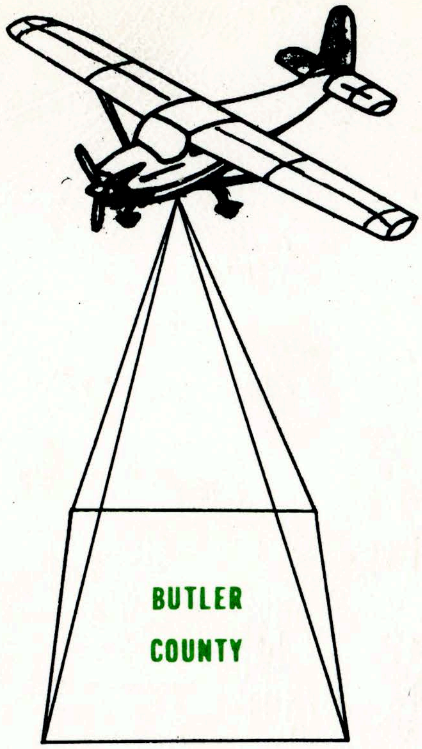

BUTLER COUNTY

MATERIALS INVENTORY

PREPARED BY THE
STATE HIGHWAY COMMISSION OF KANSAS
LOCATION AND DESIGN CONCEPTS DEPARTMENT
IN COOPERATION WITH THE
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

State Highway Commission of Kansas
Location and Design Concepts Department -
Planning and Development Department

MATERIALS INVENTORY OF BUTLER COUNTY, KANSAS

by

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Assisted by
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Photo Interpretation Section

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

1969

Materials Inventory Report No. 21

the **Why ?** **What ?** & **How ?** of this Report

This report was compiled for use as a guide when prospecting for construction material in Butler County.

> *Construction material includes all granular material, binder material, and mineral filler suitable for use in highway construction.*

Known open and prospective sites, both sampled and unsampled, and all geologic units considered to be a source of construction material are described and mapped.

> *Prospective sites are areas where geologic conditions are best for finding construction material.*

The diagram opposite shows how the MATERIALS INVENTORY SECTION may be used to evaluate and locate mapped sites.

The individually mapped sites certainly do not constitute the total construction material resources of the county. And, the data outlined in the diagram may be used for purposes other than the evaluation and location of these sites.

Beginning on page 7 is a section explaining the Geology of the county. This information (along with the maps, descriptions, and test data) provides the means of evaluating and locating additional construction material sources in the geologic units throughout Butler County.

TO LOCATE AND EVALUATE
A MAPPED SITE OF CONSTRUCTION MATERIAL IN BUTLER COUNTY

Turn To The Materials Inventory Section

See
TABULATION OF CONSTRUCTION MATERIALS
Figure 7, page 25

for MATERIAL
BY TYPE
USE COLUMN 1

For Quality Data
Figures 16&17
Pages 37&41

for MATERIAL
BY INTENDED USE
USE COLUMN 2

for **DESCRIPTION** of MATERIAL

Column 3 gives page of DESCRIPTION which includes engineering characteristics, approximate locations, and references to materials maps.

for **AVAILABILITY** of MATERIAL

Column 4 gives the general location of **AVAILABLE** material and references the materials maps.

MATERIALS MAPS

SEE PINK SHEET PAGE 43

Material source units, as well as all open and prospective sites are mapped. Each site is referenced to an individual data form.

SITE DATA FORMS

OPEN SITES - NOT SAMPLED	GREEN SHEET PAGE 45
OPEN SITES - SAMPLED	GREEN SHEET PAGE 95
PROSPECTIVE SITES - SAMPLED	GREEN SHEET PAGE 135
PROSPECTIVE SITES - NOT SAMPLED	GREEN SHEET PAGE 139

Each site data form includes a map for site location and provides information concerning landownership, material quality (if available), geologic age and site accessibility.

CONTENTS

PREFACE

This report is one of a series compiled for the Highway Planning and Research Program, "Materials Inventory by Photo Interpretation." The program is a cooperative effort of the Bureau of Public Roads and the State Highway Commission of Kansas financed by highway planning and research funds. The objective of the project is to provide a statewide inventory of construction materials, on a county basis, to help meet the demands of present and future construction needs.

Although no extensive material surveys are available for Butler County, several geologic investigations conducted by the Kansas Geological Survey provided basic geologic and material data. These include "Origin of the Shoestring Sands of Greenwood and Butler Counties, Kansas" by N. W. Bass; "Geology and Ground-water Resources of Cowley County, Kansas" by C. K. Bayne; and "Geology of the El Dorado Oil and Gas Field" by A. E. Fath. The Materials Department, State Highway Commission of Kansas, provided construction material quality data. Detailed soil and geologic information was obtained from preliminary soil surveys and centerline geological profiles prepared by the State Highway Commission.

Appreciation is extended to R. E. Frye, Fifth Division Materials Engineer and T. L. Farmer, Butler County Engineer for verbal information concerning construction materials in the area.

This report was prepared under the guidance of J. D. McNeal, State Highway Engineer; the project leader, R. R. Biege, Jr., Engineer of Location and Design Concepts; and G. M. Koontz and A. H. Stallard of the Location and Design Concepts Department.

ABSTRACT

Butler County lies in the *Flint Hills* physiographic division in south-central Kansas. It is the largest county in the state with an area of 1,549 square miles. Most of the county is drained to the south by the Walnut and Whitewater Rivers. The county road system is not extensive but most roads have an all-weather surface.

Construction material can be produced from Permian limestone and unconsolidated chert gravel deposits of Pleistocene age. Aggregate and riprap can be produced from limestone units exposed predominantly in the eastern two-thirds of the county. Chert gravel found in the southern one-half of the county is used extensively for light type surfacing and for bituminous and concrete aggregate when processed.

The most pertinent geo-engineering problems in Butler County are associated with the unstable, clayey Wellington and Holmesville Shales along with solution cavities that occur in the Fort Riley Limestone. Other common problems are water seepage from the base of the thicker limestones and from gypsum seams and limy zones in the Wellington Shale.

Because water associated with the Wellington Shale is often highly mineralized, and because of the large amount of oil industry in Butler County, high concentrations of sulfate and chloride ions are common in water supplies. Contamination of water was especially noted on the Walnut River and the West Branch of this stream.

GENERAL INFORMATION SECTION

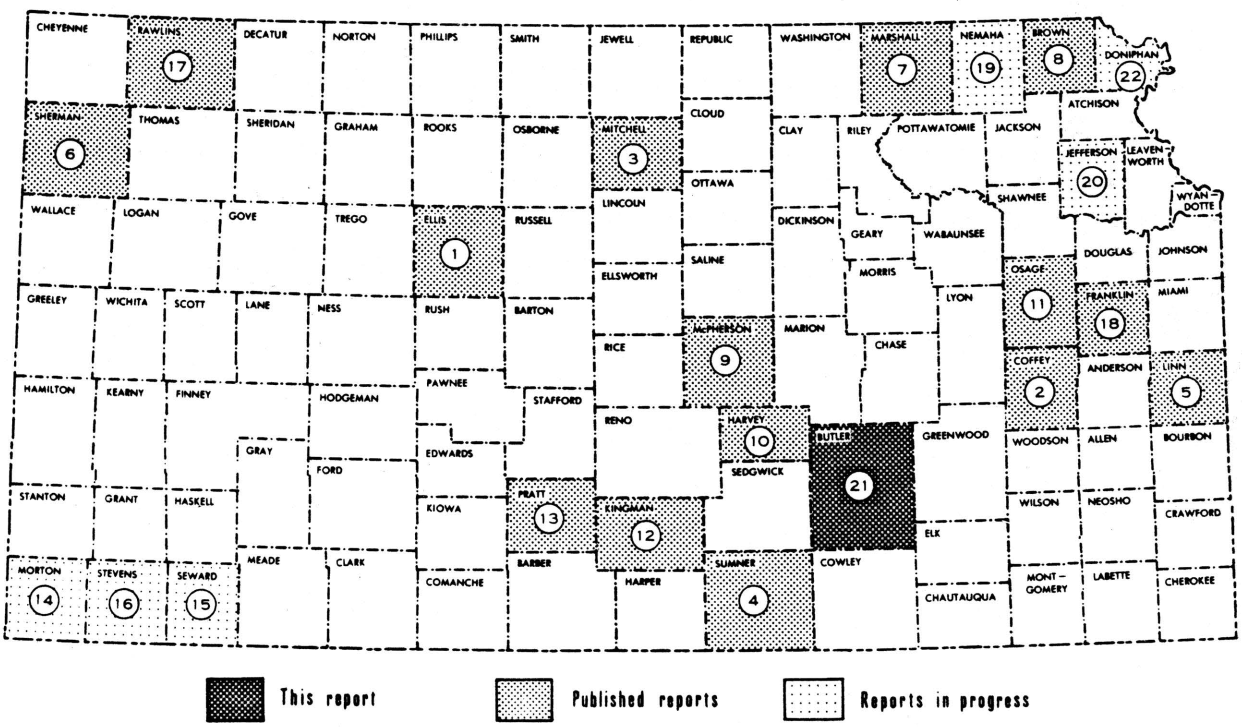


Figure 1. Index map of Kansas showing the location of Butler County along with the report number and location of other counties for which reports have been or are being completed.

FACTS ABOUT BUTLER COUNTY

Butler County has an area of 1,549 square miles. It lies in the *Flint Hills* physiographic division of Kansas and is drained mostly by the southward flowing Walnut and Whitewater Rivers.

Figure 1 shows the location of Butler County as well as other counties currently included in the materials inventory program.

Railroads serve all towns in Butler County. The Kansas Turnpike traverses the county in a northeast-southwest direction with interchanges at Cassoday and El Dorado. U. S. Highways 54 and 77 and Kansas Highways 96, 196, 177, and 254 serve various parts of the county (figure 2).

METHODS OF INVESTIGATION

This report consists of three phases: (1) research and review of available information, (2) photo interpretation, and (3) field reconnaissance.

During phase one, information on geology, soils, and construction materials was reviewed and the general geology was determined. Results of quality tests were correlated with the various geologic units.

Phase two consisted of study and interpretation of aerial photographs taken by the State Highway Commission at a scale of one inch equals 2,000 feet. Geologic source beds and open material sites were mapped and classified on these photographs. Prospective areas were selected by use of geology, photographic

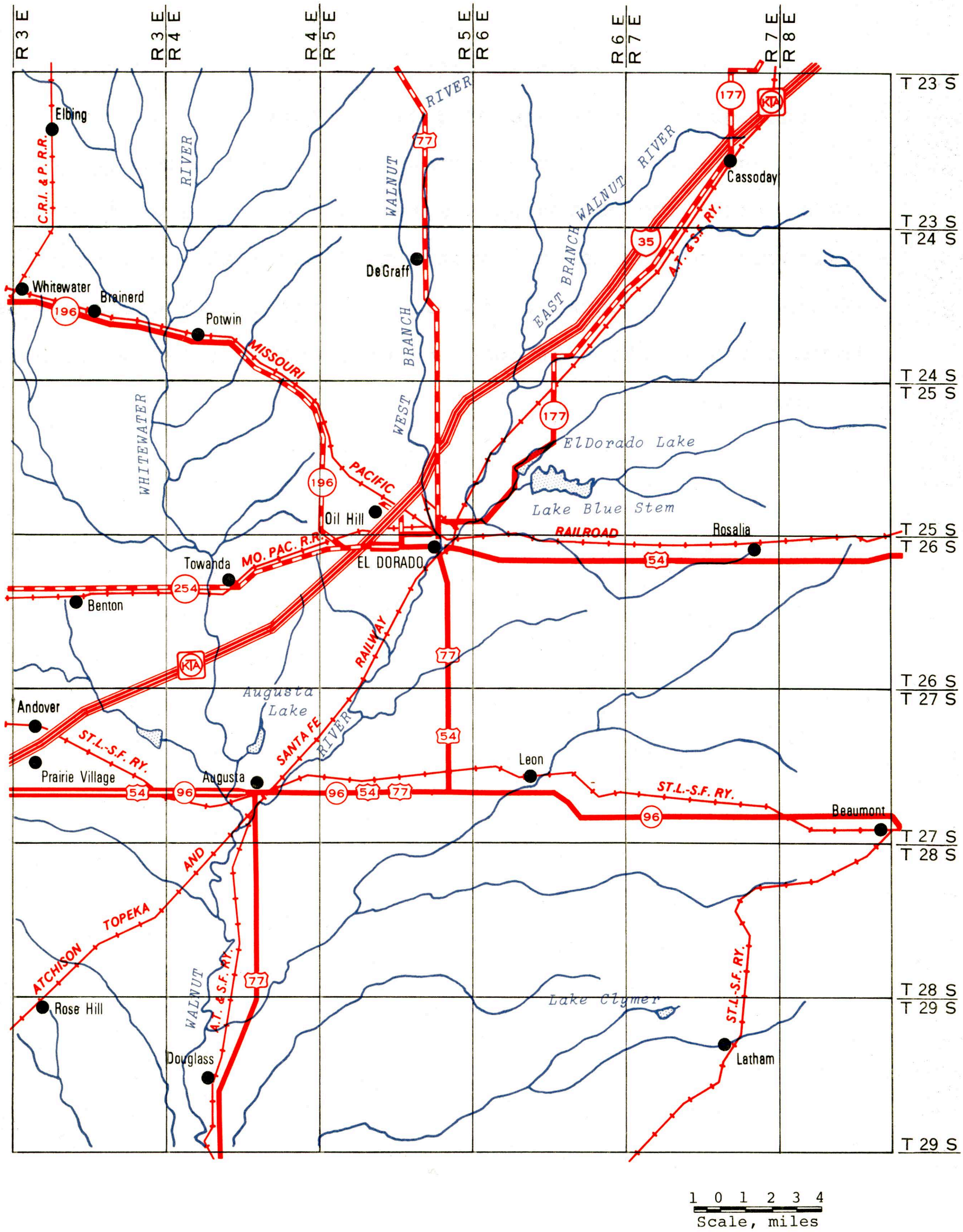


Figure 2. Drainage and major transportation facilities in Butler County.

pattern elements, and observations in the field. Figure 3 shows the photographic coverage of Butler County.

Phase three, a field reconnaissance of the county, was conducted after the photographs were studied. This enabled the interpreter to examine the construction material, to verify his mapping, and to acquaint himself with the county geology. Geologic classification of open and prospective sites were confirmed at this time.

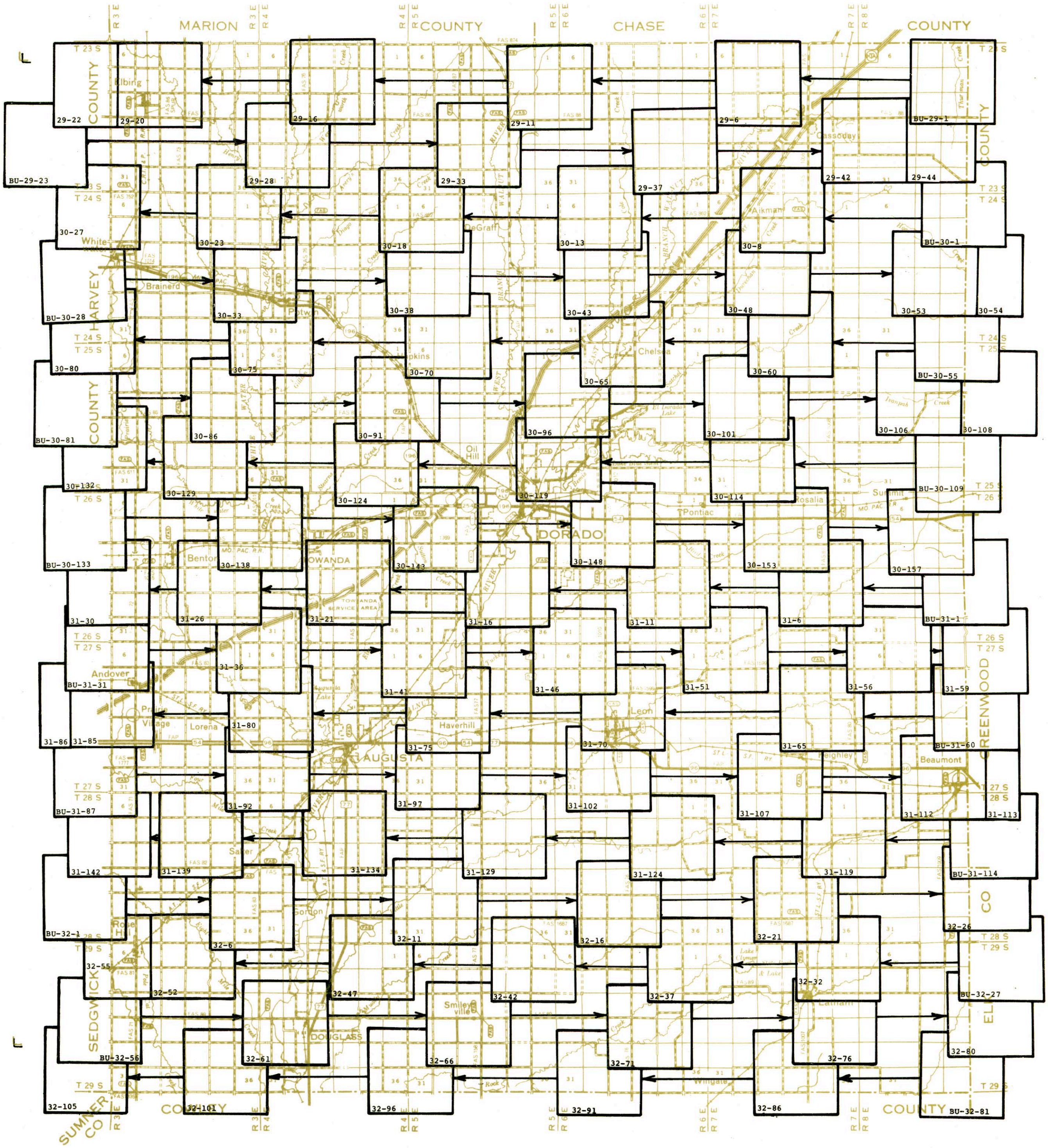
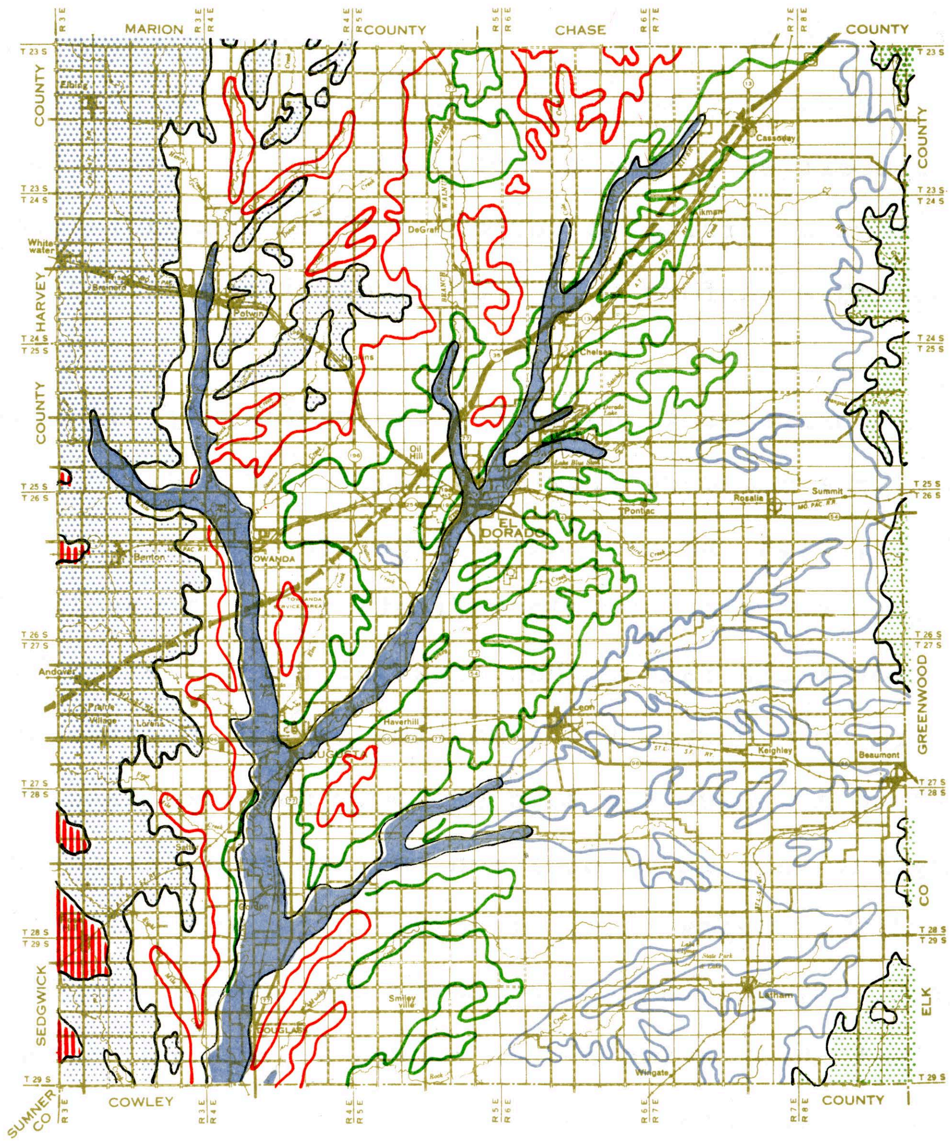


Figure 3. Aerial photographic coverage map for Butler County. The numbers refer to photographs taken by the Photogrammetry Section of the State Highway Commission of Kansas, on May 22 and 23, and July 14 and 26, 1967. Aerial photographs are on file in the Photogrammetry Laboratory, State Office Building, Topeka, Kansas.

GEOLOGY SECTION



LEGEND

Alluvium

Loess

Base Cresswell Limestone Member

Base Fort Riley Limestone Member

Base Florence Limestone Member

Wellington Formation with variable Loess and soil cover

Chase Group

Council Grove Group

GENERAL GEOLOGY

GEOLOGY is the basis for this materials inventory. Knowledge of the geology makes it possible to: (1) ascertain the general properties of the material source, (2) identify and classify each according to current geologic nomenclature, and (3) establish a uniform system of material source bed classification.

It is important to note that the quality of material from a given source may vary from one location to another especially when dealing with unconsolidated deposits.

Usually the geologic classifications of unconsolidated deposits denotes age rather than material type; therefore, deposits laid down during the same time period in different parts of the state may have the same geologic name or classification. But, they may vary in composition because of different parent material, mode of deposition, or carrying capacity of the depositing agent. By knowing the geologic age, origin, landform, and quality test information of the source units, one can derive information for untested material sites and prospective locations.

In Butler County, Permian limestones and Quaternary chert gravel deposits are sources of construction material. Figure 4, a geologic timetable, illustrates the stratigraphic position of the Permian and Quaternary geologic beds. Figure 5 is a detailed geologic column of the surface geology in the county.

The geologic units exposed in Butler County total only a few hundred feet in thickness and represent only a small part of the total rock section. However, as much as 4,000 feet of sedimentary

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

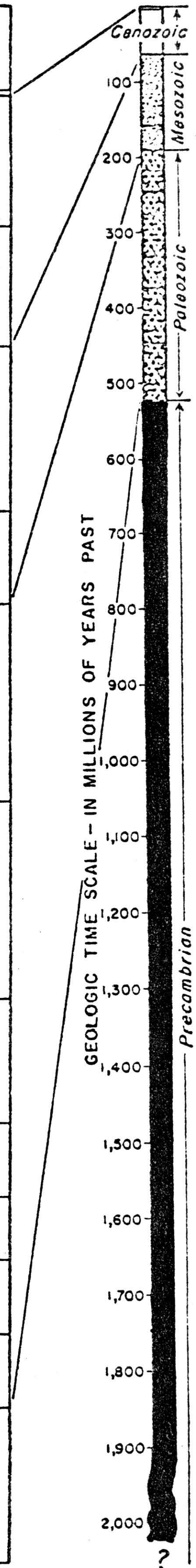


Figure 4. Geologic timetable (Reproduced with the permission of the State Geological Survey of Kansas).

rocks are buried under the county, all of which are Paleozoic in age.

The oldest rock underlying Butler County is a basement complex of Pre-Cambrian igneous and metamorphic rock. Rocks of lower Paleozoic age lie on the Pre-Cambrian and are represented primarily by Reagan Sandstone and dolomite of the Arbuckle Group. Most Paleozoic rocks are marine in origin; however, the presence of large evaporite deposits in the Wellington Formation (late Paleozoic) is indicative of a continental environment.

The county was elevated above sea level in the early Mesozoic Era and, for the most part, erosion was the prominent process throughout the era. However, it may be surmised that some deposition did occur, since rocks of this age are found 30 miles to the northwest of Butler County.

Most of the Tertiary Period in Kansas was characterized by severe erosion associated with the newly uplifted Rockies. Late in Tertiary time, streams from these mountains began to aggrade their channels in western Kansas and a thick blanket of alluvial material *(Ogallala Formation)* was deposited. However, in Butler County this material has been removed by subsequent erosion.

The Pleistocene Epoch of the Quaternary Period was a time of repeated glacial activity. The glacial stages of advancement are termed the Nebraskan, Kansan, Illinoisan, and Wisconsinan and the interglacial stages of recession and stability are referenced as the Aftonian, Yarmouthian, and Sangamonian (figure 6). Only the Nebraskan and Kansan glaciers penetrated

System	Series	Stage	Group	Formation	Member	Map Unit	Thickness	Description	Construction Material
Pleistocene	Quaternary	Recent		Alluvium and Terrace Deposits		Qalt	0-35'	Clay, silt, sand, and chert and limestone gravel.	Surfacing material on lightly traveled rural roads. Bituminous Aggregate. Concrete Aggregate. Base Course Material. Shoulder Material.
		Illinoisan Wisconsinan		Loess		Ql	0-30'	Wind-deposited clay-bound silt generally found on the stream divide areas.	None
		Nebraskan Kansan		Chert Gravel Terrace Deposits		Qnkt	0-15'	Clay, silt, sand, and chert gravel.	Surfacing material on lightly traveled rural roads. Bituminous Aggregate. Concrete Aggregate. Base Course Material. Shoulder Material.
Permian	Lower Permian	Gearyan	Sumner	Wellington Shale		Pw	0-132'±	Shale, mostly gray-green but some maroon, some limy zones and gypsum seams. Persistent limestone near the base is termed the Hollenberg Limestone.	None
			Chase	Nolans Limestone	Herington Limestone	Ph	13'±	Limestone, dolomitic, cherty in upper portion, has silty or sandy appearance, contains many geodes.	Surfacing material on lightly traveled rural roads. Bituminous Aggregate. Base Course Material. Shoulder Material.
					Paddock Shale		6-20'		
					Krider Limestone		1-3'		
				Odell Shale			20-40'		
				Winfield Limestone	Cresswell Limestone	Pc	9-30'	Upper portion is a light tan-gray limestone with the lower portion being a massive light tan limestone locally cherty with small solution cavity.	Surfacing material on lightly traveled rural roads. Bituminous Aggregate. Concrete Aggregate. Base Course Material. Shoulder Material. Riprap.
					Grant Shale		3-9'		
					Stovall Limestone		2-3'		
				Doyle Shale	Gage Shale		50-60'		
					Towanda Limestone	Pt	5-10'	Tan-gray platy limestone with small solution cavities, may represent only a thin limestone about one foot thick in the southern portion but full thickness may exist in north portion.	Surfacing material on lightly traveled rural roads. Bituminous Aggregate. Concrete Aggregate. Base Course Material. Shoulder Material.
					Holmesville Shale		35'±		
				Barneston Limestone	Fort Riley Limestone	Pfr	44-78'	Light tan to medium gray limestone with solution cavities, some of which have developed into sinks. Generally thin-bedded but may have a massive zone termed the "Rim Rock".	Surfacing material on lightly traveled rural roads. Base Course Material. Shoulder Material. Riprap.
					Florence Limestone	Pf	35'±	Light tan to gray cherty limestone prominent bed in the "Flint Hills" because of its resistance to weathering. Upon weathering only residual chert may remain.	Surfacing material on lightly traveled rural roads. Bituminous Aggregate. Concrete Aggregate. Base Course Material. Shoulder Material.
				Matfield Shale	Blue Springs Shale		15-20'		
					Kinney Limestone		15-20'		
					Wymore Shale		15-23'		
				Wreford Limestone	Schroyer Limestone		8-13'		
					Havensville Shale		10'±		
					Threemile Limestone		14-23'		
			Council Grove	Speiser Shale			33'±		
				Funston Limestone			7-25'		
				Blue Rapids Shale			15'25'		
				Crouse Limestone			16'±		
				Easly Creek Shale			12-18'		
				Bader Limestone	Middleburg Limestone		7-15'		
					Hooser Shale		3-21'		
					Eiss Limestone		16'±		
				Stearns Shale			7'±		

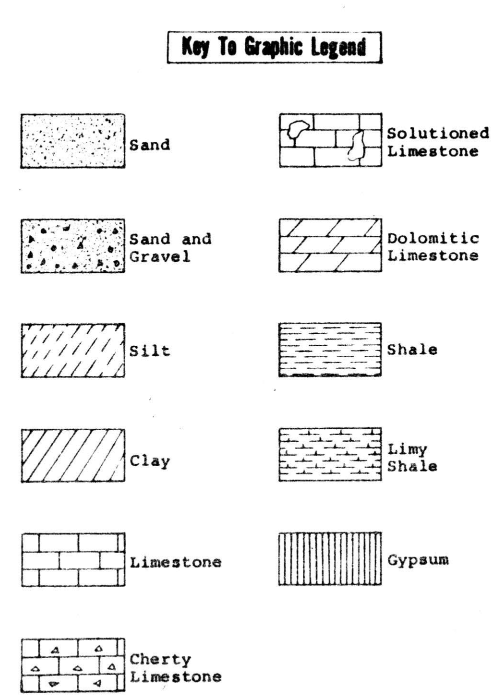


Figure 5. Generalized geologic column of the surface geology in Butler County.

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 6. Geologic timetable of the Quaternary Period.

into Kansas with only the northeastern portion of the state being directly affected. Although no ice reached Butler County, the glaciers played a controlling role in the development and classification of Pleistocene deposits. The Pleistocene geologic history, as discussed here, is based on information by Frye and Leonard (1952).

As the Nebraskan glacier started to accumulate, central Kansas was an erosional plain of subdued relief with broad alluviated valleys. At this time a major stream flowed south across

Kansan through Ottawa, Saline, McPherson, Harvey, Sedgwick, and Sumner Counties. This channel probably drained most of Butler County. With the advancement and recession of the Nebraskan Glacier, streams aggraded and degraded their channels, forming terraces. *Some* of the high Chert Gravel Terrace Deposits found along the Walnut River drainage, in southern Butler County, are classified as Nebraskan in this report.

The Kansan glacier pushed southward roughly to the Kansas River on the south and the Blue River on the west. The melting of this ice, along with Alpine glaciers in the mountains to the west, caused large amounts of water to flow through the drainage systems of the state. At this time, erosion removed most of the Nebraskan alluvium from major stream valleys and continued into the underlying bedrock. Later in the period, as the glaciers retreated and the flow of water subsided, the streams filled their valleys with alluvium. It was probably in late Kansan time when most of the Chert Gravel Terrace Deposits were formed along Walnut Creek, Muddy Creek, Little Hickory Creek, Rock Creek, and the Walnut River.

Although the Illinoisan glacier advanced only to southern Illinois, associated climatic conditions caused the initial development of the present day drainage system in Butler County. Deposits of Illinoisan age in this report are included in the *Alluvium and Terrace Deposits* map unit.

During Wisconsinan time, the valleys of the larger streams in Butler County were filled with clay, silt, and minor amounts of sand and gravel. This material underlies the stream beds and is also included in the *Alluvium and Terrace Deposits* map unit. Wind-blown silt deposits (loess), which veneers some upland areas, were laid down during this time.

The Recent Age represents the time elapsed since the last retreat of the Wisconsinan glacier. The climatic conditions throughout the age were similar to those of today.

GEO—ENGINEERING SECTION

This section is a general appraisal of the material available in Butler County for embankment, shoulder and subgrade construction. Potential ground-water problems and the quality of water available for concrete are briefly reviewed. *Detailed field investigations may be necessary to ascertain the severity of specific problems and to make recommendations in design and construction procedures.*

MATERIAL USAGE

Butler County consists of two general geologic areas: the western one-third, characterized by Loess-covered shale; and the eastern two-thirds, by limestone, cherty limestone, and shale. Although a thick section of Permian bedrock is found over the county, the section from the *Wellington Shale* through the *Florence Limestone* is most commonly exposed.

Western One-Third

Like its parent material, residual soil derived from the Wellington Shale is highly plastic and would be classified as a clay by the State Highway Commission and as an A-6 or A-7 soil by A.A.S.H.O. standards. Most Loess has a high plastic index, and is usually classified as a silty clay or silty clay loam according to the State Highway Commission and as an A-6 or A-7 soil by A.A.S.H.O. standards.

The Loess probably will not cause any pertinent geo-engineering problems. However, the clayey Wellington may require stabilization or wasting if considered for the subgrade. Also, slip-outs on backslopes constructed in the shale are common if slopes are too steep. Usually, cuts should not be steeper than 3:1 unless zones of limestone or sandstone are present. Pile tip elevations are difficult to predict in the Wellington since the pile may penetrate several feet into the weathered clay-shale before reaching desired bearing.

Several limestones, located stratigraphically below the Wellington, are exposed in the western one-third of the county.

These include, in decending order: the Herington, Cresswell, Towanda, and Fort Riley Limestone Members. The limestones will stand on a 1/2:1 and the intervening shales on a 3:1 or flatter slope.

The Holmesville Shale, found between the Fort Riley and Towanda Limestones, is of particular geo-engineering significance because it weathers to a clay, and stability problems are common.

Eastern Two-Thirds

The *thick* combination of the Florence and Fort Riley Limestone is extensively exposed in the eastern two-thirds of Butler County. Only a thin clayey soil overlies most of this limestone.

One significant geo-engineering aspect of the Fort Riley Limestone is the occurrence of solution cavities which develop into sinks in localized areas. Road alignments should avoid these areas and the weathering features of the Fort Riley should be thoroughly assessed during foundation studies.

The Florence cherty limestone is one of the most important units that make up the *Flint Hills* landscape. Although it resists erosion and makes a unique escarpment, the Florence weathers to chert rubble with a clay matrix. Because of this weathering characteristic, severe spalling occurs in cuts, especially on slopes steeper than 1/2:1. The weathering characteristics of the Florence should also be thoroughly investigated during bridge foundation studies.

POSSIBLE HYDROLOGY PROBLEMS IN ROAD CONSTRUCTION

The most severe hydrology problems will be encountered in the eastern two-thirds of Butler County. Surface water percolates down through fractures and solution cavities in limestones and moves laterally along the top of impervious shales. Ground-water problems of this nature have been encountered in the Florence, Fort Riley, Towanda, and Herington Limestones as well as limy zones and gypsiferous layers in the Wellington Formation. Seeps were also detected in the Wreford Limestone Formation and other limestone units in extreme eastern Butler County.

Ground-water problems often occur in Chert Gravel Terrace Deposits which lie on high terrain along the major drainage in southern Butler County. Seepage is common in these deposits since water is often trapped by underlying impermeable material. However, because of the *thin* nature and *limited* distribution, associated hydrology problems are not extensive.

QUALITY OF WATER

The quality of the water supply is of concern in this report because of the detrimental effect mix water containing high concentration of chloride and sulfate ions may have on Portland Cement concrete.

Water for industrial and (or) domestic use is obtained from man-made reservoirs and from wells in unconsolidated material and bedrock units. Much of this water is mineralized by evaporites (salt and gypsum) in the Wellington Formation and contaminated with chloride and sulfate ions derived from oil production. The most severely contaminated water is found in areas of extensive oil production. These areas lie west of the Walnut River and its West Branch and between the cities of Towanda and Potwin near the Whitewater River.

The most plentiful supply of ground-water is in the Alluvium of the larger stream channels. However, water from this source is highly mineralized. Usually a better quality of water is available in the alluvium of some smaller streams.

Large areas of the county are underlain by the cherty Florence Limestone, and the thin-bedded, solutioned Fort Riley Limestone. Abundant ground-water may be available in these units due to their high porosity. Locally, however, water from these units has been contaminated by oil production. In some areas waste from oil wells enters sink holes in the Fort Riley, contaminating water at this horizon and at lower elevations. Limited amounts of water may also be produced from the Threemile, Schroyer, Towanda, Cresswell, and Herington Limestones along with limy and gypsiferous zones in the Wellington Formation. Water produced from the Threemile and Schroyer Limestones is relatively pure, but highly ionized water is often produced from the Towanda and Cresswell Limestones and the Wellington Shale. Water from dark shales such as the Wellington Formation, have a high sulfate content.

Because much of the water in Butler County is highly contaminated, it is suggested that all mix water be tested before it is used in Portland Cement concrete.

MATERIALS INVENTORY SECTION

GENERAL INFORMATION

Construction material found in Butler County includes crushed limestone from bedrock units and chert gravel from terraces and alluvium.

Limestone sources include the Florence, Fort Riley, Cresswell, and Herington, none of which provide a good quality aggregate. The best quality rock is produced from the Cresswell.

Most chert gravel terraces and alluvial chert gravel, prominent in southeast Butler County, are gravels washed out of the *Flint Hills*. Washing and sorting action has rendered these deposits a better source of chert gravel than the parent rock. High quality aggregate from chert gravel terraces are costly to produce because of a clay binder, however, they are an economical source for light type surfacing.

CONTENTS OF
MATERIALS INVENTORY SECTION

TYPE and geologic source	**USE**	**DESCRIPTION**	**AVAILABILITY**
LIMESTONE			
Florence Limestone Member	Light type surfacing. Base course aggregate. Shoulder material.	26	Eastern 1/3 of the county. Plates II, IV, V, VI, VII, and VIII.
Fort Riley Limestone Member	Light type surfacing. Base course aggregate. Shoulder material. Bituminous aggregate. Riprap.	27	North-south strip through the central 1/3 of the county with exposures being especially prominent along Walnut River valley. Plates I, II, III, IV, V, VI, VII, and VIII.
Cresswell Limestone Member	Light type surfacing. Base course aggregate. Shoulder material. Concrete aggregate. Bituminous aggregate. Riprap.	29	Western 1/3 of the county along Whitewater and Walnut River drainage systems. Plates I, II, III, IV, V, and VII.
Herington Limestone Member	Light type surfacing. Base course aggregate. Shoulder material.	31	Western 1/3 of the county, mostly west of the Whitewater and Walnut River valleys. Plates I, III, V, and VII.
CHERT GRAVEL			
Chert Gravel Terrace Deposits	Light type surfacing. Base course aggregate. Shoulder material. Concrete aggregate. Bituminous aggregate.	33	Abundant deposits along Walnut Creek, Muddy Creek, Little Hickory, and the Walnut River. Plates IV, V, VI, VII, and VIII.
Alluvium and Terrace Deposits	Light type surfacing. Base course aggregate. Shoulder material. Concrete aggregate. Bituminous aggregate.	34	Produced, currently, along Little Hickory Creek and Walnut Creek but may be produced along a number of streams whose headwaters reach into the outcrop area of the Florence, Schroyer, and Threemile Limestone Members. Plates V, VI, VII, and VIII.

Figure 7. Tabulation of the construction material types and their availability in Butler County.

DESCRIPTION OF CONSTRUCTION MATERIAL

Limestone

Barneston Limestone Formation, Florence Limestone Member

The Florence Limestone, which outcrops in the eastern one-third of Butler County, is the major geologic unit forming the prominent *Flint Hills* of Kansas. It is a tan-gray cherty limestone about 35 feet thick. When weathered, the limestone is solutioned away leaving only chert rubble in a red clay matrix (figure 8).

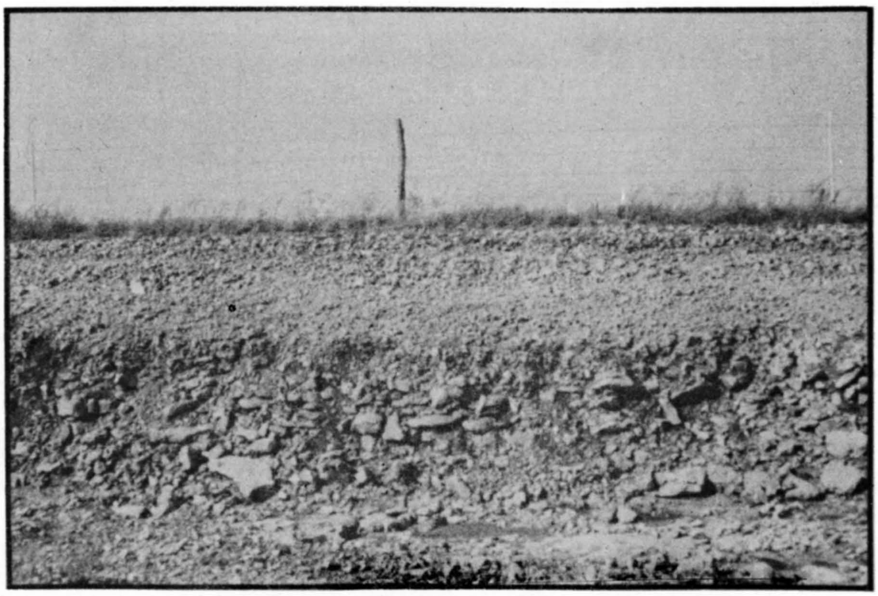


Figure 8. Chert rubble of the Florence Limestone Member, SE¼ sec. 5, T26S, R8E.

In many areas the Florence is deeply weathered and the chert rubble is obtained, on a very limited basis, for light type surfacing. However, many of the residual chert nodules are too large for use as gravel without being crushed.

Only a limited amount of fresh or unweathered rock has been quarried from the Florence. It is difficult to blast, it wears crushing equipment extensively, and its quality is generally marginal to poor. When used for light type surfacing, the sharp edges of the chert often damage automobile tires. When used in concrete, joints are difficult to saw.

Figure 16 (page 37) shows test results on one chert rubble deposit. The Los Angeles wear ran 27.7 percent and the absorption was 1.70 percent. No information was available on the soundness; however, it is known that the chert will often fail when subjected to freeze and thaw.

The Florence outcrops mostly in the eastern one-third of Butler County. The outcrop pattern is shown on plates II, IV, V, VI, VII, and VIII.

Barneston Limestone Formation, Fort Riley Limestone Member

In Butler County the normal shale interval between the Fort Riley and Florence Limestone is missing. A good exposure of the contact between the two units may be seen in the spillway of Lake Blue Stem, a few miles northeast of El Dorado.

The unit is a light gray, fine-textured limestone which weathers tan. It contains solution cavities which cause *sink holes* to occur in some areas of Butler County (figure 9). The Fort Riley is mostly thin-bedded but contains a consistent, massive, weather resistant zone called the *rimrock* (figure 10). According to the Geology Section, State Highway Commission of Kansas, the Fort Riley has a thickness that ranges from 44 to 78 feet. Over 50 feet of rock was exposed in one quarry.

Figure 9. Sink hole in the Fort Riley Limestone, NW¼ sec. 6, T26S, R5E.

The Fort Riley outcrops in a north-south zone through central Butler County. Exposures are shown on portions of all eight material map plates.

Figure 10. Typical bedding of the Fort Riley Limestone in a road cut west of Augusta. Massive rimrock zone is located in the lower portion of the photograph, SW¼ sec.21, T27S, R4E.

Most aggregate from the Fort Riley is soft and of poor quality. However, some marginal material may be produced with the better aggregate coming from weathered rock. Test data on the Fort Riley, shown in figure 16 (page 37) indicate a Los Angeles wear range from 28.0 to 61.3 percent, soundness loss ratio from 0.19 to 0.98 and an absorption from 2.98 to 11.30 percent. Because of its poor quality, the Fort Riley is not used extensively in bituminous and concrete construction; however, it is used as surfacing material on county asphalt seal projects. Some aggregate is suitable for base course and shoulder construction as well as light type surfacing material. The *rimrock* zone in the Fort Riley is an important source of riprap.

Winfield Limestone Formation, Cresswell Limestone Member

The Winfield Limestone Formation consists of three members which, in ascending order, are: Stovall Limestone, Grant Shale, and Cresswell Limestone. In northeast Butler County (SW¼ sec.17, T23S, R4E) all three members were recognized, with the Cresswell being the most prominent unit. South of township 23, a facies change has occurred with the Cresswell becoming much thicker and the Grant Shale and Stovall section thinner.

The Cresswell is the best quality limestone available in Butler County. It is a light tan-gray limestone, locally cherty, with many solution pits and contains many fossil echnoid spines. The thickness varies from nine feet in the northern one-third of the county to 30 feet in the southern two-thirds. Exposures of Cresswell are shown on plates I, II, III, IV, V, and VII.

Chert nodules, such as may be found in the Cresswell, are detrimental to overall quality as well as being difficult to crush. However, chert was noted at only one quarry, this being in the northern portion of the county (figure 11). As the Cresswell member thickens to the south, the chert becomes absent and small solution cavities become abundant. At a location a few miles north of El Dorado (NE¼ sec.26, T24S, R5E) nodules which appeared to be cherty were exposed in a road cut. However, when examined they were found to be non-cherty, and composed largely of small fossils tightly cemented together. At the time of this report two active quarries have produced large quantities of this rock - one a few miles northeast of Augusta in the NE¼ sec. 8, T27S, R4E and the other, one mile west of Douglas in the NE¼ sec.30, T29S, R4E (figure 12).

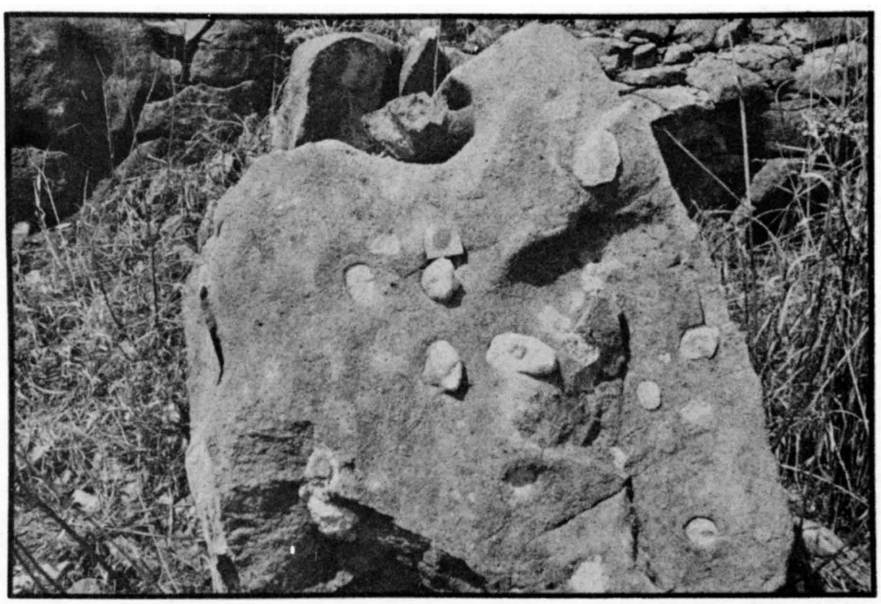


Figure 11. Chert nodules in the Cresswell Limestone in northern Butler County, SW¼ sec.17, T23S, R3E.

Figure 12. Thick, non-cherty Cresswell in a quarry, NE¼ sec. 8, T27S, R4E.

Quality of aggregate from this source is marginal. It has been used in bituminous mixes, concrete, base courses, shoulder construction, and as light type surfacing material. It may also be desirable as riprap. Detailed quality information is shown in figure 16 (page 37). Test data show the Los Angeles wear range from 25.0 to 43.3 percent, soundness loss ratio from 0.77 to 0.98, and absorption from 2.10 to 10.84 percent.

Nolans Limestone Formation, Herington Limestone Member

The Nolans Limestone Formation is composed of three members, which in ascending order, are: the Krider Limestone, Paddock Shale, and Herington Limestone. The Herington is the only member that is a source of aggregate. It is a tan-gray, silty, cherty, dolomitic limestone which contains calcite geodes. The chert is in the form of small nodules that are most abundant in the upper part. The geodes are generally 1/2 to one inch in diameter; however, some as large as one foot were noted. The bedding is thin in the upper part and massive in the lower section (figure 13).

Figure 13. Upper portion of the Herington Limestone, SE¼ sec.30, T24S, R4E.

The Herington is exposed on the western valley slopes of the Whitewater and Walnut Rivers. In northern Butler County, a few exposures are found east of the Whitewater. Outcrops of the Herington are shown on plates I, III, V, and VII.

The rock is marginal in quality, with some quarries containing material which would meet specifications for use in concrete or bituminous construction. However, the dolomitic nature may render the unit undesirable for use in concrete since dolomite is sometimes linked with concrete deterioration. Also, chert nodules and calcite geodes lower the quality of rock produced from this unit. The Herington is used for shoulder and base course aggregate as well as light type surfacing material. Test data indicate the Los Angeles wear range from 29.8 to 68.6 percent, soundness loss ratio from 0.71 to 0.97 and absorption from 2.40 to 8.56 percent. Detailed quality information on the Herington is shown in chart form in figure 16 (page 37).

Chert Gravel

Chert Gravel Terrace Deposits

Terrace deposits, composed almost entirely of gray-brown chert gravel with red clay binder, are common in the southern portion of Butler County. The average size of the gravels range from one-half to one inch in diameter (figure 14). Their thickness does not exceed 15 feet and most deposits of economic value range between five and ten feet.

The chert gravels, dated in this report as Nebraskan and Kansan in age, are abundant along Walnut Creek, Little Hickory Creek, Rock Creek, and the Walnut River. Large deposits are found on Walnut Creek near Leon and near the junction of Muddy Creek and the Walnut River south of Douglass. Chert Gravel Terrace Deposits are mapped on plates IV, V, VI, VII, and VIII.

Good quality material can be produced from these deposits, but the producer must go through the costly process of removing the clay which sticks tightly to the gravel. Tests show

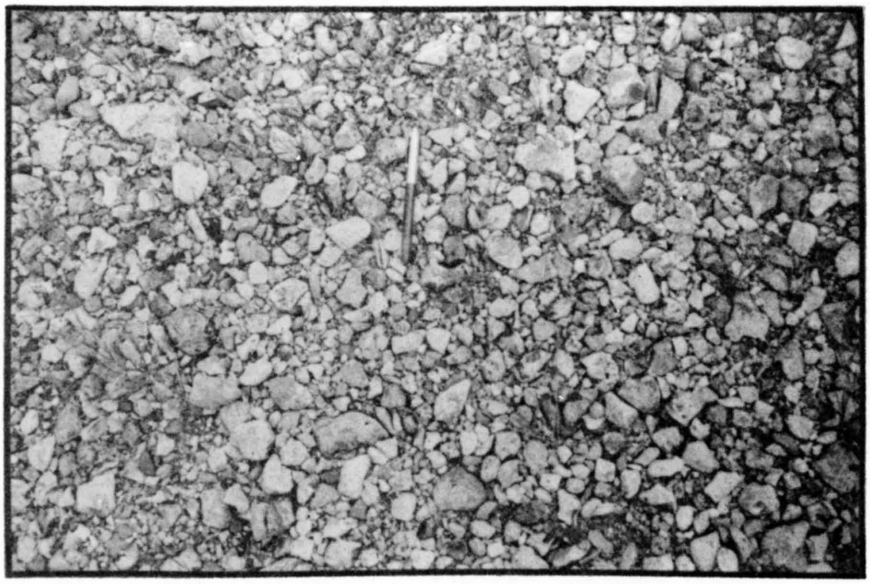


Figure 14. Chert Gravel Terrace Deposits in a pit located near the city of Leon, SW¼ sec. 35, T27S, R5E.

the Los Angeles wear ranges from 16.8 to 24.1 percent and the soundness loss ratio from 0.91 to 0.99. Although no absorption tests were conducted, one may assume a low value. Figure 17 (page 41) illustrates detailed test data on samples taken at several pit locations. Chert gravel can be processed for most construction needs, however, if used in concrete, difficulty will be experienced in sawing joints due to the extreme hardness of the gravel.

Alluvium and Terrace Deposits

The Alluvium of the Whitewater and Walnut Rivers is composed mostly of silt and clay in the upper section and granular material in the lower part. Material is not utilized from the main arterial streams; however, some tributaries, whose headwaters reach into the *Flint Hills*, are presently redepositing chert gravel. These gravels, which may be several feet thick, are important sources of material for light type surfacing. Some alluvial chert has been washed and crushed for use as concrete and bituminous aggregate as well as base course and shoulder material.

The matrix of the alluvial chert deposits normally does not adhere tightly to the gravel and can be easily removed by washing. High quality alluvial chert is currently being produced from Little Hickory and Walnut Creeks (figure 15). Although Alluvium and Terrace Deposits are shown on all plates, it is probable that material can be produced from only select deposits shown on plates V, VI, VII, and VIII.

Figure 15. Alluvial chert gravel in a pit along Little Hickory Creek where the raw material is crushed, sorted, and washed, N½ sec.14, T28S, R6E.

Quality test data indicate the Los Angeles wear range from 17.9 to 27.1 percent, the soundness loss ratio from 0.97 to 0.99, and the absorption on one sample was 3.18 percent. Additional test information on alluvial material is shown in figure 17 (page 41).

Site Data Form No.	Type of Material	Date of Test	SP.GR. Wet	SP.GR. Dry	L.A. Wear	% Absorption	% Soundness	Source of Data	Type of Sample
Source of Data: Herington Limestone - Ph									
LS+57	Limestone	12-28-61	2.49	2.34	51.0(B)	6.38	0.81	Lab. No. 20582	Crushed
		12-15-61			51.4(B)			Lab. No. 20581	Crushed
		08-01-61	2.58	2.47	42.6(B)	4.27	0.96	Lab. No. 17945	Crushed
		04-20-60	2.41	2.22	56.9(B)	8.56	0.65	Lab. No. 11115	Crushed
		04-21-60	2.57	2.48	36.2(B)	3.81	0.94	Lab. No. 11202	Crushed
		05-03-60	2.54	2.43	40.8(B)	4.61	0.96	Lab. No. 11293	Crushed
		11-19-59	2.59	2.50	42.0	3.89	0.97	Lab. No. 7913	Unknown
LS+53	Limestone	08-28-62	2.51	2.41	32.0(B)	5.57	0.91	Lab. No. 24279	Crushed
		07-23-57	2.61	2.53	32.5(B)	3.40	0.92	Lab. No. 99572	Ledge
		07-23-57	2.56	2.44	38.5(B)	4.82	0.87	Lab. No. 98571	Ledge
		08-22-56	2.65		35.7	3.07	0.94	Lab. No. 94381	Crushed
		10-25-54	2.70		29.0(B)	2.40	0.97	Lab. No. 85245	Crushed
		04-14-53	2.58		36.4(B)	4.62	0.88	Lab. No. 78327	Ledge
		04-14-53	2.48		41.9(B)	6.52	0.94	Lab. No. 78328	Ledge
		11-09-49			51.4(B)			Lab. No. 65541	Crushed
LS+52	Limestone	08-02-65	2.56	2.43	47.5(B)	5.01	0.89	Lab. No. 65-2762	Crushed
		11-08-49			37.5(B)			Lab. No. 65542	Crushed
		06-30-49					0.78	Lab. No. 63640	Ledge
LS+56	Limestone	03-09-60	2.50	2.35	51.2(B)	6.41	0.71	Lab. No. 10755	Crushed
		09-16-54	2.48		53.9(A)	6.79	0.85	Lab. No. 84810	Crushed
		09-16-54	2.48		53.9(A)		0.83	Lab. No. 84810	Crushed
		07-28-49			29.8(A)			Lab. No. 64005	Ledge
		07-28-49			41.8(A)			Lab. No. 64004	Ledge
		07-28-49			68.6(A)			Lab. No. 64003	Ledge
LS+84	Limestone	10-02-59	2.53	2.39	63.8(B)	5.77	0.73	Lab. No. 8999	Crushed
		04-25-59	2.52	2.39	53.6(B)	5.22	0.92	Lab. No. 8859	Crushed
		04-12-57	2.58	2.46	47.2(B)	6.96	0.85	Lab. No. 97396	Unknown
		09-07-56	2.50			5.88		Lab. No. 94660	Crushed
LS+51	Limestone	01-14-54	2.44		40.2(B)	4.56	0.87	Lab. No. 81664	Crushed
LS+69	Limestone	03-23-50			48.6(A)			Lab. No. 67028	Crushed
LS+49	Limestone	01-28-49	2.56		48.2(A)	4.17	0.93	Lab. No. 61814	Ledge
		01-28-49	2.58		47.4(A)	3.49	0.96	Lab. No. 61815	Ledge
		01-28-49	2.57		46.3(A)	3.91	0.92	Lab. No. 61816	Ledge
		01-28-49	2.54		46.2(A)	4.53	0.96	Lab. No. 61817	Ledge
		01-28-49	2.56		37.4(A)	3.90	0.96	Lab. No. 61818	Ledge
		05-06-46	2.44	2.29	50.4(A)	6.65	0.91	Lab. No. 49876	Crushed
		05-03-46	2.56	2.46	59.3(A)	4.21	0.84	Lab. No. 49874	Crushed
		05-06-46	2.58	2.50	47.8(A)	3.07	0.95	Lab. No. 49875	Crushed
		05-21-46	2.58	2.49	40.8(A)	3.55	0.92	Lab. No. 50073	Crushed
		05-21-46	2.55	2.45	43.0(A)	4.08	0.91	Lab. No. 50072	Crushed
		12-26-41	2.48		48.7(A)	5.30		Lab. No. 43956	Unknown
		12-12-41	2.42		48.7(A)	6.00		Lab. No. 43957	Unknown
		12-12-41	2.54		48.7(A)	4.00		Lab. No. 43958	Unknown
		12-12-41	2.60		48.7(A)	3.00		Lab. No. 43959	Unknown
		12-12-41	2.60		48.7(A)	3.30		Lab. No. 43960	Unknown
Source of Data: Cresswell Limestone - Pc									
LS+80	Limestone	02-13-68	2.43	2.30	31.5(B)	5.61	0.77	Lab. No. 68196	Crushed
		12-30-65	2.46	2.35	30.9(B)	4.62	0.89	Lab. No. 655726	Crushed
		04-19-60	2.49	2.39	30.4(B)	3.99	0.89	Lab. No. 111116	Crushed
		05-21-59	2.48	2.39	29.3(B)	3.55	0.96	Lab. No. 6850	Crushed
		10-04-56	2.33		27.0(B)	2.43	0.98	Lab. No. 95134	Crushed
		10-04-56	2.51		25.0(B)	2.77	0.98	Lab. No. 95141	Crushed
		10-29-56			26.0			Lab. No. 95504	Crushed
		10-15-56	2.43		27.0(B)	4.29	0.98	Lab. No. 95139	Crushed
		06-27-65	2.45		30.7(B)	4.06	0.97	Lab. No. 93473	Crushed
		04-30-56	2.47		25.2(B)	4.23	0.95	Lab. No. 92414	Crushed
		04-30-56	2.47		26.8(B)	3.67	0.95	Lab. No. 92413	Crushed
		04-30-56	2.46		27.8(B)	3.91	0.96	Lab. No. 92411	Crushed
		04-30-56	2.46		27.2(B)	3.93	0.97	Lab. No. 92412	Crushed
		06-27-56	2.45		30.2(B)	4.27	0.98	Lab. No. 93475	Crushed
		03-16-56	2.56		25.0(B)	2.10	0.98	Lab. No. 91776	Crushed
LS+68	Limestone	01-18-68	2.45	2.34	31.0(B)	4.94	0.91	Lab. No. 68-4	Crushed
		04-14-67	2.45	2.35	33.4(A)	4.26	0.81	Lab. No. 67-1227	Crushed
		03-02-67	2.46	2.35	33.5(B)	4.59	0.94	Lab. No. 67-528	Crushed
		11-29-66	2.45	2.35	32.7(A)	4.44	0.97	Lab. No. 66-5155	Crushed
		02-08-66	2.45	2.34	33.1(B)	4.68	0.94	Lab. No. 66-199	Crushed
		03-04-65	2.45	2.34	33.2(B)	4.53	0.94	Lab. No. 65-58-P	Crushed
		10-15-64	2.44	2.34	29.6(B)	4.65	0.98	Lab. No. 36913	Crushed
		07-08-64	2.45	2.33	34.2(B)	5.31	0.95	Lab. No. 35085	Crushed
		04-03-64	2.42	2.31	34.9(A)	4.80	0.94	Lab. No. 33397	Crushed
		02-14-64	2.43	2.33	31.6(B)	4.60	0.95	Lab. No. 32601	Crushed
		11-01-63	2.44	2.32	43.3(B)	4.93	0.96	Lab. No. 31259	Crushed
		04-29-63	2.41	2.28	33.6(B)	5.50	0.93	Lab. No. 27891	Crushed
		08-08-62	2.36	2.21	39.6(B)	6.77	0.95	Lab. No. 24228	Crushed
		06-07-62	2.41	2.29	35.7(B)	5.25	0.96	Lab. No. 22819	Crushed
		08-28-61	2.40	2.29	33.6(B)	4.91	0.94	Lab. No. 18592	Crushed
		02-21-62	2.40	2.22	32.2(B)	5.52	0.92	Lab. No. 21180	Crushed
		03-30-61	2.37	2.24	35.4(B)	5.72	0.97	Lab. No. 15891	Crushed
		02-08-60	2.38	2.26	38.0(B)	5.73	0.94	Lab. No. 10345	Crushed
		10-02-59	2.38	2.24	37.5(B)	5.95	0.95	Lab. No. 9010	Crushed
		08-28-59	2.38	2.25	39.0(B)	5.87	0.92	Lab. No. 8460	Cores
		08-28-59	2.38	2.23		6.54	0.94	Lab. No. 8462	Crushed
		08-28-59	2.39	2.25	36.8(B)	6.03	0.91	Lab. No. 8461	Crushed
		04-06-59	2.37	2.22	37.7(B)	6.68	0.95	Lab. No. 6153	Crushed
		04-01-59	2.36	2.20		6.89		Lab. No. 6159	Crushed
		02-24-59	2.36	2.20	38.6(B)	7.16	0.91	Lab. No. 5680	Crushed
		05-19-58	2.50		27.5	3.95	0.87	Lab. No. 1480	Unknown
		05-19-58	2.36		30.2	5.63	0.91	Lab. No. 1481	Unknown
		05-19-58	2.36		31.2	6.02	0.93	Lab. No. 1482	Unknown
LS+76	Limestone	02-16-60	2.49	2.40	31.2(B)	2.40	0.89	Lab. No. 10344	Unknown
		05-20-59	2.44	2.34	31.9(B)	4.12	0.99	Lab. No. 6828	Unknown
LS+82	Limestone	12-31-64	2.45	2.37		3.61		Lab. No. 38232	Crushed
		10-12-64	2.44	2.34		4.32		Lab. No. 36938	Crushed
		08-29-63	2.45	2.35	28.6(A)	4.35	0.95	Lab. No. 30029	Crushed
		04-20-62	2.43	2.32	29.6(B)	4.70	0.90	Lab. No. 21705	Crushed
LS+85	Limestone	06-14-57	2.14	1.93	43.3(B)	10.84	0.97	Lab. No. 97998	Unknown
		06-14-57	2.43	2.32	33.3(B)	4.53		Lab. No. 98000	Unknown
		06-14-57	2.36	2.33	35.5(B)	5.83	0.98	Lab. No. 97999	Unknown
		06-14-57	2.36	2.23	38.7(B)	5.80		Lab. No. 98001	Crushed
LS+66	Limestone	12-25-62	2.46	2.38	29.6(B)	3.60	0.94	Lab. No. 90766	Crushed
		01-25-56	2.50		26.0(B)	3.26	0.95	Lab. No. 91217	Crushed
LS+67	Limestone	02-15-56	2.38		35.6(B)	5.20	0.94	Lab. No. 91444	Crushed
LS-81	Limestone	06-04-53	2.54		25.6(A)	3.03	0.96	Lab. No. 78809	Crushed
		03-04-53			25.0(A)		0.96	Lab. No. 77957	Ledge
LS+87	Limestone	01-14-54	2.33		39.0		0.93	Lab. No. 81663	Unknown
LS+63	Limestone	01-01-54	2.58		21.4	3.12	0.89	Lab. No. 61832	Ledge
		01-01-54	2.58		24.1	3.00	0.83	Lab. No. 61833	Ledge
		01-01-54	2.53		26.6	4.08	0.84	Lab. No. 61834	Ledge
		01-01-54	2.58		27.2	2.62	0.88	Lab. No. 61835	Ledge
		08-07-61	2.48	2.40	26.4(B)	3.40	0.97	Lab. No. 18242	Crushed
		04-05-56	2.55		27.2(B)	2.91	0.97	Lab. No. 92122	Crushed
		01-31-49	2.58		21.4(A)	3.12	0.89	Lab. No. 61832	Ledge
		02-01-49	2.58		24.1(A)	3.00	0.83	Lab. No. 61833	Ledge
		02-01-49	2.53		26.6(A)	4.08	0.84	Lab. No. 61834	Ledge
		02-01-49	2.58		27.2(A)	2.62	0.86	Lab. No. 61835	Ledge
		03-27-42	2.53		26.6(A)	3.40	0.95	Lab. No. 44660	Ledge

Figure 16. Results of tests completed on samples taken from the Florence, Fort Riley, Cresswell, and Herington Limestone Members.

Site Data Form No.	Type of Material	Date of Test	SP.GR. Wet	SP.GR. Dry	L.A. Wear	% Absorption	% Soundness	Source of Data	Type of Sample
Source of Data: Ft. Riley Limestone - Pfr									
LS+55	Limestone	04-12-67			31.6(C)			Lab. No. 67-1263	Crushed
		06-05-63	2.33	2.21	45.8(B)	7.60	0.90	Lab. No. 29451	Crushed
		05-07-63	2.47	2.35	30.8(B)	5.17	0.88	Lab. No. 28156	Crushed
		11-08-62	2.46	2.36	28.0(B)	4.40	0.96	Lab. No. 25731	Crushed
		06-05-63	2.33	2.21	36.8(B)	5.50	0.96	Lab. No. 28564	Crushed
		11-20-57	2.39	2.26	31.3(B)	6.06	0.88	Lab. No. 100105	Unknown
LS+83	Limestone	03-02-67	2.29	2.09	52.5(B)	9.72	0.88	Lab. No. 67-529	Crushed
		02-05-54	2.49		38.7(B)	4.39	0.74	Lab. No. 82084	Unknown
		02-05-54	2.32		46.5(B)	7.71	0.87	Lab. No. 82083	Unknown
		02-05-54	2.30		43.3(B)	7.94	0.90	Lab. No. 82082	Unknown
		02-05-54	2.50		30.0(B)	4.00	0.83	Lab. No. 82081	Unknown
		02-05-54	2.38		36.4(B)	5.76	0.82	Lab. No. 82080	Unknown
		02-05-54	2.02		50.8(B)	8.89	0.92	Lab. No. 82079	Unknown
		01-31-49	2.46		35.3(B)	4.94	0.67	Lab. No. 61831	Crushed
		01-31-49	2.28			9.29	0.87	Lab. No. 61830	Ledge
		01-31-49	2.35			6.62	0.76	Lab. No. 61829	Ledge
		01-31-49	2.51			4.39	0.81	Lab. No. 61828	Ledge
		01-31-49	2.46			5.01	0.59	Lab. No. 61827	Ledge
		01-31-49	2.44			4.92	0.70	Lab. No. 61826	Ledge
		01-31-49	2.45			5.01	0.74	Lab. No. 61825	Ledge
		01-31-49	2.47			3.94	0.66	Lab. No. 61824	Ledge
		07-10-46	2.24	2.01	54.8(A)	11.02	0.83	Lab. No. 51070	Crushed
		07-10-46	2.26	2.05	61.3(A)	10.04	0.75	Lab. No. 51072	Crushed
		07-11-46	2.31	2.13	58.2(A)	8.32	0.91	Lab. No. 51074	Crushed
		07-11-46	2.28	2.09	55.4(A)	8.91	0.98	Lab. No. 51073	Crushed
LS+60	Limestone	05-07-67	2.45	2.32	33.9(B)	5.42	0.83	Lab. No. 34012	Crushed
		06-06-60	2.45	2.33	32.4(B)	4.98	0.87	Lab. No. 11739	Crushed
		06-11-58	2.45	2.33		5.11		Lab. No. 1941	Crushed
		05-16-58	2.45	2.33	30.2(B)	5.02	0.83	Lab. No. 1552	Crushed
		04-15-68	2.47	2.35	32.0(B)	5.39	0.82	Lab. No. 987	Crushed
		04-15-68	2.47	2.35	32.0(B)	5.26	0.84	Lab. No. 988	Crushed
LS+50	Limestone	08-19-60	2.43	2.28	42.7(B)	6.39	0.84	Lab. No. 12506	Crushed
		06-02-60	2.40	2.25	38.8(B)	7.09	0.80	Lab. No. 11658	Crushed
		07-24-56	2.40		42.0(B)	7.32	0.76	Lab. No. 93933	Crushed
		07-17-56	2.41		41.5(B)	7.09	0.71	Lab. No. 93784	Crushed
		06-30-56	2.39		42.6(B)	7.33	0.81	Lab. No. 93513	Crushed
		06-26-56	2.41		41.7(B)	6.52	0.74	Lab. No. 93400	Crushed
		06-26-56	2.43		37.3(B)	6.13	0.77	Lab. No. 93397	Crushed
		05-22-56	2.42		37.8(B)	6.63	0.78	Lab. No. 92760	Crushed
		05-17-56	2.42		37.8(B)	9.48	0.76	Lab. No. 92715	Crushed
		05-07-56	2.42		35.8(B)	6.77	0.77	Lab. No. 92514	Crushed
		02-16-56	2.45		33.0(B)	6.06	0.77	Lab. No. 91427	Crushed
		01-30-56	2.39		40.2(B)	7.00	0.68	Lab. No. 91257	Crushed
		09-30-55	2.37		38.8(B)	7.51		Lab. No. 89786	Crushed
LS+58	Limestone	05-21-56	2.40		39.8(B)	6.93	0.75	Lab. No. 92761	Crushed
		05-22-56	2.39		41.8(B)	9.53	0.76	Lab. No. 92763	Crushed
		05-09-56	2.43		35.6(B)	6.40	0.74	Lab. No. 92562	Crushed
		04-11-56	2.41		43.6(B)	6.83	0.79	Lab. No. 92189	Crushed
		04-10-56	2.47		37.0(C)	6.04	0.79	Lab. No. 92172	Crushed
		02-29-56	2.35		45.8(B)	7.00	0.77	Lab. No. 91574	Crushed
		09-30-55	2.35		38.8(B)	6.92	0.78	Lab. No. 89784	Crushed
		07-24-56	2.29		45.4(B)	7.44	0.81	Lab. No. 93931	Crushed
		07-16-56	2.30		45.7(B)	7.06	0.85	Lab. No. 93751	Crushed
		06-27-56	2.34		42.6(B)	7.26	0.82	Lab. No. 93474	Crushed
LS+65	Limestone	04-04-57	2.44	2.32	36.7(B)	5.37	0.81	Lab. No. 97236	Crushed
		03-07-55	2.36		36.4	6.06	0.79	Lab. No. 86750	Crushed
		01-28-54	2.19		41.4(B)	9.17	0.98	Lab. No. 81966	Unknown
		01-28-54	2.24		45.2(B)	8.22	0.92	Lab. No. 81965	Unknown
		01-28-54	2.18		47.4(B)	8.22	0.95	Lab. No. 81964	Unknown
		03-23-50			48.0(A)			Lab. No. 71216	Crushed
		12-18-51	2.39		42.3(A)	5.69	0.78	Lab. No. 71296	Ledge
		01-11-50	2.18		48.5(A)	7.60	0.95	Lab. No. 66120	Crushed
		01-28-49	2.18		41.5(B)	6.70	0.94	Lab. No. 61813	Crushed
		01-28-49	2.50			4.29	0.70	Lab. No. 61812	Ledge
		01-28-49	2.57			6.09	0.92	Lab. No. 61811	Ledge
		01-25-49	2.17			8.75	0.93	Lab. No. 61809	Ledge
		01-25-49	2.25			8.76	0.87	Lab. No. 61810	Ledge
		03-04-47	2.50	2.40	34.9(A)	4.39	0.50	Lab. No. 53840	Ledge
		03-05-47	2.50	2.38	35.8(A)	4.74	0.66	Lab. No. 53805	Ledge
		03-19-47	2.10		44.2(A)	7.54	0.86	Lab. No. 53989	Crushed
		03-19-47	2.17		42.5(A)	7.05	0.79	Lab. No. 53990	Crushed
		05-03-46	2.18	2.03	48.5(A)	7.62	0.94	Lab. No. 49870	Crushed
		05-03-46	2.02	1.90	52.6(A)	6.21	0.92	Lab. No. 49871	Ledge
		05-03-46	2.18	2.01	50.6(A)	8.23	0.95	Lab. No. 49872	Ledge
LS+86	Limestone	05-07-56	2.34		43.6(B)	8.16	0.80	Lab. No. 92512	Crushed
		12-09-55	2.36		41.1(B)	7.30	0.75	Lab. No. 90726	Crushed
LS+62	Limestone	08-20-54	2.28		47.4(B)	8.66	0.73	Lab. No. 84436	Unknown
LS+54	Limestone	09-30-55	2.39		37.6(B)	7.04	0.82	Lab. No. 89785	Cores
LS+75	Limestone	01-28-54	2.25		48.2(B)	11.11	0.89	Lab. No. 81962	Unknown
		01-28-54	2.26		50.9(B)	10.28	0.94	Lab. No. 81961	Unknown
		01-28-54	2.25		51.3(B)	10.83	0.87	Lab. No. 81960	Unknown
		01-28-54			36.0(B)	5.56	0.94	Lab. No. 81959	Unknown
		02-28-49	2.41		38.2(A)	5.65	0.76	Lab. No. 62073	Ledge
		02-03-49	2.26		37.4(A)	10.87	0.82	Lab. No. 61887	Ledge
		02-03-49	2.27		54.5(A)	11.30	0.69	Lab. No. 61886	Ledge
		02-02-49	2.27		55.0(A)	9.90	0.88	Lab. No. 61885	Ledge
		12-15-41	2.29		50.6(A)	8.50		Lab. No. 43962	Unknown
		12-15-41	2.22		52.2(A)	10.70		Lab. No. 43963	Unknown
LS-73	Limestone	01-28-54	2.41		35.2(B)	5.78	0.95	Lab. No. 81958	Unknown
		01-28-54	2.70		39.4(B)	6.83	0.94	Lab. No. 81957	Unknown
		01-28-54	2.28		52.5(B)	9.72	0.95	Lab. No. 81956	Unknown
		02-16-49	2.30		58.1(A)	9.37	0.89	Lab. No. 61941	Ledge
		02-16-49	2.34		45.8(A)	7.36	0.90	Lab. No. 61940	Ledge
		02-16-49	2.44		35.3(A)	4.47	0.89	Lab. No. 61939	Ledge
		02-19-47	2.36	2.19	42.2(A)	7.72	0.84	Lab. No. 53652	Ledge
		02-19-47	2.37	2.24	46.3(A)	6.05	0.79	Lab. No. 53651	Ledge
		02-19-47	2.31	2.12	47.0(A)	8.87	0.87	Lab. No. 53653	Ledge
LS+61	Limestone	04-04-51	2.47		33.0(A)	4.45	0.75	Lab. No. 71309	Ledge
		04-04-51	2.51		34.6(A)	3.88	0.85	Lab. No. 71304	Ledge
		04-04-51	2.44		34.0(A)	4.84	0.90	Lab. No. 71298	Ledge
		04-04-51	2.26		38.9(A)	6.54	0.95	Lab. No. 71296	Ledge
		02-03-49	2.41		41.9(A)	5.35	0.74	Lab. No. 61902	Crushed
		02-03-49	2.67			8.70	0.79	Lab. No. 61901	Ledge
		02-03-49	2.14		32.9(A)	4.61	0.82	Lab. No. 61900	Ledge
		02-03-49	2.46			4.98	0.56	Lab. No. 61899	Ledge
LS+88	Limestone	02-09-49	2.36		43.5(A)	6.55	0.84	Lab. No. 61910	Ledge
		02-09-49	2.40		39.6(A)	5.53	0.82	Lab. No. 61909	Ledge
		02-09-49	2.44		36.0(A)	4.69	0.87	Lab. No. 61908	Ledge
		02-09-49	2.46		35.8(A)	5.26	0.52	Lab. No. 61907	Ledge
		02-09-49	2.49		31.2(A)	2.98	0.92	Lab. No. 61903	Ledge
LS+71	Limestone	12-30-47			48.4(B)	8.96	0.80	Lab. No. 57926	Crushed
		01-28-49	2.32		46.6(A)	7.95	0.91	Lab. No. 61823	Ledge
		01-28-49	2.33			7.22	0.86	Lab. No. 61822	Ledge
		01-28-49	2.37			6.67	0.87	Lab. No. 61821	Ledge
		01-28-49				6.20	0.88	Lab. No. 61820	Ledge
		01-28-49	2.38			6.26	0.87	Lab. No. 61819	Ledge
		01-14-48	2.34	2.16	47.1(B)		0.80	Lab. No. 58100	Crushed
		07-17-47	2.38	2.24	42.5(A)	6.30	0.90	Lab. No. 55644	Crushed
		07-17-47	2.37	2.23	45.7(A)	6.57	0.92	Lab. No. 55643	Crushed
LS+74	Limestone	02-08-49	2.26		47.6(A)	9.94	0.91	Lab. No. 62074	Ledge
		02-01-54	2.35		44.0(B)	7.33	0.89	Lab. No. 81963	Unknown
		02-03-49	2.33		40.8(A)	7.71	0.88	Lab. No. 61888	Ledge
		02-01-49	2.39		45.9(A)	6.79	0.82	Lab. No. 61872	Ledge
		02-01-49	2.34		43.6(A)	7.97	0.83	Lab. No. 61871	Ledge
		01-31-49	2.37		44.9(A)	10.34	0.19	Lab. No. 61870	Ledge
		12-12-41	2.30		48.4(A)	7.60		Lab. No. 43951	Unknown
		12-12-41	2.43		48.4(A)	5.90		Lab. No. 43950	Unknown
		12-12-41	2.49		48.4(A)	3.70		Lab. No. 43949	Unknown
		12-05-41	2.32		45.7(A)	7.40		Lab. No. 43943	Unknown
Source of Data: Florence Limestone - Pf									
RC+59	Residual Chert	12-15-41	2.57		27.7(A)	1.70		Lab. No. 43966	Unknown

Figure 16. Continued

Site No.	Material	Percent Retained 1½	3/4	3/8	4	8	16	30	50	100	Wash	G.F.	L.L.	P.I.	Sp.Gr. Wet	Sp.Gr. Dry	Wt./Cu.Ft.	%L.A. Wear	Soundness	% Absorption	Source of Data
Source of Material: Nebraskan and Kansan Terrace Deposits - Qnkt																					
CG+70	Chert Gravel	7	39	64	79	86	90	91	92	93	6.7	6.41						20.2(A)	0.94		Lab. No. 81953
															2.35			20.2(A)	0.98		Lab. No. 23616
												4.34						20.9(A)	0.94		Lab. No. 61938
												4.33						19.2(A)	0.91		Lab. No. 61942
												7.02			2.35				0.95		Lab. No. 44189
CG+78	Chert Gravel																	22.7(C)	0.98		Lab. No. 86751
																		23.6(B)	0.97		Lab. No. 82086
CG+79	Chert Gravel	1	23	54	69	76	80	83	84	84	15		42	23				19.2(A)	0.99		Lab. No. 82078
												4.34						16.8(B)	0.98		Lab. No. 61943
												4.75			2.44			20.5(B)	0.91		Lab. No. 51067
																		17.1(B)			Lab. No. 43373
												5.64					94.0	17.0(B)			Lab. No. 42726
												7.51			2.44		89.0	18.6(A)			Lab. No. 42727
CG+72	Chert Gravel	13	37	53	62	70	74	75	76	77	23		50	28				19.2(A)	0.98		Av. 81955
												5.13						22.1(A)	0.92		Lab. No. 61944
												4.07						24.1(B)			Lab. No. 49842
Source of Material: Alluvium and Terrace Deposits - Qalt																					
CG+77	Chert Gravel		54	100	100	100	100	100	100	100					2.45	2.37		17.9(B)	0.99	3.18	Lab. No. 66-3518
												6.87			2.45			27.1(B)	0.98		Lab. No. 68-1191
															2.45			18.8(B)	0.97		Lab. No. 59432

Figure 17. Results of some gradation and quality tests on gravel from Chert Gravel Terrace Deposits and the Alluvium and Terrace Deposits map units.