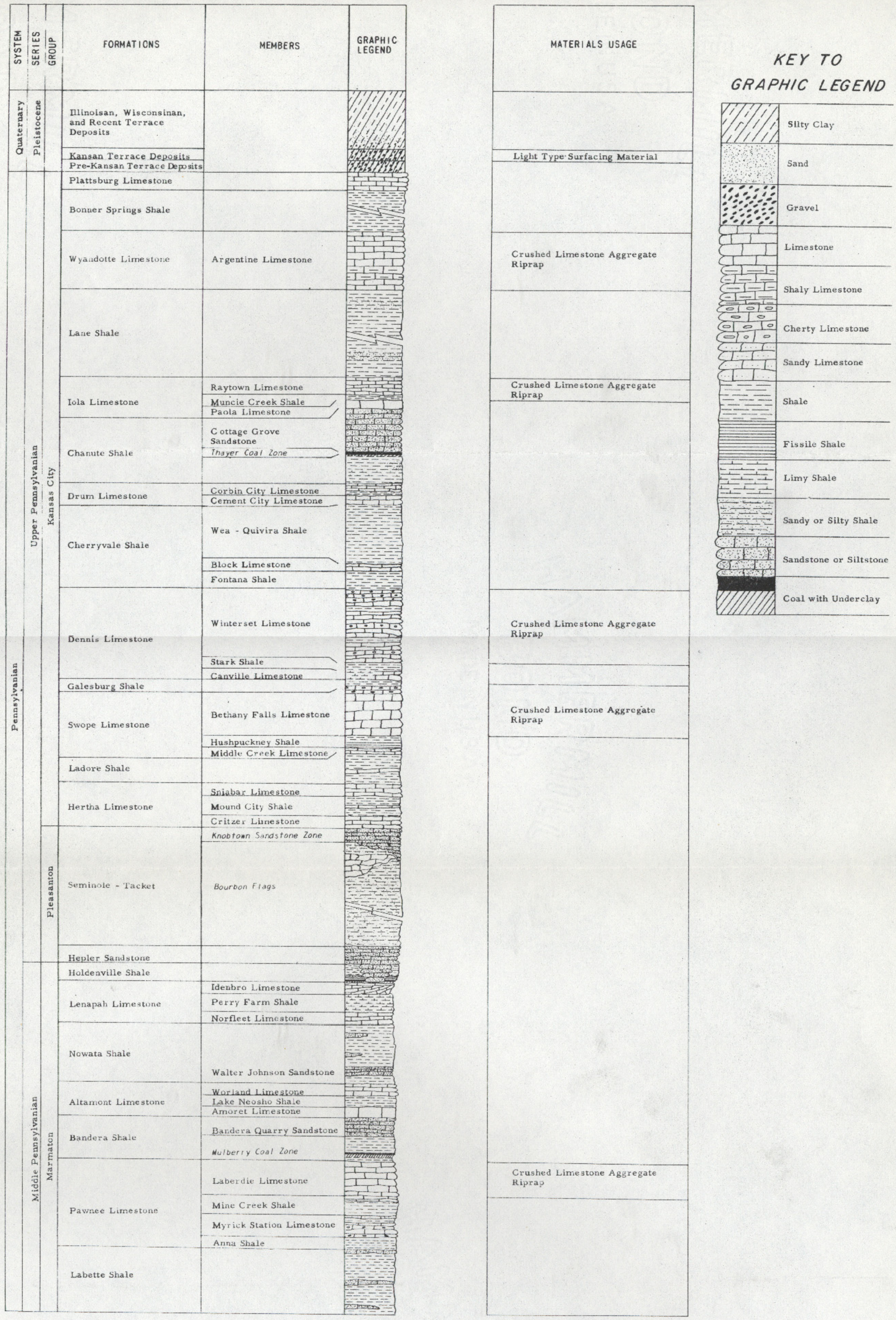


*Figure 6. Generalized geologic column of the surface geology of Linn County.*

nothing but remnants of a widespread terrace, most of which has been removed by erosion. In this report, and on the county materials maps, they are referred to as Kansan terrace deposits.

The Illinoisan Stage was marked by another cycle of erosion and deposition along the major drainage channels in Linn County. In all the major stream valleys, the top of Illinoisan terraces are from 10 to 30 feet above the present flood plain. These deposits are composed of locally derived chert and limestone gravel at their base and grade upward into fine sand, silt, and clay.

The Marais des Cygnes and other streams in Linn County continued to degrade their channels after the deposition of the Illinoisan age deposits. This period of erosion came to a close in Wisconsinan time and deposition became the dominant geologic process. During this cycle of deposition, which still prevails today, the present flood plains of the major streams have been developed. They are underlain by as much as 50 feet of locally derived chert and limestone gravel, fine sand, silt, and clay. Deposits of this material, along with those laid down in Illinoisan time, are shown on the county materials maps as Illinoisan, Wisconsinan, and Recent Terrace Deposits.

## Construction Materials Inventory

This section of the report inventories the construction materials resources of Linn County. Inasmuch as limestone suitable for the production of construction material is abundant in the county, only geologic units which can be economically utilized for this purpose in the foreseeable future are included in this inventory. Figure 6 (Page 15) is a generalized geologic column of the surface geology of Linn County which shows the relative stratigraphic position of each source bed. The county materials map, which is divided into six equal portions (Plates I through VI), shows the geographic locations where construction material source beds are exposed or near the surface.

A tabulation of the various types of material available in Linn County is shown in Figure 7. The source beds from which each type of material can be produced are listed along with the page number where the engineering properties of each of these material source beds are described.

| Material Type | Geologic Source | Description | Locality where available |
|---|---|---|---|
| Limestone | Laberdie Limestone | Page 19 | Southeastern portion of the county. |
| | Bethany Falls Limestone | Page 23 | Eastern 2/3 of the county. |
| | Winterset Limestone | Page 24 | Western 2/3 of the county. |
| | Raytown Limestone | Page 25 | Extreme west-central and northwestern portion of the county. |
| | Argentine Limestone | Page 27 | Extreme northwestern corner of the county. |
| Chert Gravel | Kansan Terrace Deposits | Page 28 | East-central part of the county. |

*Figure 7. A recapitulation of the construction material types and their availability in Linn County.*

Although numerous geologic units of Pennsylvanian age are exposed in Linn County, only five limestones are considered to be source beds for construction materials. Quaternary deposits of Kansan, Illinoisan, Wisconsinan, and Recent Age are shown on the materials map; however, the Kansan deposits are the only ones significant as materials sources. The Illinoisan, Wisconsinan, and Recent deposits are included on the materials map to delineate the flood plain of the major drainage.

Figure 8 (Page 20), tabulates the results of quality tests performed on samples taken from the Laberdie, Bethany Falls, Winterset, and Argentine Limestone Members. At the time of this report, no quality information was available on the Raytown Member in Linn County. The tabulation indicates a fairly uniform quality from the tested sites; however, note was taken during the investigation that a facies change does occur in some of the units, and the quality may change from place to place. The five limestone source beds generally remain the same thickness, with the exception of the Argentine which exhibits an extreme variation from north to south over a short horizontal distance.

The following discussion describes the engineering characteristics of each of the five limestone units and of the Kansas Terrace Deposits.

## Pennsylvanian System

### *Laberdie Limestone Member, Pawnee Limestone Formation*

The oldest geological unit, significant as a materials source which is exposed in Linn County, is the Laberdie Limestone Member. This unit, which ranges in thickness from six to eight feet, is a light gray, wavy-bedded limestone which breaks into slabs when weathered. Some natural oil saturation sometimes occurs at the base of the Laberdie.

Field evidence indicates that the Laberdie Limestone has a more exaggerated dip in a somewhat differing direction from the normal northwest regional dip. For example, this unit is exposed in the ditch along highway K-239 near the west Prescott city limits where it has an elevation of 880 feet, and again, approximately one mile away at the junction of Highways US-69 and K-239 where its elevation is 820

| Location | Type and thickness of material quarried | Specific Gravity (Saturated) | Specific Gravity (Dry) | Los Angeles Wear-% (Grade B) | Absorption-% | Soundness Loss Ratio | Remarks |
|---|---|---|---|---|---|---|---|
| Source of material: Winterset Limestone Member, Dennis Limestone Formation | | | | | | | |
| SW¼ sec. 25, T21S, R22E | 20'+ Limestone | 2.53 | 2.46 | 34.6 | 3.29 | 0.98 | Average of 4 samples |
| SE¼ sec. 28, T21S, R21E | 12' Limestone | 2.54 | 2.46 | 39.7 | 3.31 | 2.97 | 1 sample |
| NE¼ sec. 13, T21S, R21E | 12' Limestone | 2.55 | 2.46 | 35.9 | 2.60 | 0.98 | 1 sample |
| Source of material: Argentine Limestone Member, Wyandotte Limestone Formation | | | | | | | |
| SW¼ sec. 23, T19S, R21E | 28' Limestone | 2.60 | 2.51 | 31.8 | 3.04 | 0.98 | Average of 3 samples |
| Source of material: Bethany Falls Limestone Member, Swope Limestone Formation | | | | | | | |
| NW¼ sec. 19, T22S, R24E | 14' Limestone | 2.53 | 2.46 | 32.1 | 2.82 | 0.96 | Average of 3 samples |
| SE¼ sec. 36, T19S, R24E | 12' Limestone | 2.59 | 2.55 | 30.3 | 1.82 | 0.98 | Average of 2 samples |
| SE¼ sec. 30, T19S, R25E | 8' Limestone | 2.62 | 2.58 | 26.1 | 1.68 | 0.99 | 1 sample |
| NE¼ sec. 25, T22S, R24E | 12' Limestone | 2.56 | 2.51 | 35.7 | 2.10 | 0.99 | Average of 2 samples |
| Source of material: Laberdie Limestone Member, Pawnee Limestone Formation | | | | | | | |
| SW¼ sec. 11, T23S, R25E | 10' Limestone | 2.52 | 2.47 | 27.3 | 2.10 | 0.97 | 1 sample |

*Figure 8. Results of tests completed on samples taken from the Winterset Limestone, Argentine Limestone, Bethany Falls Limestone and Laberdie Limestone.*

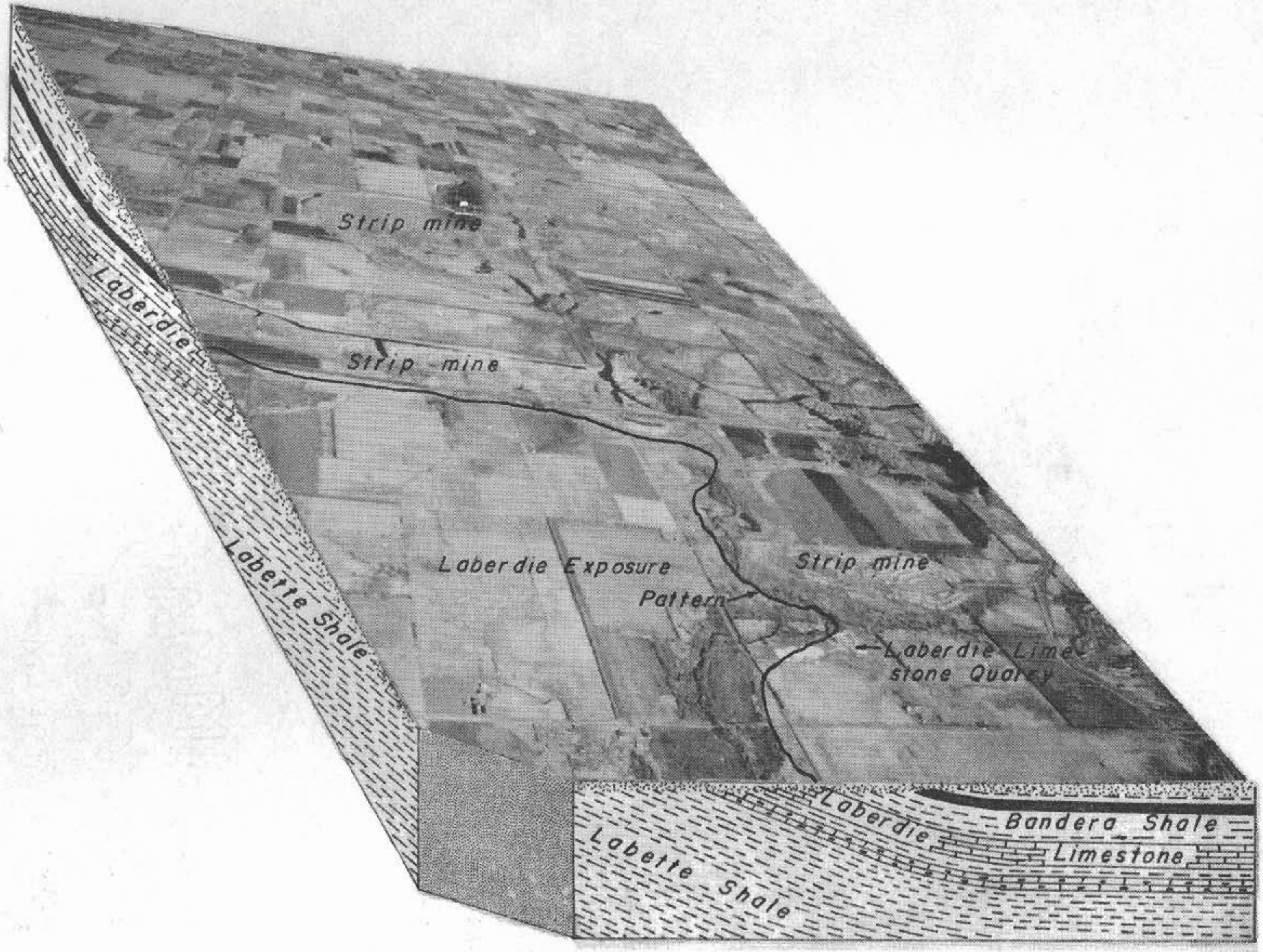


*Figure 9. Block diagram illustrating the subsurface structure typical of the Laberdie Limestone Member and associated beds in southeastern Linn County.*

feet. This means that the unit dips about 60 feet in one mile; however, a more severe dip is encountered at some locations within this area.

The distorted bedding of the Laberdie is also evidenced in some of the strip coal mines in this area. Inasmuch as the shale interval between the Laberdie and the overlying Mulberry coal zone has a consistent thickness, the structural features of the limestone and coal are very similar. In some of the mines the coal dips as much as 15 degrees indicating that the underlying limestone is also dipping very rapidly. Figure 9 (Page 21), illustrates this relationship. Because of this erratic structure, the amount of overburden encountered at a quarry site may vary a great deal.

Because exposures of the Laberdie are limited to the extreme southeastern portion of the county, the Laberdie has not been extensively used as a source of construction material. In Linn County only one Laberdie Limestone quarry was found to have produced material recently (Figure 10).

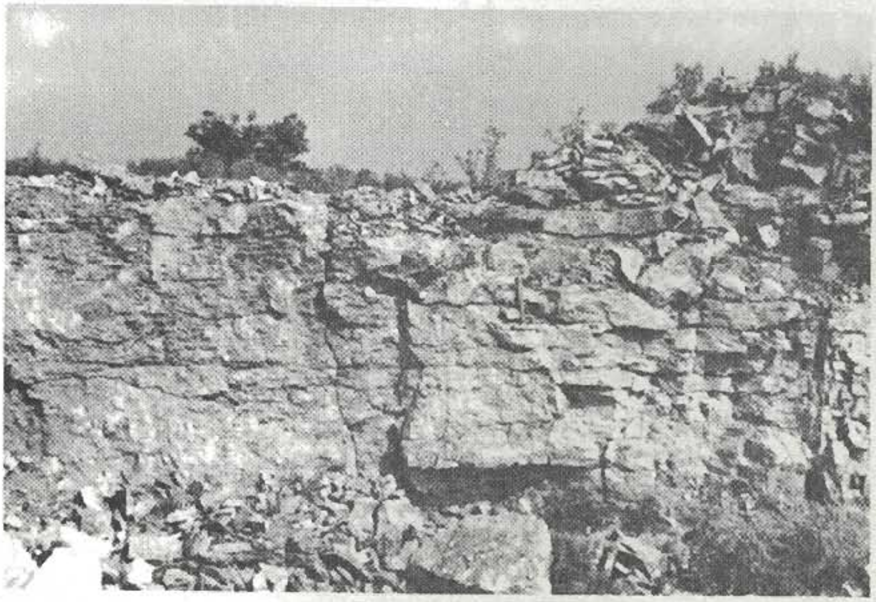

*Figure 10. Face of an open quarry in the Laberdie Limestone, SW¼ sec. 11, T23S, R25E.*

Figure 8 (Page 20), shows the results of tests completed on samples taken from this quarry. The results of these tests indicate that a good quality material, which would meet aggregate specifications for most phases of road construction, can be produced from this unit in Linn County.

*Bethany Falls Limestone Member, Swope Limestone Formation*

The Bethany Falls Limestone Member is a light gray, massive, fine-textured limestone which has a consistent thickness of about 15 feet. Exposures of this member are extensive over the eastern two-thirds of Linn County with the exception of the southeastern corner. Figure 11 illustrates some typical Bethany Falls Limestone in an abandoned quarry.

*Figure 11. Face of an open quarry in the Bethany Falls Limestone, NE¼ sec.28, T20S, R24E.*

Figure 8 (Page 20) shows the results of quality tests performed on samples of limestone taken from several Bethany Falls Limestone quarries in Linn County. These tests indicate the limestone has good quality and would probably meet specifications for most phases of road construction. The wide exposure area of the unit, adequate thickness, and good quality are merits which make the Bethany Falls Limestone one of the most important sources of construction material in Linn County.

*Winterset Limestone Member, Dennis Limestone Formation*

The Winterset Limestone Member is a gray, wavy-bedded, cherty limestone which, locally, may have thin shale partings. A cross-bedded, oolitic character was noted in some exposures in Linn County. The total thickness of the unit in the county ranges from 30 to 40 feet; however, in the exposure area, the total thickness can seldom be found because erosion has removed varying amounts of the limestone. Figure 12 illustrates a quarry face of about 20 feet in the Winterset Limestone.

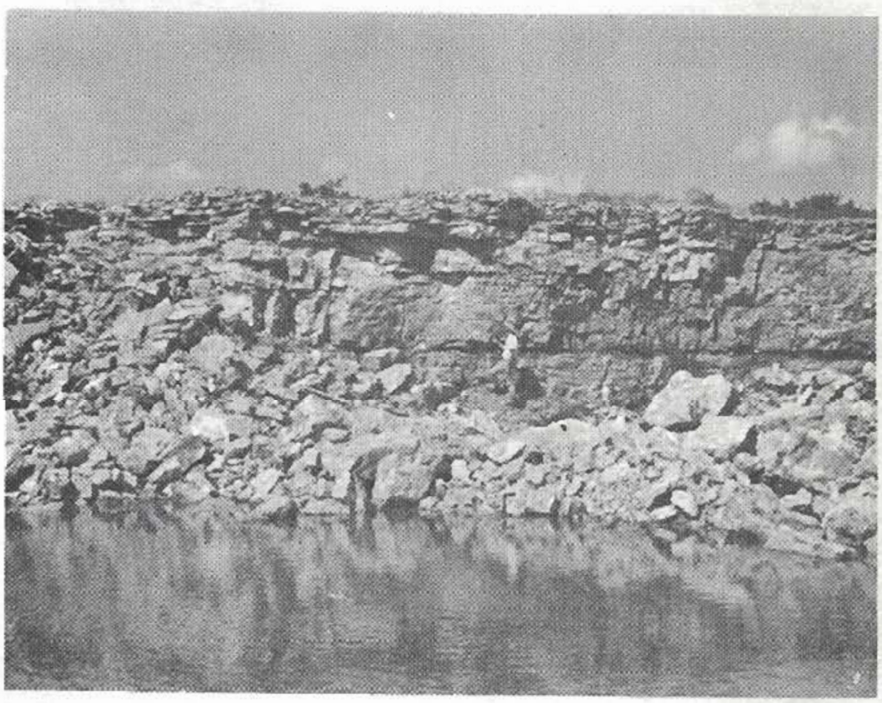

*Figure 12. Face of an open quarry in the Winterset Limestone, SW¼SE¼ sec.28, T20S, R22E.*

This limestone is exposed or near the surface in much of the western two-thirds of Linn County. At some locations, both the Winterset Limestone and the Bethany Falls Limestone, which lies a few feet below, are exposed on the same hillside. The Murray Quarry, located near Centerville, has obtained material from the Winterset, but has the underlying Bethany Falls Limestone as a reserve material source bed.

Figure 8 (Page 20), shows the results of tests performed on samples taken from several Winterset Limestone quarries in Linn County. These tests indicate that limestone from this source is of good quality. The thin shale partings sometimes found in the unit may lower the quality and make the material unsuitable for use in some phases of road construction; however, if proper precautions are taken to prevent contamination from the shale zones, a material of good quality can be anticipated.

*Raytown Limestone Member, Iola Limestone Formation*

The Raytown Limestone Member in Linn County is a light gray, fine to medium-textured limestone which has a thin bedded, flaggy appearance, especially where weathered. Figure 13 (Page 26), is a photograph taken in an old, abandoned Raytown Limestone quarry, illustrating the typical bedding of the unit in Linn County. Exposures of this unit are found in the extreme west-central and northwest part of Linn County. Because this unit weathers in such a manner that it does not leave a prominent escarpment, it is difficult to find good exposures of the limestone within the county. At most of the sites visited during this investigation, the Raytown appeared to be too thin to quarry; however, information obtained from the State Geological Survey of Kansas indicates that the unit ranges from five to

13 feet in thickness where it has been protected from weathering by overlying material. In view of this fact, it will be necessary to locate quarrying operations in areas where some consolidated overburden is present in order to obtain good quality rock. When prospecting for a quarry site in the Raytown, one should look slightly upslope from the dashed line indicating the outer limit of the exposure (Plates I and III). Such a procedure might accentuate finding the Raytown with some overburden but with sufficient thickness to make production feasible.

There is a small abandoned Raytown quarry in the SE¼ sec.28, T20S, R21E. (Figure 13). No material is currently being produced from this unit because thicker limestone, which can be quarried more economically, is available in this part of the county. Inasmuch as no materials have been produced recently from the Raytown in Linn County, no quality test results are available for this unit.

*Figure 13. Face of an abandoned quarry in the Raytown Limestone, SE¼ sec.24, T20S, R21E.*

*Argentine Limestone Member, Wyandotte Limestone Formation*

In Linn County, the Argentine Limestone Member probably exhibits the greatest variation in thickness and lithology of all the producing materials beds. In the extreme northwest corner of the county, where the limestone is best exposed, it is a light gray, wavy-bedded, fine grained limestone with numerous secondary calcite vein fillings. The Argentine has a thickness of approximately 35 feet in this area, but thins rapidly to the south. Near Parker, approximately four miles south of the north county line, the unit is about 2.5 feet thick. South of Parker, in the exposure area of the unit, the thickness varies from two to three feet and the lithology grades to a dark blue-gray limestone.

One limestone quarry (Giles Quarry) is producing material from the Argentine in Linn County. The quarry operator reported that about 31 feet of limestone is being quarried at this location. A view of the face of the Giles Quarry is shown in Figure 14.

*Figure 14. Face of an open quarry in the Argentine Limestone, SW¼ sec.23, T19S, R21E.*

The results of quality tests performed on a sample of limestone taken from the Argentine Limestone Member in the county is tabulated in Figure 8 (Page 20). These data indicate that material of good quality, which would meet aggregate specifications for most phases of road construction, can be produced from the Argentine.

Quaternary System

*Kansan Terrace Deposits*

Chert gravel of Kansan Age is found only in the eastern extremity of Linn County on the south side of the Marais des Cygnes River. This gravel is brown in color and is generally bound with a red clay matrix. Deposits of this material ranging in thickness from one to five feet are found about 40 to 50 feet above the present flood plain of the river.

The major percentage of gravel from the Kansan Terrace Deposits ranges from one inch down to one-half inch in diameter. A photograph illustrating the texture of this material is shown in Figure 15.

*Figure 15. A close-up view of Kansan Age chert gravel showing the texture of the material.*

Gravel from the Kansan Terrace Deposits has been used extensively in Linn County for surfacing lightly traveled rural roads; however, no material from this source has been used in bituminous or concrete construction because of the high clay content of these deposits. This clay could be removed by washing the material, but because of the lack of adequate water supplies and the availability of crushed limestone aggregate in this area, it is economically infeasible to process this material for use in highway construction.

## Geo-Engineering

The purpose of this section of the report is to list and briefly describe the geologic units exposed in Linn County which possess certain engineering properties that may affect the stability and (or) maintenance cost of a road. Precautionary measures are included which can be exercised to aid in the construction of good quality roads. This geo-engineering discussion is considered from three points of view: 1. material usage in road construction, 2. hydrology problems in road construction and 3. mineralization of water resources.

### Material Usage Considerations

The usage of material in Linn County is considered from the three following aspects: 1. embankment and subgrade construction, 2. backslope steepness and stabilization and 3. bridge foundation support.

#### *Embankment and Subgrade Construction*

Most of the exposed geologic units in Linn County have been encountered at some time in the construction of highway embankment and subgrade. However, experience has shown that plastic mantle material, clay shales, and coal zones with the accompanying underclay are not recommended for subgrade or shoulder construction due to their shrinkage and swell characteristics. Some plastic material can be used for embankment if properly placed in the middle part; however, consideration must be given to the height of the fill to insure that the shear strength of the material is not exceeded by the weight from above.

In Linn County, caution should be exercised when encountering a soil developed in the stratigraphic section including the Chanute Shale, Drum Limestone, and Cherryvale Shale Formations (See stratigraphic column, Figure 6, Page 15), inasmuch as a thick residual soil often developes which has undesirable plastic properties. The development of the thick soil mantle is probably associated with continual ground-water seepage through certain horizons in this part of the stratigraphic column. Slides sometimes develop on this thick mantle and, thus, may be a problem in road construction. Within the stratigraphic zone just discussed, the Thayer Coal of the Chanute and the Fontana Shale Member of the Cherryvale merit special recognition. When the Thayer Coal and the associated underclay is encountered in road construction, its use should be avoided in the subgrade because of the persistent plastic properties. The Fontana Shale Member *appears to have mineralogical properties which causes* it to lose strength more readily than other shales when subjected to wetting and drying beneath a pavement. This shale should be avoided in the subgrade in both cuts and embankments.

The Mulberry Coal zone, located near the base of the Bandera Shale Formation, is near the surface in the southeast part of the county and has been mined extensively in the past for fuel. Some structure exists in the beds in this area with gently dipping domes and adjacent synclines being prominent. Most mines are located on the dome structure. All the strip mines investigated were filled with water which has resulted, in part, from moisture carried in the coal zone, but surface runoff may have contributed some to the contained water. Material from the coal and underclay zone should be avoided in the subgrade because of its wet plastic nature.

Even though the zones mentioned have presented major problems during subgrade and embankment construction, similar problems may be encountered in other shale units found in Linn County. Thus, precaution should be exercised with any of the Pennsylvanian shales in the various construction projects.

*Backslope Steepness and Stabilization*

The various material types found on a road construction project will require varying backslope angles for stabilization purposes. The degree of weathering to which the consolidated units have been subjected is of prime importance when the backslope angle is being determined. Normally, the mantle material is set on slopes not steeper than 3:1 and most are set on 4:1 and seeded. Slopes steeper than 3:1 may cause a problem in maintenance because of water erosion.

Geologic data obtained on previous projects indicate that nearly all the limestones are placed on a 1/4:1 slope. However, a gentler slope is not uncommon if the stability of the limestone is questionable. For example, a shaly limestone zone may be placed on a 1/2:1 or flatter slope.

The backslope angle in shale units will vary depending upon their composition and the degree to which they have been weathered. Sometimes the composition of a shale unit will vary considerably within a relatively short horizontal distance. For example, a shale to sandstone facies change is observed in the Pleasanton Group in many areas. The shales, if weathered, will generally be set on a 3:1 or 4:1 slope and if unweathered, on a 1:1 or 2:1 slope. The Fontana Shale probably should not be set on slopes steeper than 3:1 regardless of its weathered state because of its tendency to lose strength readily.

Sandstone beds, such as the Hepler, will probably be set on a 1:1 or 2:1 slope. If the sandstone bed is poorly consolidated, a more gentle backslope may be desirable.

When alternating beds of limestone and shale exist in the backslope, benching at the base of the limestones may be desirable for stability purposes. Such benches will support some vegetation on top of the shale surface, catch spalled off material, and prevent undercutting and eventual slumping of the outer edge of the limestone units. Benching is more costly than normal backslope construction inasmuch as additional right-of-way is needed, and the construction operation is somewhat more costly, but less maintenance may be required in the long run by having the benches.

*Bridge Foundation Support*

It is probable that nearly all the major bridges in Linn County will be supported by bedrock units. Although the major drainage contains considerable unconsolidated material, the thickness and strength of this mantle is not great enough to warrant the use of frictional type pile for the footing.

The limestones and sandstones should give adequate support in both spread and pile type situations. If piling is used, adequate bearing should be obtained with very little penetration in these units.

However, some precaution should be exercised in sandstones of the Pleasanton Group inasmuch as they have exhibited poor cementation in some exposure areas. Such poorly cemented sandstone could be vulnerable to scour in spread footing situations and on driven supports, it could allow some pile penetration.

The major bridge support problems in Linn County will be associated with the soft weathered shales and coal zones. Weathering of shale near the top of the unit to a soft condition is prominent in alternate beds of limestone and shale inasmuch as water will penetrate through cracks and solution channels in limestone and move along the top of the impervious shale. However, some weathering may be found at the base of a shale unit in some instances. Caution should be exercised when planning a spread footing type bridge support in shale to insure that stable unweathered material is available to provide the foundation. In piling situations, some penetration can be expected in weathered shale but unweathered shale should provide adequate bearing with limited penetration. When planning a shale support, soundings should penetrate below a stable shale zone to insure against a soft material underneath. Because of plastic properties inherent to the Fontana Shale, it should be avoided if possible, as a bridge foundation material.

Coal zones, such as the Thayer and Mulberry, carry extensive water and are generally underlain by a soft underclay. Bridge supports should not be set in this coal zone or underclay. Because of the unstable condition of the coal zone, consideration should be given to a support set a short distance above this horizon.

Hydrology Problems in Road Construction

As indicated on the geologic column in Figure 6 (Page 15), the rock stratification in Linn County is characterized by alternating beds of limestone, shale, and some sandstone. Some of the shale units contain zones of sandstone and coal. Also, varying gradations of limy shale, shaly limestone, sandy shale, and sandy limestone are common. In an area of high annual precipitation (such as Linn County), alternating types of geological formations, such as sandstone and shale, have inherent properties which may cause ground-water problems in road construction. Any porous material underlain by an impervious material may contribute to ground-water problems, and certain beds have been observed as troublesome zones in Linn County by geologists employed by the State Highway Commission of Kansas.

Ground-water problems in the following units have required special attention in Linn County: 1. the base of the Myrick Station Limestone Member and the top of the Anna Shale Member, 2. a limy zone in the Mine Creek Shale Member, 3. the Mulberry Coal Zone of the Bandera Shale Formation, 4. the sandstone zones in the Nowata Shale Formation, 5. the sandstone and limestone zones of the Pleasanton Group, 6. the base of the Critzer Limestone Member and the top of the Pleasanton Group, 7. the base of the Sniabar Limestone Member and the top of the Mound City Shale Member, 8. the base of the Middle Creek Limestone Member and the top of the Ladore Shale Member, 9. the base of the Bethany Falls Limestone Member and the top of the Hushpuckney Shale Member, 10. the base of the Winterset Limestone Member and the top of the Stark Shale Member and 11. the Thayer Coal and sandstone zones of the Chanute Shale Formation. Because of the extensive exposure area of the Bethany Falls and Winterset Limestone Members in Linn County, a large number of hydrology problems are associated with these units. The structural domes and adjacent synclines along with thickening and thinning of beds in the county may eliminate ground-water problems in some instances or substantially intensify the problems in other cases.

As previously mentioned, a considerable amount of ground-water is associated with the coal zones. Extensive mined out areas in southeastern Linn County (abandoned Mulberry Coal Mines) merit some consideration as potential ground-water problems. Both abandoned strip mines and shaft mines are found in the area with the strip mines being more prevalent. Because all strip mines investigated contained water along with highly plastic shale waste, they should be avoided in road construction. However, these pits can not always be by-passed. In such instances, special treatment of the area to be crossed by the road can produce a stable subgrade. Shaft mines are few in this county with only small areas being mined out underground, but precaution should be exercised if a proposed roadway is to come near or cross one of these mines because of the possibility of cave-in.

If a road construction project is proposed, a geologic field check should be made to ascertain if any water-carrying zones will be encountered along the proposed alignment. If troublesome conditions are found to exist, some of the following courses of action should be taken to prevent road failure due to water being induced into the subgrade: 1. construct special ditches to intercept water-carrying zones and drain ground-water away, 2. construct underdrains beneath the roadbed to intercept the water before it can enter the subgrade and cause damage to the roadbed and 3. adjust proposed alignments and grades to avoid areas where troublesome ground-water situations exist.

Mineralization of the Water Resources

According to ground-water information on Linn County obtained from William Seevers (State Geological Survey of Kansas), water from some sources in the county has a high chloride and (or) sulfate ion concentration. Therefore, caution should be exercised when selecting a source of water for use in concrete mixes.

The alluvial deposits in the valleys of the Marais des Cygnes River and its larger tributaries are the best source of ground-water in Linn County. Except for some isolated locations where this source may be contaminated by oil field brine, fairly large quantities of good quality water can usually be produced from such deposits.

Some wells in Linn County obtain small quantities of water from the various bedrock units. In general, wells with depths of more than 100 feet produce water which has a high chloride content. A high sulfate content can be anticipated in wells producing from black shales or coal zones. Inasmuch as water from bedrock units may contain high concentrations of chlorides and sulfates, it should be chemically analyzed before being approved for use as mixing water in concrete.

Abandoned strip mines in the southeastern portion of the county contain water which may have high sulfate concentrations. If a mine is filled primarily with water derived from the Mulberry Coal zone, the sulfate concentration will probably be high; however, if most of the water in the mine is the result of surface drainage, the mineral content may be relatively low. Due to the possibility of sulfate contamination, water from these pits should be analyzed before being used in concrete.

## GLOSSARY OF SIGNIFICANT TERMS

Absorption: Determined by tests performed in accordance with AASHO (American Association of State Highway Officials) designation T 85.

Alluvial deposits: Deposits of clay, silt, sand or gravel which have been laid down by running water.

Bedding: A characteristic of some rock units which shows distinct and successive layers or strata due to the manner in which it was formed.

Dolomite: Rocks composed largely of calcium magnesium carbonate, $CaMg(CO_3)_2$.

Facies change: Lateral change in the physical properties of a given bed as a result of a gradual change in its depositional environment and (or) parent material. For example, a shale unit may grade into a sandstone and still maintain its relative stratigraphic position.

Geologic structure: The attitude of the rock units (i.e. whether they are horizontal or tilted).

Geologic unit: This term is used in this report to denote (1) a geologic formation, (2) a geologic member or (3) an unconsolidated deposit of Pleistocene age.

Ground-water: Water in the zone of saturation (i.e. below the water table). In a more general and popular sense, any water that is standing in or passing through the ground is called "ground-water."

Igneous rocks: Rocks produced under conditions involving great heat, as rocks crystallized from molten material.

Light type surfacing: A surface course constructed from aggregate which is not bound by water, cement, or bituminous material.

Liquid limit: Determined by tests performed in accordance with Section Y1-18 of the State Highway Commission of Kansas Standard Specifications, 1966 edition.

Los Angeles wear: Determined by tests performed in accordance with AASHO designation T 96 as modified by Section Y1-14 of the State Highway Commission of Kansas Standard Specifications, 1966 edition.

Material source bed: A particular geologic unit, consolidated or unconsolidated, that provides material for construction purposes.

Matrix: The earthly material which binds or encloses sand or gravel particles at their place of deposition.

Metamorphic rocks: Rocks which have been crystallized or otherwise altered by intense heat.

Open materials site: A pit or quarry which has produced or is producing material suitable for construction purposes.

Plastic index: Determined by tests performed in accordance with Section Y1-18 of the State Highway Commission of Kansas Standard Specifications, 1966 edition.

Oolitic limestone: Limestone composed of minute rounded concretions resembling fish roe.

Soundness: Determined by tests performed in accordance with Section Y1-15 of the State Highway Commission of Kansas Standard Specifications, 1966 edition.

Specific gravity: Determined by tests performed in accordance with AASHO designation T 84 for sand and gravel and AASHO T 85 for crushed stone.

Stratigraphic position: The vertical position of a geologic unit in relation to other geologic units.

Terrace: A plain built up by the deposition of sediments by water.

Unconsolidated deposits: Deposits of clay, silt, sand or gravel. These deposits may be laid down by either wind or water action.

Wash: (Material passing the No. 200 sieve) Determined by tests performed in accordance with AASHO designation T 11.

Weight per cubic foot: Determined by tests performed in accordance with AASHO designation T 19.

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