NSF Science Teachers Institute........ 1958

KANSAS STATE TEACHERS COLLEGE
EMPORIA, KANSAS

Second Geologic Field Conference

Saturday, June 7, 1958

in the

Flint Hills

of Lyon, Chase, Morris, and Wabaunsee Counties, Kansas

....

Field trip conducted by

State Geological Survey of Kansas, University of Kansas

Lawrence, Kansas

SECOND GEOLOGIC FIELD CONFERENCE

in

the FLINT HILLS

of Lyon, Chase, Morris, and Wabaunsee Counties, Kansas

June 7, 1958

For

National Science Foundation SCIENCE TEACHERS INSTITUTE...Summer 1958
KANSAS STATE TEACHERS COLLEGE, EMPORIA, KANSAS
Director of Institute .....Otto M. Smith, Oklahoma State University
Co-Directors ....Merle E. Brooks and Weldon N. Baker, KSTC

Conference Leaders .... J.M. Jewett and Stanton Ball,
State Geological Survey of Kansas
C. F. Gladfelter, KSTC

Pre-conference talks (June 5, 6).....Frank C. Foley, William W. Hambleton,
J.M. Jewett, and Grace Muilenburg,
State Geological Survey

Guidebook prepared under supervision of Grace Muilenburg

State Geological Survey, University of Kansas, Lawrence, Kansas
Frank C. Foley, Director
William W. Hambleton, Associate Director

June 1958

CONTENTS Page

ILLUSTRATIONS

CONFERENCE PROGRAM

Pre-conference talks on geology....

Thursday and Friday afternoons, June 5 and 6.

Field conference	8:30 a.m. Saturday, June 7. Start from Science Hall, KSTC. Route: Emporia-Strong City via U.S. 50; Strong City-Elmdale and Camp Wood via Cottonwood Falls; Elmdale-Council Grove via U.S. 50 and K. 13; Council Grove-Allen via U.S. 56; Allen-Eskridge via country road; Eskridge-Alma-glacial deposit area via K. 99.
Stop 1	Exposure of Florena Shale (bed above Cottonwood in Beattie Limestone) about 3 miles east of Strong City, Chase County.
Stop 2	Exposures of rock layers from top of Foraker limestone upward to Cottonwood limestone (lowermost member of Beattie limestone), on hill east of Cottonwood River, near Elmdale, Chase County.
Stop 3	LUNCH. Study of Permian rocks at Camp Wood.
Stop 4	Exposures of Threemile Limestone (member of Wreford Limestone) and Speiser Shale in road cut along K. 13, about 4 miles south of Council Grove, Morris County.
Stop 5	Algae in Funston Limestone, in road cut about 1 mile east of Morris-Lyon County line, on U.S. 56, Lyon County.
Stop 6	Outcrop of Red Eagle limestone. Fossil algae in Howe limestone (uppermost bed of Red Eagle), in road cut about 3 miles north of Allen, Lyon County.
Stop 7	Glacial deposits. Many boulders to be seen, in pasture east of K. 99, about 7 miles north of Alma, Wabaunsee County.

We wish to thank the YMCA headquarters in Topeka for granting permission to use facilities at Camp Wood at the noon hour.

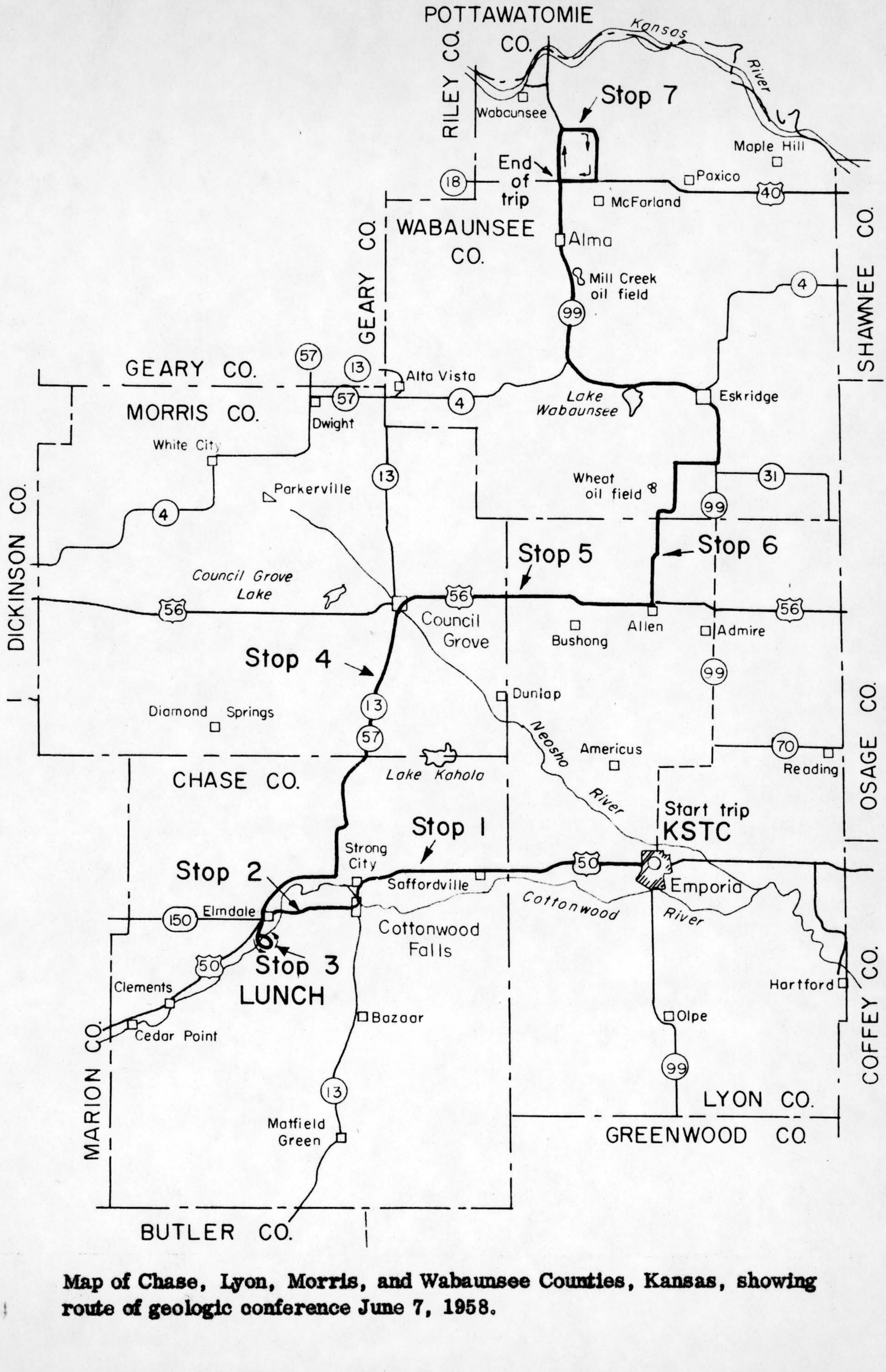
INTRODUCTION

Lessons in geology may be learned at any place that can at all qualify as the "open"; at least there can be an attempt at learning. An ancient philosopher has said, "The love of mountains is best," but lovers of mountains must love, too, the open plains and lower ranges of the prairie country. The Flint Hills region of Kansas offers a great variety of lessons in geology.

A short excursion in the Flint Hills gives us a view of rock layers that reveal much history, no little part of which concerns faunas and floras of ancient seas. The hills and valleys tell stories of erosion and the whole landscape is a chapter on history that is much more modern. Climate much different from that of the present is recorded by glacial deposits in a locality in the northern part of the field-trip route.

Some persons have failed to see anything beautiful in this region, and the hills have been called "barren" and "depressing". Perhaps the Flint Hills are more pleasing when they are at least in part understood. We hope that you will like the Flint Hills.

J. M. J.



Map of Chase, Lyon, Morris, and Wabaunsee Counties, Kansas, showing route of geologic conference June 7, 1958.

ROAD LOG

Approximate
mileage

0.0 Assemble for conference at front entrance of Science Hall, KSTC, Emporia, 8:30 a.m.

Emporia is the county seat of Lyon County. The population is 15,166 (1957 census). Approximate altitude is 1,140 feet above sea level.

Incorporated as the Emporia Town Company in 1857, Emporia has lived up to its Greek name (from Emporus, meaning merchant) during its first 100 years. Because of its location on the eastern edge of the Flint Hills region, which is a world-famous grazing land, Emporia has been for many years an important shipping center for cattle. The city also is one of the state's oldest cultural and educational centers. KSTC, for example, was opened as the State Normal School in February 1865, at which time educational institutions dedicated to the training of teachers were practically unknown in this part of the United States.

Lyon County, organized in 1858, has an approximate land area of 852 square miles. The population is 24,652 (1957 census). Principal industries are cattle raising and shipping and farming. Industrial minerals include oil, sand and gravel, and stone.

Physiographically, the eastern two thirds (or three-fourths) of Lyon County is in the Osage Cuestas and the western part in the Flint Hills. Land surfaces range from about 1,050 feet to 1,450 feet above sea level. Outcropping rocks, sedimentary in origin, range in age from Pleistocene (approximately the last 1 million years) to Pennsylvanian (210 million to 235 million years old).

Most of the city of Emporia is built on the Emporia Terrace, which is composed of Pleistocene, or Ice Age, deposits. Bedrock exposed in Emporia, north and west of KSTC campus, is late Pennsylvanian in age.

Drive west on West 12th Avenue.

0.8 College of Emporia, on right.

Founded by the Presbyterian synod of Kansas in October 1882, the College of Emporia was opened formally in November 1883. Attendance the first year was 17; the second year, 80. Present enrollment exceeds 200.

The Anderson Memorial Library at the College of Emporia (note stone building with dome), which was dedicated June 4, 1902, is believed to be the first Carnegie library established west of Mississippi River and the first Carnegie library on an American college campus. It was erected as a memorial to John Byars Anderson, a former trustee of the college, who lent books to Andrew Carnegie when Carnegie was a miner boy in Pennsylvania.

1.0 Turn left (south) on Lincoln Street.

1.5 Turn right (west) on 6th Avenue (U.S. 50). Continue west on U.S. 50.

2.0 Stockyard on left. Leave Emporia.

From the west edge of Emporia to the curve in the highway just east of Plymouth, we are on the Emporia Terrace. This extensive terrace, which was developed during the Kansan Stage of the Great Ice Age (Pleistocene time), rises about 20 feet above the alluvial floodplain of Cottonwood River. To the north are higher terraces, developed earlier in the Pleistocene period, and south across the river are lower terraces, developed later in the Pleistocene period.

3.85 Kansas Turnpike; underpass.

5.6 Cottonwood Friends Church, on left.

6.0 Cottonwood School, on right.

7.25 Cross Linck Creek.

8.55 Plymouth Store, on right.

8.95 Town of Plymouth.

In the vicinity of Plymouth, leave Emporia Terrace and travel on floodplain surface for several miles.

The sands and gravels of the alluvium and terrace deposits along Cottonwood and Neosho Rivers are important sources of ground water. At several places there are pits where terrace gravels and alluvial sand and gravel are obtained chiefly for use as road metal. An occurrence of volcanic ash in the Emporia Terrace in Emporia (between 6th and 7th Avenues just east of Garfield Street) was mined for use as an abrasive around 1910. Some of the silts in these deposits are potential ceramic raw materials.

"Geology, Mineral Resources, and Ground-Water Resources of Lyon County, Kansas" (Volume 12 of the State Geological Survey of Kansas publications), by Howard O'Connor and others, contains detailed information on the rock formations, including their economic value.

9.7 Leave Lyon County, enter Chase County.

Chase County , organized in 1859, has an approximate land area of 774 square miles, and the population is 4,285 (1957 census). The principal industry is cattle raising--about 70 percent of the county's area is unplowed grassland. Oil, gas, sand and gravel, and stone are among the industrial minerals.

All of Chase County is in the physiographic province known as the Flint Hills--escarpments and upland, dissected by the Cottonwood River and its tributaries, are dominant features. Range in elevation is from about 1,100 feet above sea level to about 1,500 feet above sea level. Outcropping bedrock is Permian in age (a geologic period existing between 185 million and 210 million years ago), and surficial deposits are Pleistocene and Tertiary in age.

"Geology, Mineral Resources, and Ground-Water Resources of Chase County, Kansas" (Volume 11 of the State Geological Survey of Kansas publications), by Raymond C. Moore and others, contains maps and text that present in detail the areal and economic geology of this Flint Hills county.

11.2 Dunlap to right (north).

12.1 Saffordville to left (south).

14.4 Note terrace gravels.

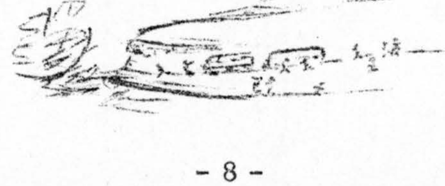
About 3 miles west of the Lyon-Chase County line, we will go from the floodplain onto a high terrace. Some of the terraces north of Cottonwood River in eastern Chase County have elevations that are from 50 to 100 feet above the present floodplains. Tops of terraces are remnants of former floodplains.

14.8 Neva Limestone, uppermost member of the rock formation called Grenola Limestone, exposed in road cut. This is the first noticeable exposure of bedrock to be seen along U.S.50 west of Emporia. During the next mile we will see occasional outcrops of Grenola Limestone and Eskridge Shale.

15.2 Neva Limestone exposures.

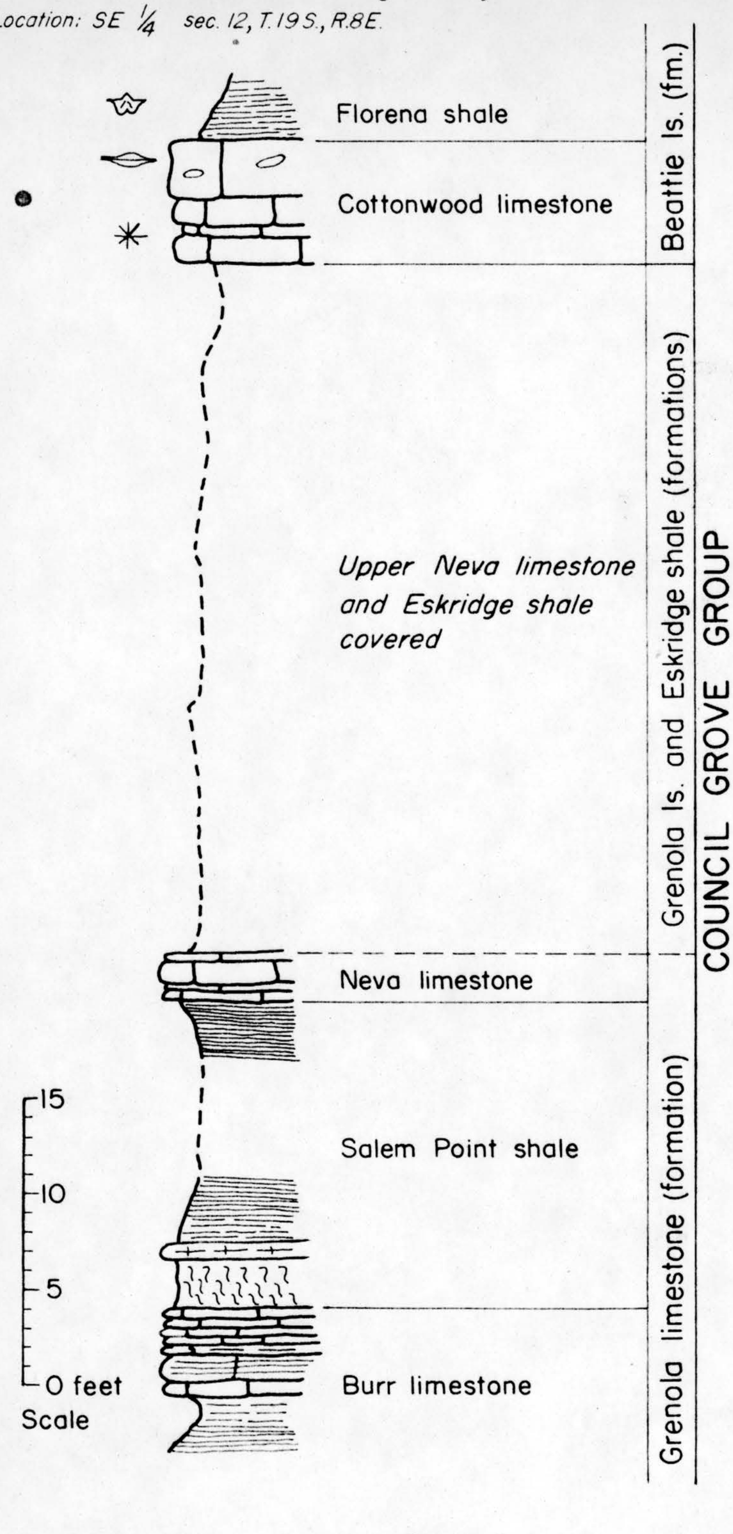
15.9 Cross Peyton Creek.

16.2 STOP 1. Buses park at picnic area, on left. (Geology described on next page.)



STOP I. Fossil-collecting locality in Permian rocks east of Strong City, Chase County

Location: SE 1/4 sec. 12, T. 19 S., R. 8 E.



Section measured by Stanton Ball, State Geological Survey 1957

Several types of fossils may be found in the Florena shale exposed near a roadside park on U. S. 50 about 3 miles east of Strong City. The brachiopod Chonetes is especially abundant.

Fusulinids and algae may be seen in the Cottonwood limestone, which occurs below the Florena shale.

The graphic section on the left shows the sequence of Permian rocks exposed at this place.

KEY TO SYMBOLS USED FOR ROCK TYPES SHOWN IN SECTIONS IN THIS BOOKLET

KEY TO FOSSIL SYMBOLS USED IN THIS SECTION AND IN ALL SECTIONS IN BOOKLET

- Brachiopods and other fossils
- Fusulinids
- Pelecypods (clams)
- Algae

Continue west on U.S. 50. Except for exposures of Grenola Limestone and Eskridge Shale in the valley area about a mile ahead, outcropping rocks seen between STOP 1 and Strong City are younger than the Beattie Limestone. Most are rocks of the Council Grove Group, but high on the hills east of Strong City rocks of the Chase Group may be seen.

19.6 Section in road cut: Blue Rapids Shale up to and including a part of the Threemile Limestone. Entire sequence of Funston Limestone and Speiser Shale formations shown. The Threemile is the lowermost unit of the Wreford Limestone formation.

19.85 City limits, Strong City. The Flint Hills Rodeo, annual event at Strong City, is on. Cowboys and others (perhaps even science teachers) from all parts of the world attend. (Stay with the bus and Professor Gladfelter will expound.)

20.3 Turn south on K.13; drive through business district of Strong City.

Altitude at Strong City, which has a population of 659 (1957 census), is about 1,180 feet above sea level.

Settled in 1871 and 1872, on the mainline of the Atchison, Topeka, and Santa Fe Railroad about 1 1/2 miles north of Cottonwood Falls, Strong City was known as Cottonwood Station until 1881. In that year the name was changed to Strong City, in honor of W. B. Strong, then president of the Santa Fe Railroad.

The cattle-feeding operations west of town, where several thousand steers commonly are being fattened at one time (you'll see?) indicate the prominence of the cattle industry in this Flint Hills community. In past years Strong City was one of the country's major rock-products centers. Nearby quarries supply especially large quantities of building stone and crushed rock for the railroads. Limestones that have been quarried include Neva, Cottonwood, Morrill, Eiss, Crouse, Funston, and Threemile.

20.7 Railroad, 5 tracks.

21.45 Floodplain of Cottonwood River.

21.85 City limits, Cottonwood Falls.

22.1 Cross Cottonwood River. Dam and old mill site on right.

22.2 Turn right on Main Street in Cottonwood Falls; proceed toward Elmdale.

The population of Cottonwood Falls, county seat of Chase County, is 1,039 (1957 census). Altitude is about 1,200 feet.

Cottonwood Falls was incorporated as a town in 1858 (third-class city in 1872). Early in its history Cottonwood Falls became noted for the excellent quality of building stone obtained from quarries in the neighborhood. The most famous is the Cottonwood Limestone, which throughout the years has remained one of the most popular of the state's building stones. The stone has been used extensively over a wide area. The Chase County courthouse in Cottonwood Falls, built of Cottonwood Limestone in 1870, not only is a fine example of Victorian architecture but also shows the attractiveness and durability of the stone. Most of the stone in the Statehouse at Topeka is Cottonwood Limestone from Chase County.

Outcropping rocks between Cottonwood Falls and Elmdale are of the upper part of the Council Grove group and the lower part of the Chase group. (See page 35.)

22.8 Sterns Shale and Eiss Limestone exposed.

23.4 Note erosional escarpments of left.

23.8 Upper Bader formation; Hooser Shale and Middleburg Limestone exposed.

23.95 Rocks exposed: Eiss Limestone up to Crouse Limestone.

24.7 Hills on either side capped by Wreford Limestone.

25.6 Windmill on right. Wreford Limestone exposed on left.

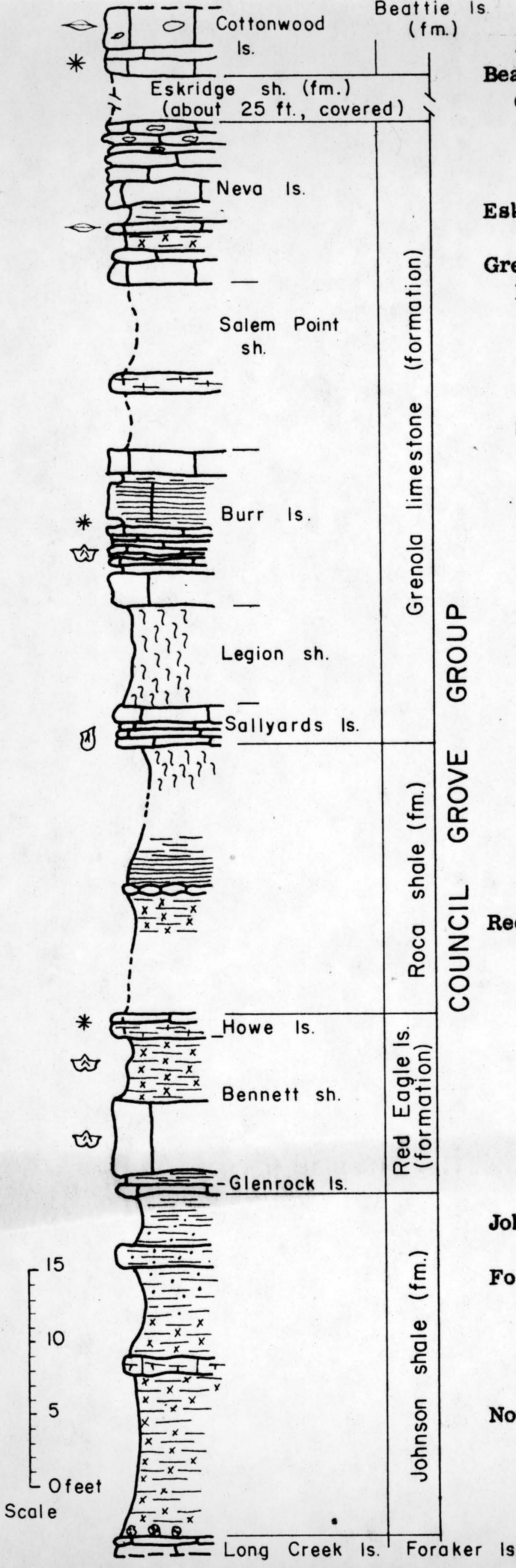
26.35 Crossroads. On Wreford Limestone. Road has followed east dip of rocks.

26.8 On Cottonwood Limestone.

26.9 STOP 2. Elmdale Hill. Graphic section on next page. (Buses unload on top of hill; then proceed to foot of hill across bridge, where reloading will take place.)

Elmdale Hill is one of the best localities in the state where Permian stratigraphy can be studied. Here one can observe a sequence of rock layers of the Council Grove Group from the Cottonwood Limestone at the base of the Beattie formation (top of hill where buses unloaded) down to the Americus Limestone at the base of Foraker formation (near water level in Cottonwood River at foot of hill).

As we go down the hill we will examine some of these 200-million-year-old rock units and perhaps collect fossil and mineral specimens. Fusulinids, brachiopods, sea-urchin spines, crinoid fragments, and algae are among the fossils found here. Zones of red chert, quartz, and celestite in the Long Creek Limestone near the base of the section are of interest to geologists.



STOP 2. Elmdale Hill, Chase Co.

Location: Cen. sec. 26, T. 19 S., R. 7 E.

Beattie limestone:

Cottonwood limestone member:

Limestone, light gray, weathers nearly white; upper part slightly cherty, numerous small fusulinids; lower part, platy, algal.

Eskridge shale:

Shale, covered.

Grenola limestone:

Neva limestone member:

Limestone, yellowish gray, and shale, gray and yellow; upper limestone pitted by weathering; fusulinids somewhat abundant in limestone and shale in lower part; lowermost part algal.

Salem Point shale member:

Shale, mostly covered, soft limestone "box work" in middle part.

Burr limestone member:

Limestone, light ashy gray, dense, but composed of microscopic foraminifera and algae; breaks into angular blocks that ring when struck with hammer.

Legion shale member:

Shale, dark gray, weathers yellowish and spotted; contains brachiopods (Neospirifer), crinoid fragments.

Sallyards limestone member:

Limestone, light ashy gray, thin to platy beds; grades into calcareous shale below.

Roca shale:

Shale, partly covered, contains impure limestone in middle part.

Red Eagle limestone:

Howe limestone member:

Limestone, bluish gray, mass of small fossils, foraminifera, and algae.

Bennett shale member:

Shale and dolomitic limestone; abundance of fossils in shale; sea urchin spines plentiful; persistent zone of small brachiopods (orbiculoids) in basal part.

Glenrock limestone member:

Limestone, gray, fusulinids.

Johnson shale:

Shale and impure limestone.

Foraker limestone:

Long Creek limestone member:

Limestone, gray, zone of red chert (and quartz) and celestite at top; not well exposed along road.

Note: remainder of Foraker formation is fairly well exposed in river bank south of road. Americus limestone member is slightly above normal water level. *(Section measured by Howard G. O'Connor, 1947)*

Leave Elmdale Hill, head west across Cottonwood River. We are again on the alluvial surface of Cottonwood Valley.

28.1 Arrive at Elmdale, The altitude here is about 1,200 feet above sea level.

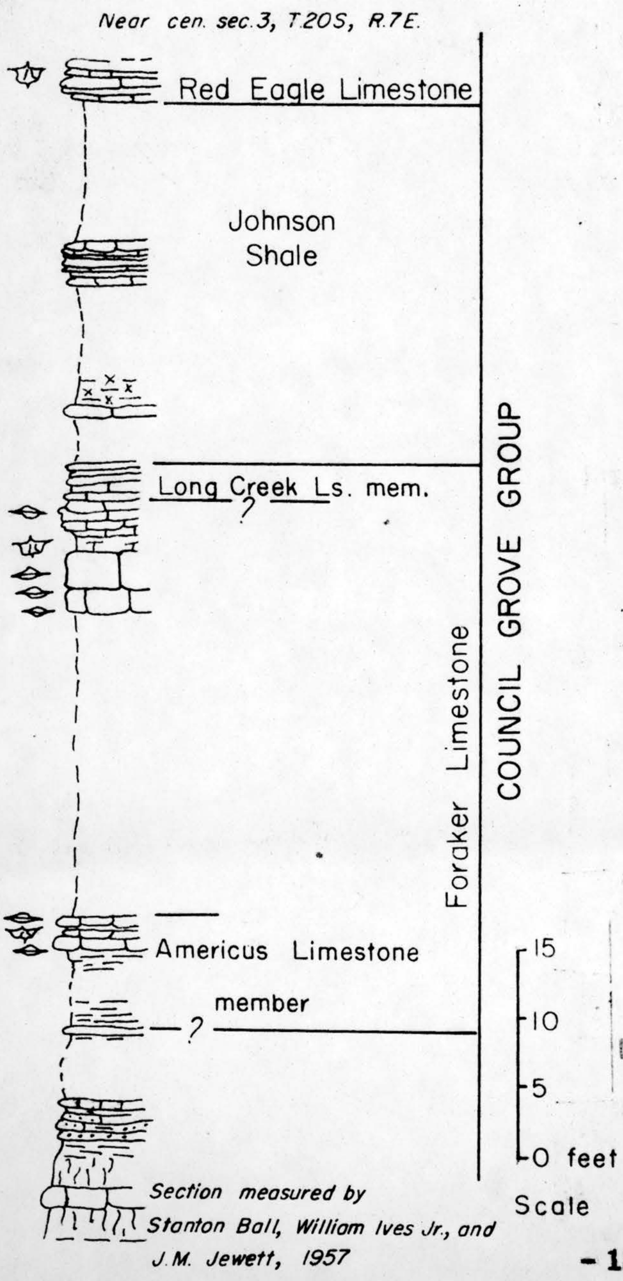
Elmdale, which became a third-class city in 1904, is an important cattle-shipping station.

28.4 Turn left (in Elmdale), parallel to railroad tracks. Follow road.

30.3 Arrive at bridge-entrance (6 ton load limit) to Camp Wood, on southeast side of Cottonwood River. Enter <u>Camp Wood.</u>

<u>STOP 3.</u> Follow conference leaders. General discussion of the geology of area. Study of some of the rocks shown in the section below. LUNCH

STOP 3. Camp Wood



An interesting aspect of rock study is an attempt to note characteristics that give the successive ledges individuality. Rocks exposed here at Camp Wood lend themselves to this type of study. For example, the pitted surface of the Red Eagle Limestone seen at the top of the section is a weathering characteristic that may be identified over large areas. A platy limestone or siltstone commonly occurs in the upper part of the Johnson Shale, (Remember Elmdale Hill?)

Sparse fragments of celestite and quartz are characteristic of the upper part of the Long Creek Limestone. An abundance of fusulinids (fossils that look like wheat grains) characterize the Hughes Creek Shale. The Americus Limestone, which crops out near the east end of the lake dam, weathers out as large distinct blocks for many miles in the Flint Hills area. A suggestion of this is seen here. Below the Americus the Hamlin Shale contains a succession of argillaceous limestones and siltstones separated by arenaceous shales. Note the bed of algae in about the middle of the Hamlin and the lobate appearance of the rocks in the lower part.

Board buses. Retrace route to Elmdale.

32.7 Turn left (in Elmdale); railroad crossing (3 tracks).

32.8 Junction, U.S. 50. Turn right (northeast) on U.S. 50.

Surface on alluvium of Cottonwood Valley.

33.25 Cross Middle Creek.

34.7 Cross Diamond Creek.

35.35 Neva Station.

36.0 Note east dip of rocks on left (north); this is the east flank of the Nemaha Anticline. Type exposure of Neva Limestone on left.

37.15 Bedrock, Beattie limestone and younger Council Grove rocks, exposed in road cuts for next half mile. From the time we left Camp Wood until now, we have been on the floodplain of the Cottonwood River.

38.9 Junction, U.S. 50 and K.13 and K.57. Turn right, right away.

39.0 Turn right again and be thankful for an air-conditioned bus.

> Here the lowing herds graze high
> And in the air we sense(?)
> The strength Strong City lives by.

39.1 Continue northward on K. 13 and K.57.

The hill to the left is capped by Wreford Limestone of the Chase Group of Permian rocks. Continue up Fox Creek Valley; the hills on either side are capped by Wreford Limestone and younger rocks of the Chase Group. In road cuts, for the next 6 or 61/2 miles, rock units of the upper Council Grove Group are exposed.

41.4 The stone house, stone barn, and other stone farm buildings on the left are examples of the usefulness of Chase County limestones. The house, built in 1881, is of Cottonwood Limestone and the barn of Wreford Limestone. (Ask Professor Gladfelter to tell the story of the wine cellars.)

41.9 Schoolhouse to left of highway constructed of Cottonwood Limestone; built in May 1882. Rocks in the Bader Limestone are exposed in the road cut.

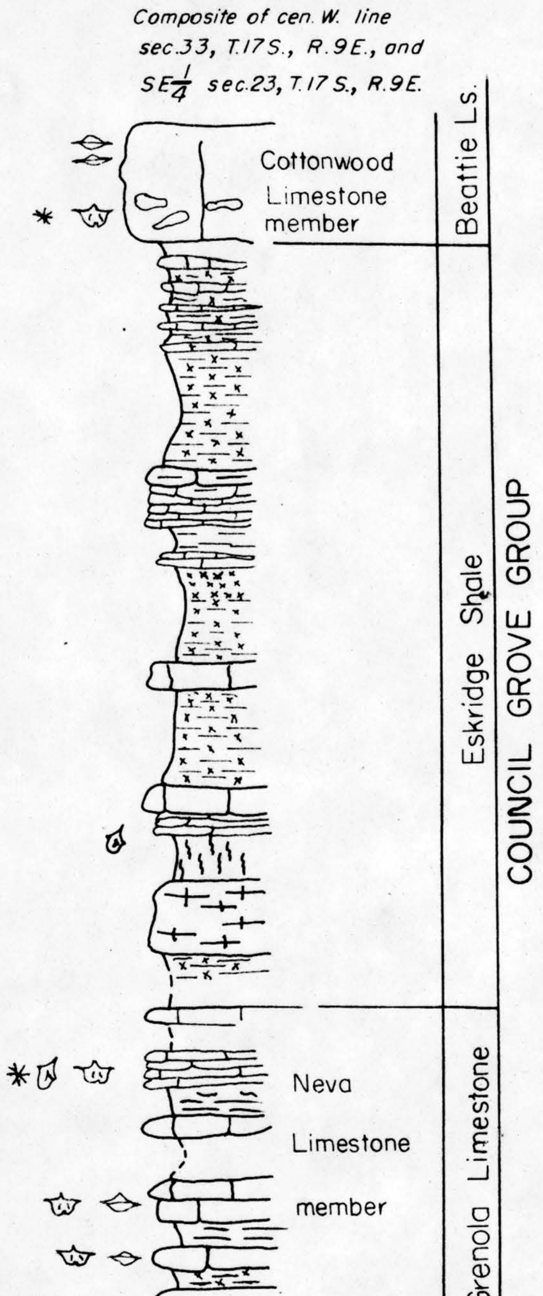
44.3 Funston Limestone exposed.

45.1 Outcrop of Wreford Limestone.

45.6 Kinney Limestone.

45.7 Florence Limestone, lowermost member of the Barneston Limestone, Chase Group, crops out on either side of the road.

The Flint Hills Upland surface we will be on for the next 5 or 6 miles is developed on the Barneston Limestone, of which the Florence Limestone and the Fort Riley Limestone are conspicuous members. Note the expansive views from this vantage position.



Section measured by Stanton Ball, 1957

Section at Lake Kahola.

Lake Kahola is on the Chase-Morris County line 6 miles east of Kansas 13. A graphic section of rocks exposed in the lake's spillway, secs. 34 and 35, T. 17 S., R. 9 E., Morris County, is included here.

Several kinds of highly colored rocks may be seen in the Eskridge Shale, and the limestones above and below also are interesting.

Undercutting in the Eskridge Shale below the Cottonwood Limestone is evidence that the construction of the dam was not based on adequate geologic advice.

48.05 Leave Chase County, enter Morris County.

Organized in 1858, Morris County has an approximate area of 707 square miles and a population of 8,003 (1957 census). Livestock raising and farming are major occupations. Mineral resources include oil, sand and gravel, stone, and gas.

Morris County, like Chase County, is in the heart of the Flint Hills region and the landscape is dominantly grass-covered upland and benchlike slopes. Altitudes are about the same as in Chase County. Except for the surficial deposits of Pleistocene and Tertiary age, rock units that crop out are Permian in age.

48.6 Outcrop of Fort Riley Limestone. The Fort Riley Limestone ranks with the Cottonwood Limestone as one of the state's best building stones.

50.15 Fort Riley Limestone.

50.6 Outcrop of Florence Limestone. Because of the flint, or chert, that persists in this rock unit, commonly it is called "Florence flint."

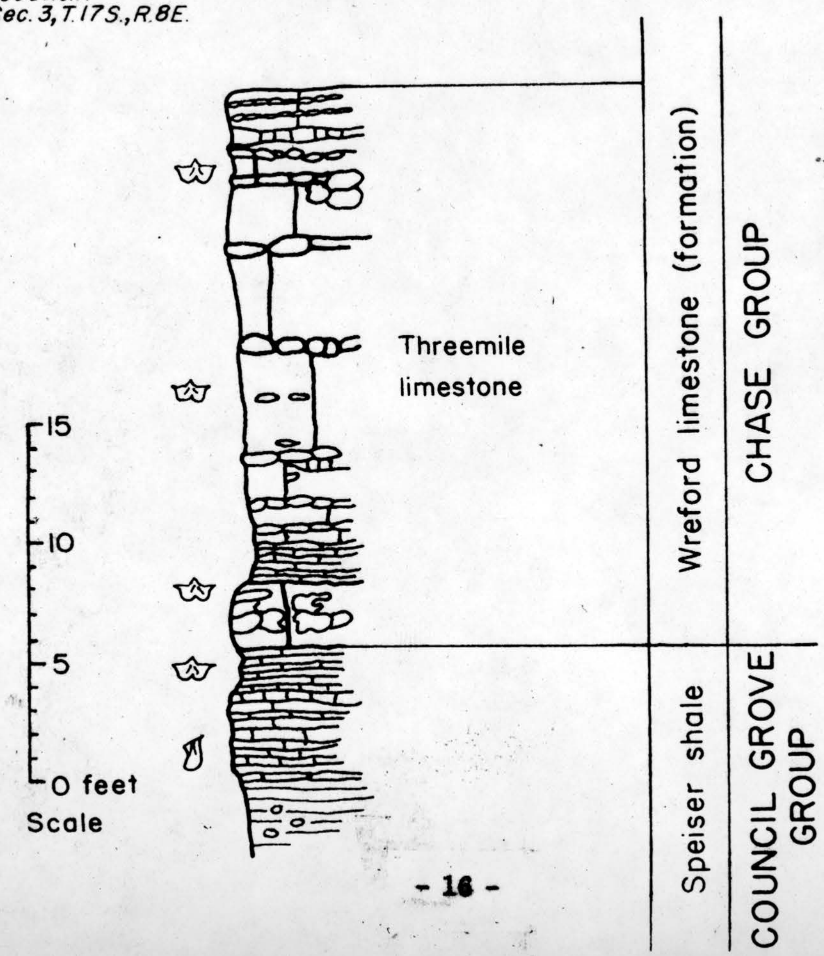
51.4 Florence Limestone.

53.0 Wreford Limestone exposed. Surface from here to STOP 4 developed on Wreford.

53.6 <u>STOP 4.</u> Buses park along highway.

STOP 4. Inactive limestone quarry and road cut in flinty limestone, on K.13 south of Council Grove, Morris County.

Location: Sec. 3, T.17S., R.8E.



Most of the transgressive phases of the Threemile cyclothem (see page 28) are represented in the roadside exposure.

Observe the chert in the limestone. Look for fossils.

Section measured by Donald E. Hattin, University of Kansas, 1954

From STOP 4 to Council Grove outcropping rocks are Wreford Limestone and lower rocks down to (or close to) the base of the Crouse Limestone.

54.0 Fourmile Creek.

56.85 Funston Limestone to Threemile Limestone exposed.

57.2 Threemile Limestone.

57.5 City Limits, Council Grove. Outcrop of Crouse limestone at city limits.

Council Grove, county seat of Morris County, has an approximate altitude of 1,230 feet above sea level. The population (1957 census) is 2,683.

Council Grove, although not incorporated as a town until 1858, is "chuck-full" of nearly a century and a half of Kansas history--four centuries, if we include Father Padilla's missionary work and his fatal journey in the vicinity in 1545. Travelers during the early 1880s considered the spot a favorite camp site and crossing of Neosho River. In 1825, under the famous Council Oak, the U.S. Government negotiated with the Osage Indians a treaty for the right-of-way for the trade route known as the Santa Fe Trail. U.S. 56 through Council Grove follows this old trail.

Much of the city's historic lore is preserved in the Kaw Mission Museum. The mission building of native stone (probably Wreford Limestone), dates back to 1849 and 1850, when the Methodist Episcopal Church South, established a school for the Kaw Indians brought to the reservation surrounding Council Grove in 1847. Post Office Oak, Last Chance Store, Hays Tavern, and Hermit's Cave are among other historic places to visit in Council Grove.

Today's Council Grove is a shopping and market center for the prosperous ranching and diversified farming country that surrounds it.

57.8 Elm Creek.

58.1 Railroad crossing (single track).

58.25 Junction K.13 and U.S. 56. Turn right (east). Hays Tavern to left.

58.4 Neosho River.

58.5 Madonna of the Trail Monument, Post Office Oak, and Council Oak on left.

58.85 Railroad crossing.

58.95 Garfield School on left.

59.6 Historical Marker on left (north). Leave Council Grove.

We are driving on Wreford Limestone. In the first road cut, base of Threemile Limestone. In second road cut, about a mile east of Council Grove, Funston Limestone.

59.9 Wreford Limestone.

60.05 Threemile Limestone (lowermost member of Wreford formation).

Wreford Limestone and slightly lower rocks in road cuts for next several miles.

62.9 Outcrop of Threemile Limestone.

64.9 Junction with road to Dunlap. Morning* School, Dist. 70 left (north). Continue on U.S. 56.

65.9 Leave Morris County, enter Lyon County. Outcrop of Crouse Limestone at county line.

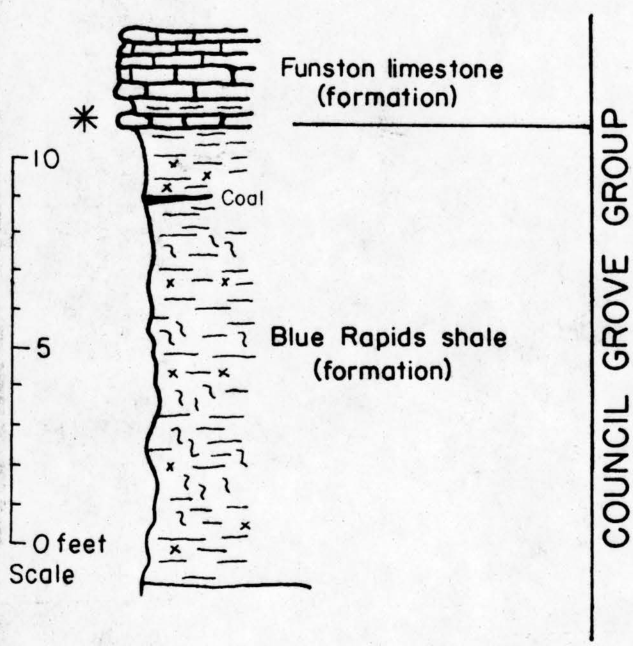
66.1 Speiser Shale exposed at top of section.

66.5 Funston limestone exposed.

66.75 STOP 5. Buses park along highway.

STOP 5. Colonies of fossil algae in limestone along U.S. 56 near Lyon-Morris County line, in Lyon County.

Location: SE 1/4 sec. 7, T.16 S., R.10E.



This locality was chosen for a stop because of the unusual occurrence of fossil algae. In early Permian time algae were important limestone builders. Here one finds, near the base of the Funston limestone, colonies of fossil algae encrusting clam shells and perhaps other objects.

Section measured by Howard G. O'Connor, State Geological Survey 1951

67.3 Funston Limestone.

68.5 Bridge, Bluff Creek. Cottonwood Limestone exposed in creek bed. We are going up in the rock section, into the Wreford Limestone.

69.0 Funston Limestone.

69.5 Speiser Shale, Threemile Limestone.

70.9 Junction with road to Bushong. Continue on U.S. 56.

71.45 Wreford Limestone outcrops.

71.25 Crouse Limestone up to Funston Limestone.

73.2 Cottonwood Limestone quarry on left (north of highway, east of crossroads).

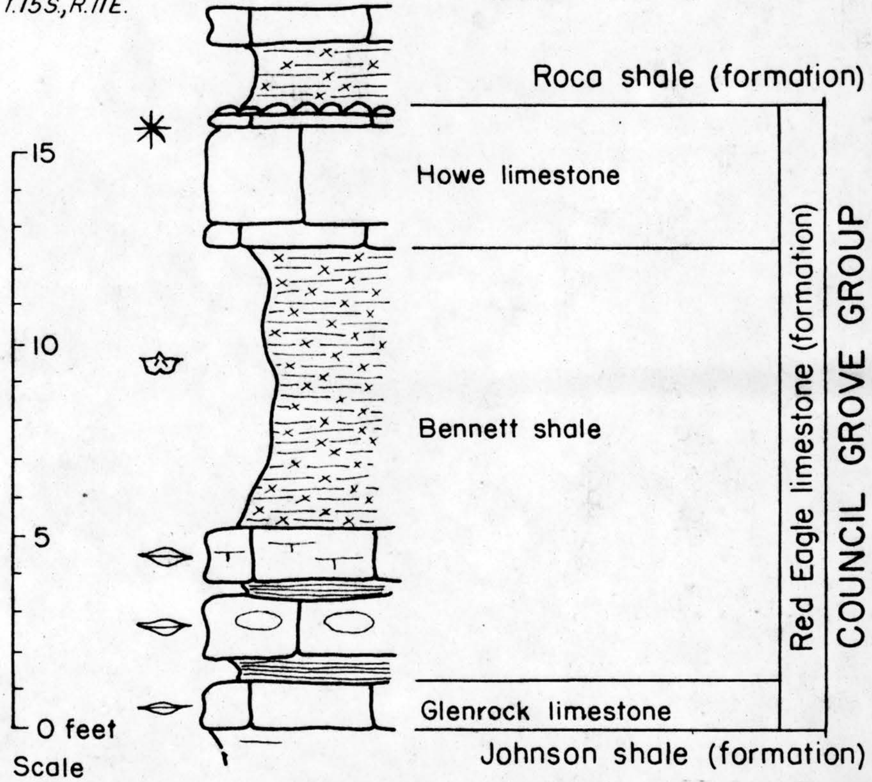
75.9 Crossroads at northern limits of Allen. Foraker Limestone, lowermost formation of the Council Grove Group, exposed south and west of crossroads. Altitude approximately 1,340 feet above sea level.

Turn left (north) on country road. We are east of the Flint Hills proper, in the physiographic province known as the Osage Cuestas. Bedrock exposures, almost to the base of the Council Grove Group, are older than any we have yet seen on this field trip.

79.1 <u>STOP 6.</u> Buses stop just south of bridge to unload. Proceed across bridge.

STOP 6. Roadside exposure of fossiliferous limestone and shale, about 3 miles north of Allen, Lyon County

Location: Cen. W line sec. 35, T.15S., R.11E.



Section measured by Stanton Ball, State Geological Survey 1957

Walk across bridge to buses. Continue north.

80.3 Bridge across One Hundred Forty Two Mile Creek.

81.1 About one-half mile to east there is an exposure of 25 to 30 feet of reeflike development in the Red Eagle Limestone, which is not present at the last stop. Also out of sight in pasture to east, there are several sinkholes in this limestone reef.

81.6 Leave Lyon County, enter Wabaunsee County.

Wabaunsee County, named for the Pottawatomie chief Wabonsa (signifying "The Dawn of the Day") was organized in 1859. The county has an approximate area of 791 square miles and a population of 6,935 (1957 census). Major sources of income are from ranching and diversified farming. Oil, sand and gravel, and stone are chief mineral resources.

Eastern Wabaunsee County is in the Osage Cuestas physiographic province the western part in the Flint Hills, and the northern border at the edge of the Glaciated Region. Altitude is about 900 feet above sea level in the Kansas River valley in the northeastern corner and almost 1,500 feet in the area south and west of Alma. Most of the outcropping bedrock is Permian in age, but upper Pennsylvanian rocks are exposed along the eastern edge. Pleistocene deposits, which include the glacial till in the northern part, cover bedrock in parts of the county.

81.9 Since 1884, when a Canadian designed and built the barn seen on the left (some say he originally was thinking of a distillery), cattle on the Coffman ranch have lived "in style". The stone in the barn was quarried on the ranch and local rocks (Cottonwood, Red Eagle, and Grenola limestones) were used to construct a stone wall around 6,000 acres. (On the rocks!) Turn right (east).

82.95 Turn left (north).

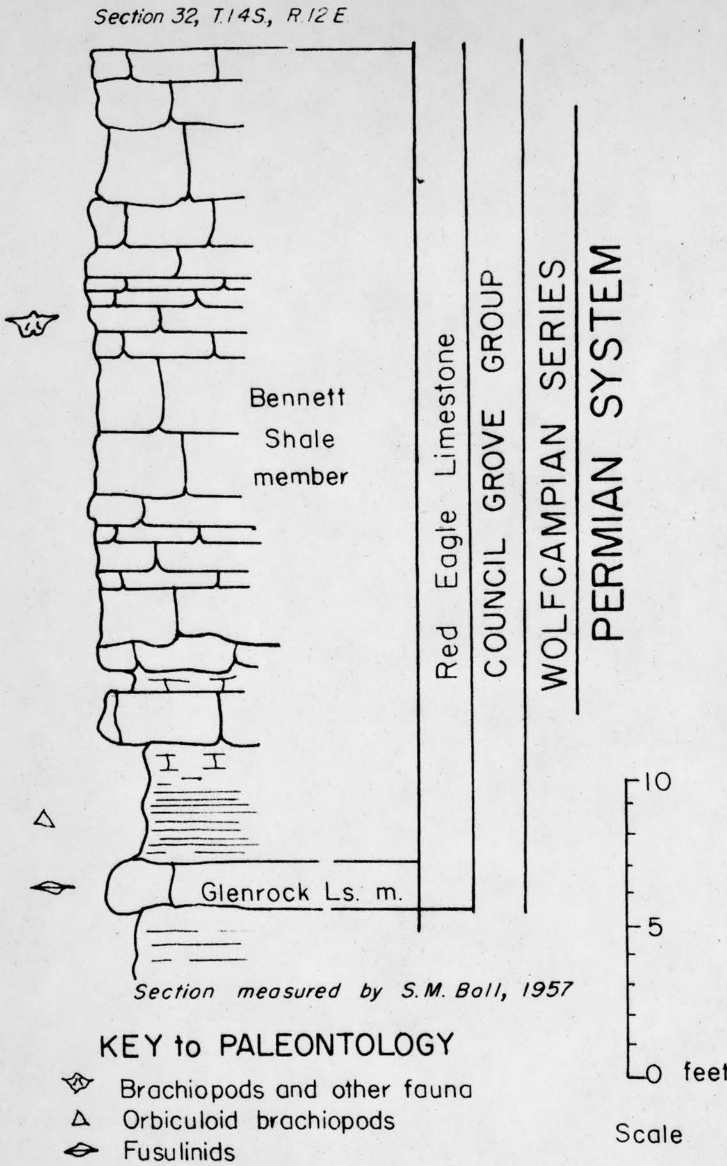
83.85 Wheat oil field, approximately 1 mile to left. This oil field was discovered in 1951. Production is from one well in the Simpson rocks (Ordovician age) at a depth of 3,230 feet. As of December 31, 1957, the field has yielded 18,601 barrels of oil. During 1957, production was 1,869 barrels.

86.5 Turn right (east).

87.3 Bridge across northern branch of Marais des Cygnes River.

88.1 Quarries in Red Eagle Limestone on both sides of road.

88.5 Crossroads. Continue east to K.99. Quarry in Red Eagle Limestone on right, near crossroads. Large quantities of crushed rock from the quarry were used as aggregate in the construction of the Kansas Turnpike. (A rock section at this quarry location is shown on next page.)



Exposure at Concrete Materials Construction Company quarry about 4 miles south of Eskridge.

The Red Eagle Limestone shows several facies, or different aspects, along its line of outcrop. Southward from this quarry for several miles, a thick accumulation of dolomitic limestone in the Bennett Shale part of the formation forms a "reef."

Some details of the Red Eagle formation along its line of outcrop from the vicinity of Bennet, Nebraska, to Osage County, Oklahoma, are described by H.G. O'Connor and J.M. Jewett in Bulletin 96 Part 8 of the State Geological Survey.

89.95 **Arrive at K.99. Turn left (north) on K. 99; drive to Eskridge.**

93.45 **Follow K. 99.**

93.7 **Curve left on K. 99.**

93.9 **Eskridge, city limits.**

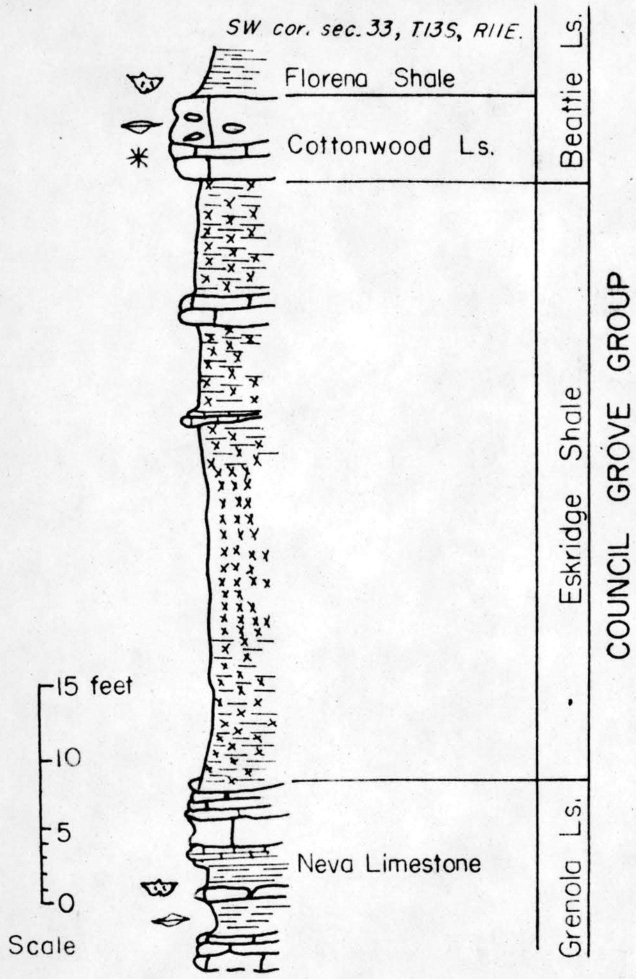
Eskridge was first laid out in 1868, but was not settled until 1881, when the Atchison, Topeka, and Santa Fe Railroad was completed to the site. Its population (1957 census) is 579.

94.3 **Intersection K. 99 and K. 4 in main part of Eskridge. Continue northwest on K. 99 and head toward Lake Wabaunsee.**

95.9 **Wreford Limestone outcrops. (What! No haybailers?)***
*** On May 24, 1957 a hay bailer was seen about here.**

98.85 Lake Wabaunsee on left. (No swimming on Saturdays.)

99.5 Eskridge Shale and Cottonwood Limestone especially well exposed in section on left.



Section measured by Stanton Ball, 1957

Geology at Lake Wabaunsee

Some of the most interesting rocks of all the bedrock section of the Flint Hills country are exposed here along K. 99, north of the dam at Lake Wabaunsee. The Florena Shale, the same stratum we saw at Stop No. 1 (this field conference), is at the top of the section. You will note the same abundance of marine fossils.

The Cottonwood Limestone is one of the most easily recognized rocks in Kansas. The Cottonwood --because of its light color and weathering characteristics, its rather uniform overall thickness, the small fusulinids and small chert nodules in the upper part, a band of platy algal remains in the middle part, and the sparsely fossiliferous (except for algae) lower part --is a "key" bed in Lower Permian stratigraphy.

The bright colors of the Eskridge shale are the chief characteristics of this unit. In general, bright, varicolored shales (principally reds, purples, and greens) mark the opening and closing parts of megacyclothems (see page 28) in these rocks. Impure clam-bearing limestones commonly are characteristic of these kinds of sediments.

In places in the Flint Hills the upper part of the Neva Limestone assemblage contains an interesting limestone that occurs (where present) slightly above the uppermost Neva Limestone bed we see here. This "super" limestone of the cycle commonly is a mass of shell fragments, and it represents prolific waters of a shallow and retreating sea. The "main" ledge of the Neva, which is the uppermost part here, was deposited in deeper water. With its somewhat variable facies, all in all, the Neva Limestone is one of the best rock layers in the Flint Hills that can be studied by anyone trying to picture conditions in the ancient Kansas seas.

99.6 Exposures of Florena Shale and Morrill Limestone.

100.7 Threemile Limestone.

101.4 Threemile Limestone.

We are driving onto the Flint Hills Upland. Refer to page 26 for an article on the Flint Hills.

103.8 Bridge.

104.1 Bridge.

104.45 Junction, K.99 and K. 4. Stone school on left. Turn right (north) on K. 99.

104.5 Cottonwood Limestone forms pavement in creek. Florena Shale and Morrill Limestone in creek bank. This is the only known exposure of Florena Shale without fossils.

104.9 Middleburg Limestone.

As we go north on K. 99, we have an excellent opportunity to observe relief near the eastern border of the Flint Hills proper. Note the angular, steplike slopes of the hills in contrast with the more rounded shapes of the valleys. See pages 29 and 30 for a description of Flint Hills landscape.

106.2 Exposure of Neva Limestone in creek under bridge.

106.35 Cottonwood Limestone.

108.55 Mill Creek oil field on right. The Mill Creek oil field was discovered in 1950. Production is from Viola Limestone of Ordovician age, at a depth of about 2,923 feet. Cumulative production, as of December 31, 1957, was 230,203 barrels of oil, and 23,362 barrels of oil came from the 4 producing wells during 1957.

112.4 West Branch Mill Creek.

113.1 City limits, Alma. <u>STOP</u> for refreshments !

Alma, the county seat of Wabaunsee County, has a population of 787 (1957 census). The altitude here is about 1,065 feet above sea level.

Alma is a shipping point of importance for the surrounding agricultural and livestock-raising region. The first house at this site was built in 1867 and in 1868 the town became the county seat. Throughout the years rock from quarries in the vicinity has been utilized as building stone and aggregate for construction purposes.

113.6 Turn right on K.99 in Alma.

114.5 Outcrops of rocks from Red Eagle Limestone to Burr Limestone.

114.9 Bridge.

115.3 Road to McFarland.

115.6 Quarry in Neva Limestone, on right.

116.75 Cottonwood Limestone outcrop.

117.35 Morrill Limestone outcrop.

117.4 U.S. 40. Cross with caution! Continue northward on K.99.

117.45 Cottonwood Limestone and Eskridge Shale outcrops.

117.9 Stone schoolhouse (Hinderville) on left; built in 1898. Could be that first teacher got "book larnin" at State Normal School, Emporia.

118.5 Railroad track.

118.75 Cottonwood Limestone.

120.9 Turn right on inconspicuous road and watch out for boulders (glacial erratics, that is!). Inactive Cottonwood Limestone quarry northeast of road intersection.

122.1 STOP 7. Buses park on road and hope for no traffic! Follow conference leaders (on foot) into pasture area for a look at boulders and a talk on glacial geology.

EVIDENCE OF GLACIATION

Historical geology obviously must be written on the basis of circumstantial evidence. Whether one makes the statement that a salt-water sea was here in early Permian time (see page 35) or that a sea of ice was here at a much later date, he is basing his statements or deductions on what can be seen at the present rather than what was documented directly in the past. Present conditions, we believe, can be explained only by certain conditions that existed at some former time. For example, how can we account for the large number of sea-urchin spines in the Bennett Shale on Elmdale Hill in a way other than that the shale is a deposit that accumulated on a sea floor?

The arrival at acceptable explanations has not been a simple procedure and, it seems at times, even a reasonable one. Glacial geology, like other phases of geology, has been subjected to much debate and controversy. A geologist still held to have been an outstanding authority in certain phases of geology, in a book published in 1889 made this statement, "Indeed there is no evidence that a glacial sheet ever existed on any part of the continent; none that gives any warrant to the hypothesis of a glacial period." Present-day geologists hold the "glacial period" to be practically self-evident.

Northeast Kansas was visited by the earliest two of four or five ice sheets that invaded North America in the present (Pleistocene) geologic epoch. In general glacial ice covered the area in Kansas that now is north of Kansas River and east of Big Blue River. A much larger area was affected by floods that resulted from the melting ice and from changes in climate. The deposit in northern Wabaunsee County is classed as till--material deposited directly from the ice. The size and weight of boulders hardly can allow any thought of their having been carried far by water alone. Their worn surfaces and lack of angularity, however, declared that they have been subjected to a great deal of abrasion by water-carried smaller rock fragments. The boulders, cobbles, and pebbles here are composed of hard, durable rock, mainly quartzite and granite. It may well be that less durable rock carried by the glaciers has long since decayed into clay and other products of rock deterioration. While probably it is true that the clay one sees here with the "erratic" rocks mostly came as clay (shale), a part of it probably is the less soluble residue of limestone and other rocks not so durable as granite and quartzite.

122.3 Note boulders in pasture on either side.

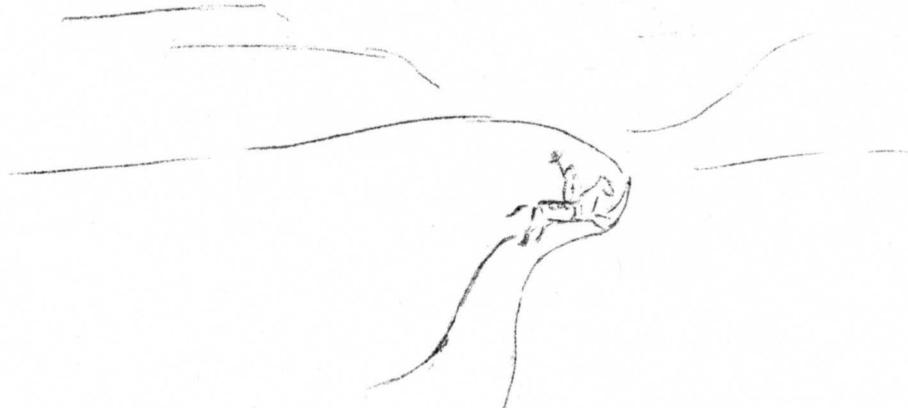
123.45 Turn right (south). Go south to U.S. 40.

124.0 Cottonwood Limestone.

126.95 Arrive at U.S. 40.(K.99 is 2 1/2 miles to the west.) END OF TRIP!

To go toward Topeka, turn left on U.S. 40. To go to Emporia or points south and west, turn right on U.S. 40. Take K. 99 (2 1/2 miles to right) south (left) to Emporia.

We hope you like the Flint Hills!



THE FLINT HILLS

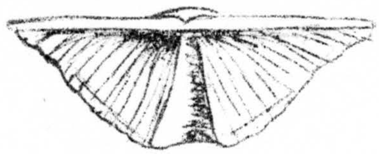
J. M. Jewett, State Geological Survey, University of Kansas

The Kansas Flint Hills landscape is unique. It is doubtful that one can find anywhere else the same kind of rock-terraced hills and the same type of wood-fringed valleys cut from bluestem-covered slopes, where crenulated bands of contrasted vegetation make a life-sized geologic map of the whole countryside. These hills, once called "Permian Mountains", stretch north-south beyond the borders of the state, although they are somewhat subdued across the northern border in Nebraska and they are less angular in Oklahoma, where they merge into the Osage Hills.

In eastern Kansas rock layers in the outer part of the earth's crust slant gently westward or slightly north of west. This inclination of strata--<u>but not of land surface</u>--is away from the Ozark region. Erosion, working for a long time, has removed a great amount of rock, and layer after layer farther and farther to the west has been erased. The present surface across the beveled rock layers is, therefore, like a fallen deck of cards, or overlapping shingles on a roof.

After remaining as nearly a featureless plain for a long time, the ancient surface of eastern Kansas once more was attacked by erosion, which carved it into the present landscape, a series of cuestas. The eastward-facing escarpments of the cuestas are nearly parallel but are marked by concentrically arranged re-entrants where major and minor drainage channels intersect them. Notice that the rock layers dip westward but that the land surface slopes to the east. The Flint Hills comprise the most rugged of these cuestas with eastward-facing escarpments in eastern Kansas. Farther west in Kansas, the Smoky Hills are cut in less regular formations of resistant sandstone; their history is quite distinct from that of the Flint Hills. East of the Flint Hills in southern Kansas the Chautauqua Hills, because they are cut from different kinds of rock, have different shapes.

The greater relief of the Flint Hills --that is, greater than that of similar cuestas farther east--cannot be credited alone to the nature of the bedrock from which the hills are carved. Seemingly the Flint Hills mark an erosional remnant or a relic divide. One may say, perhaps, they represent the meeting of two areas of different erosional history, which is characterized by the nature of the bedrock. Had some as yet unknown factors been different, hills of about the same height could have developed in other parts of eastern Kansas and would have been characterized by the bedrock of the place.



The Bedrock of the Flint Hills Country

Stratigraphy of the Flint Hills region is represented graphically on page 35. The Flint Hills have not been defined or limited definitely either geographically or geologically. The more extensive uplands in the area, however, are developed on parts of the Wreford Limestone or, higher, on the Barneston Limestone. Over large areas the Florence Limestone or the Fort Riley Limestone, which occurs a little above the Florence, is the surface rock just below the bluestem-producing upland soil. Hence it might be well to regard the westernmost occurrence of the Fort Riley Limestone, where it is the bedrock next below the soil cover, as the western boundary of the Flint Hills. To delineate an eastern border would be more difficult; one might do no better than to regard the contact of Pennsylvanian and Permian rocks (somewhat lower than represented in generalized section on page 35) as the eastern extent of the Flint Hills.

The lower Permian rocks in Kansas, from which the Flint Hills are etched, are comprised almost entirely of shales and limestones. Two of the limestone formations, the Wreford and the slightly younger (and higher) Barneston, contain large quantities of chert or flint. Authorities differ as to the definitions of chert and of flint; for our purposes the two terms are interchangeable. This material, which may be regarded as either rock or mineral, is cryptocrystalline silica (silicon dioxide). Hence it may be regarded as a noncrystalline variety of quartz. Chalcedony also is nonchrystalline silica, but commonly the name is used for material that is more translucent than flint or chert. In both limestone members of the Wreford formation flint is abundant, as it is in the Florence Limestone, lowermost member of the Barneston formation. Flint is present in almost all Pennsylvanian and Permian limestone formations in Kansas, but its abundance is commonly not so great as it is in these three limestones (Threemile and Schroyer of the Wreford and Florence). The flint, partly embedded in the rocks and more especially strewn as debris along the hillsides, gives these hills their name. (Bluestem belt also is a suitable term for the Flint Hills country, Kansas' great pasture land.)

Most of the bedrock layers in the Flint Hills country are marine deposits. In early Permian time sea water covered this part of North America. The presence of marine conditions was interrupted now and then, however, by withdrawals of sea waters. It is believed that the red shales, which are characteristic of some of the shale formations, are composed of material that accumulated in a position slightly above sea level, and that green shales accumulated in a nearshore but marine environment. It is obvious that many shales (because they contain an abundance of fossil marine invertebrate animals) and limestones (also largely composed of marine organisms) were formed on sea floors. It is interesting to note the great abundance of fossil marine algae in some of the limestones.

The lower Permian rocks, like outcropping Pennsylvanian rocks in Kansas, offer a-abundant evidence that they were deposited under cyclic conditions; that is to say, a regular sequence of rock types occurs over and over again. Rocks of a single cycle of this kind comprise a <u>cyclothem</u>. The rock types, or phases of the cyclothems, were controlled by marine conditions, nonmarine conditions, regression of sea waters, transgression of sea waters (and hence salinity), depth of water, and nature of the biota (which depended on the foregoing and other factors), and perhaps other conditions. The overall cause of the changing conditions and their regular occurrence seemingly was astronomical.

Many cycles as displayed by the sediments are incomplete, and there are multiple cycles. A span of rocks representing a more or less complete cycle of two or more cyclothems is termed a <u>megacyclothem</u>. The following details of two cyclothems, comprising the "Wreford megacyclothem", is quoted from Donald E. Hattin, "<u>Depositional Environment of the Wreford Megacyclothem (Lower Permian) of Kansas.</u>" The "r" implies regression of sea water; "t", transgression. Red shale is, according to Hattin, believed to represent nonmarine deposition, as is also sandstone (0 in the Threemile cyclothem). Number 6 in each cyclothem seemingly records the greatest depth of sea water and/or farthest-from-shore conditions.

Threemile cyclothem

2. Green shale*
3r. Mudstone
4r. Molluscan limestone
5r. Calcareous shale*
6r. Cherty limestone
6. Chalky limestone*
6t. Cherty limestone
5t. Calcareous shale
4t. Molluscan limestone
3t. Mudstone
2t. Green shale
1t. Red shale
0. Sandstone †

Schroyer cyclothem

1. Red shale
2r. Green shale
4r. Algal limestone
5r. Calcareous shale
6. Cherty limestone
5t. Calcareous shale
4t. Molluscan limestone
3t. Mudstone
2. Green shale*

* absent in southern Kansas
† absent in northern Kansas

The order of stratification of the rocks listed above is (upward) from "0" in the Threemile cyclothem to "1" in the Schroyer cyclothem. At Stop No. 4 (this field conference) one may see several phases of the Threemile cyclothem, especially phase 6t. and lower.

At other places one sees other phases of other cyclothems. Calcareous, abundantly fossiliferous shale is well represented in the Florena Shale as seen at Stop No. 1. Elsewhere the Bennett Shale (middle member of the Red Eagle formation) is analogous. The Cottonwood Limestone (a member of the Beattie formation), which contains abundant marine fossils, especially fusulinids, and little chert, is in part a deep-water phase of a cycle. Parts of the Neva Limestone (of the Grenola formation) represent a similar phase. Yet it must be emphasized that each formation and each member of the formations had their own environmental conditions and no two rock layers are alike.

It should be noted also that much remains to be learned before the environmental conditions under which these rocks were formed are well understood. Seemingly algal limestone occurs only in the regressive stages of some cyclothems (as in the Schroyer) but clearly is a part of the transgressive stages in others.

It would be remiss not to say that the origin of flint (chert) is not certainly understood. Possibly a large percentage of the flint is due to the presence, in Paleozoic seas, of sponges that formed spicules of silica secreted from sea water by the organisms.

It is rather plain that limestone, as seen in the Flint Hills, is largely if not entirely organic in origin. Seemingly chemically precipitated limestone is all but nonexistent. Obviously most of the shales can be explained by the deposition of clay and mud, but the source is only hypothetical. The bright colors shown in several formations in the Flint Hills are subject to more research. Also much research based on fossil studies remains to be done.

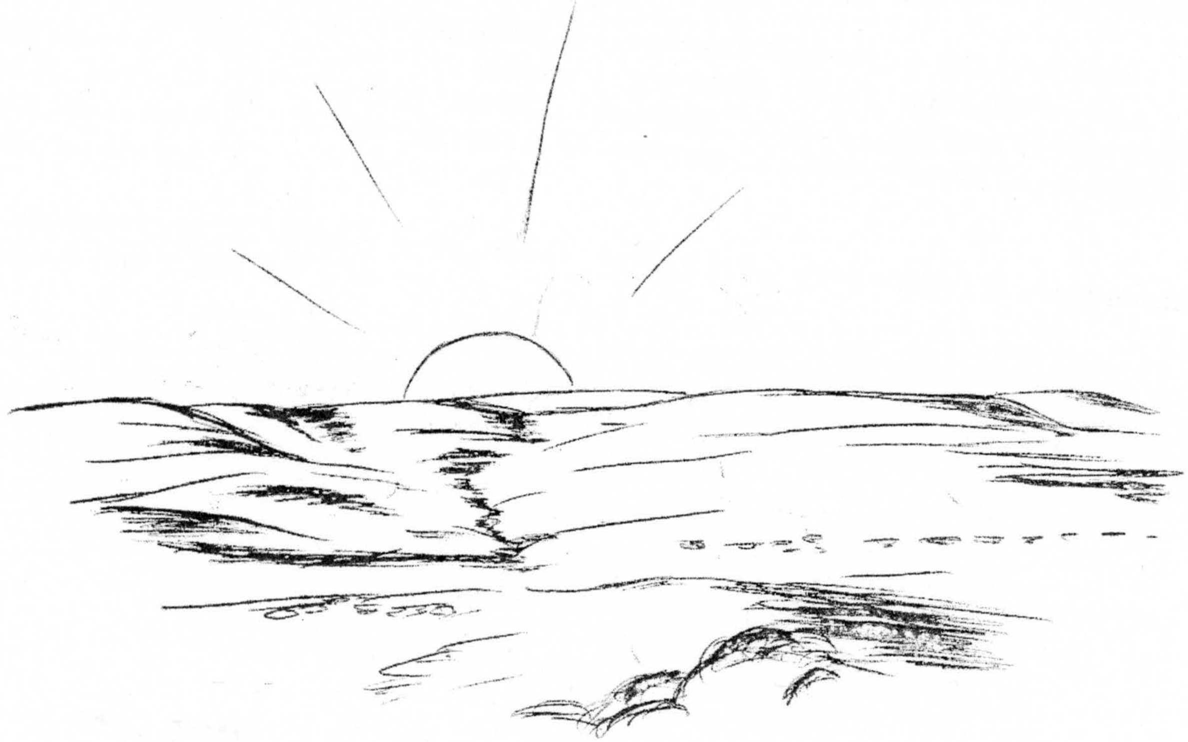
The Landscape

The upland surface of the Flint Hills reaches in several places, and exceeds in a few, 1,500 feet above sea level. The highest point on the road between Cottonwood Falls and Elmdale Hill is a few feet above 1,380 feet. Nearby hills capped by Wreford Limestone are as high as 1,400 feet. A few miles southwest of Cottonwood Falls, hills capped by Fort Riley Limestone are 1,400 feet above sea level. Within a distance of three miles in that area the difference in relief is slightly more than 300 feet from the valley of Cottonwood River up to the Flint Hills uplands. At the foot of Elmdale Hill (Stop No. 2, this field conference) Cottonwood River flows at an elevation slightly lower than 1,160 feet. The outcrop of Cottonwood Limestone on Elmdale Hill is at about the 1,300-foot level.

The beauty of the Flint Hills is not so much in the rather abrupt relief of hilltop above river valley as in the slopes that combine angles with convex curves in the upper reaches and concave ones below in accordance with sculpturing in delicate balance between erosive power and resistance of rock protected by tough sod. The shape of the hills is not fixed by character of bedrock alone. Thick accumulations of unconsolidated rock debris make up terraces along the valleys of eastern Kansas streams, and here in the Flint Hills the highest of these steplike land forms are high on the hillsides. This situation, which lends credence to the theory of the hills marking an old drainage divide, tempers the ruggedness of the terrain and adds to the charm.

As the seasons march on, various kinds of herbaceous vegetation, mixed with the more enduring bluestem grass but growing in accordance with outcropping rocks, take on various shades of mixed greens. Sharp boundaries in vegetation cover seemingly are in accordance with slight differences in water content and with still fewer differences in mineral content of the rocks.

In any season and at any time of day there is beauty in the Flint Hills. In early morning and near sunset time the scene is especially pleasing.



THE MINERAL RESOURCES OF THE FLINT HILLS

By Stanton Ball, State Geological Survey, University of Kansas

INTRODUCTION

The grass-producing soil of the Flint Hills was one of the earliest of the mineral resources to be exploited in Kansas. Abilene, Dickinson County, is the oldest of the famous Kansas cattle towns. Since 1915, the El Dorado oil field has kept Butler County and the southern Flint Hills in the limelight of Kansas' oil industry. Limestone, gravel, and sand have been used for many years. These reserves are by no means exhausted. Ground water, gas, and clay are other raw mineral materials of economic value in the Flint Hills.

Grasslands

Because of the availability of good grazing land, the Flint Hills have long been the heart of the Kansas cattle country. Cattle are bought primarily from Texas and Oklahoma in the spring, fattened on Flint Hills grass, and sold in the fall at a substantial profit. The recent drought that was experienced throughout Kansas for several years placed quite an effective damper on the cattle industry.

Oil and Gas

Active oil development in the Flint Hills has been carried on for approximately 50 years. Nationally significant production was initiated with the discovery of the El Dorado field in 1915. The El Dorado field led all oil fields in Kansas, the Midcontinent, and the United States in production in the year 1918. Through the years this field has ranked consistently among the top five or six producers in Kansas and in 1956 it was again in the lead.

Greenwood, Butler, and Cowley Counties lead the Flint Hills in secondary recovery projects. North of southernmost Lyon County no secondary recovery projects were recorded during 1956. However, primary oil-producing areas do exist in the central and northern Flint Hills.

The amount of gas produced in the Flint Hills is by far less than the amount of oil. During 1956 about 800,000,000 cubic feet of gas was produced in Flint Hills counties. Of this amount 493,136,000 cubic feet was produced in Cowley County, 134,289,000 cubic feet in Marion County, and 50,858,000 cubic feet in Chase County.

Limestone, Sand, and Gravel

Abundant limestone suitable for building material is available in the Flint Hills. The most widely quarried strata used for building purposes are Cottonwood, Fort Riley, Funston, and Neva limestones. The beauty of many state buildings has been made possible by use of these ledges. Limestones of the area also are utilized as agricultural limestone, crushed rock and riprap, raw material for the manufacture of cement, flux in blast furnaces and in metallurgy, and other products having a variety of uses.

Many deposits of chert gravels and sand occur in and along the stream valleys. These reserves are being constantly replenished as erosion proceeds.

Soil

Another natural resource of great value is soil. The upland soils are residual in origin, being derived largely from the limestone upon which they have developed. These upland soils are texturally a silt in the surface layer and a clay in the subsoil. The soil material of the stream-bottom lands is either alluvial or colluvial. The alluvium is deposited upon the floodplains by overflow waters and the colluvial material is washed from nearby slopes. There is little difference chemically or texturally between the true alluvium and the colluvial materials. The leading crops produced on these soils are wheat, corn, prairie hay, and alfalfa.

Ground Water

The availability of water, necessary to the life process, is extremely important. Everywhere the geology of an area determines the mode of occurrence of its ground water. Ground-water resources sufficient for ordinary farm and stock use are obtained from porous surficial deposits and from fissured near-surface limestones. Larger quantities, generally sufficient for city supplies, are obtained from alluvium of the larger streams. The ground-water reservoirs of the Flint Hills are recharged primarily by precipitation and by seepage from streams and ponds.

(A list of selected references appears on pages 36 and 37.)

CLASSIFICATION OF OUTCROPPING ROCKS IN CHASE, LYON, MORRIS and WABAUNSEE COUNTIES, KANSAS

QUATERNARY SYSTEM
- Pleistocene Series
  - Recent and Wisconsinan Stages
    - Alluvium
  - Illinoian Stage
    - Wiggam Terrace deposits
  - Kansan Stage
    - Emporia Terrace deposits (Meade Group)
    - Kansas Till
    - Atchison Formation (not known to be present south of Kansas River)

PERMIAN SYSTEM
- Leonardian Series
  - Sumner Group
- Wolfcampian Series
  - *Chase Group
  - *Council Grove Group
  - *Admire Group

PENNSYLVANIAN SYSTEM
- Virgilian Series
  - *Wabaunsee Group
  - Shawnee Group

QUATERNARY SYSTEM and/or TERTIARY SYSTEM
- Pre-Kansan deposits

* Named units (formations and members) in the Chase, Council Grove, Admire, and Wabaunsee Groups, and in the upper part of the Shawnee Group are listed on this page and the following page. A graphic column of rocks exposed along the conference route appears on page 35.

\- - - - - -

In general the uppermost (youngest) bedrock in any county occurs on hills in the western part of the county; the lowermost (oldest) in valleys in the eastern part.

Exposed bedrock in:

Chase County includes section (in ascending order) from West Branch Shale of the Admire Group to rocks in the lower part of the Sumner Group--all Permian in age.

Lyon County includes section from Calhoun Shale in the upper part of the Shawnee Group (Pennsylvanian age) to Barneston Limestone of the Chase Group (Permian age).

Morris County includes Grenola Limestone (Council Grove Group) to lower part of the Wellington Formation (Sumner Group)--all Permian rocks.

Wabaunsee County includes Willard Shale of the Wabaunsee Group (Pennsylvanian age) to Doyle Shale of the Chase Group (Permian age).

PERMIAN SYSTEM
- Leonardian Series
  - Sumner Group
    - Wellington Formation (lower 100 feet, approximately)
- Wolfcampian Series
  - Chase Group
    - Nolans Limestone
      - Herington Limestone member
      - Paddock Shale member
      - Krider Limestone member
    - Odell Shale
    - Winfield Limestone
      - Cresswell Limestone member
      - Grant Shale member
      - Stovall Limestone member
    - Doyle Shale
      - Gage Shale member
      - Towanda Limestone member
      - Holmesville Shale member
    - Barneston Limestone
      - Fort Riley Limestone member
      - Oketo Shale member
      - Florence Limestone member
    - Matfield Shale
      - Blue Springs Shale member
      - Kinney Limestone member
      - Wymore Shale member
    - Wreford Limestone (con't. next page)

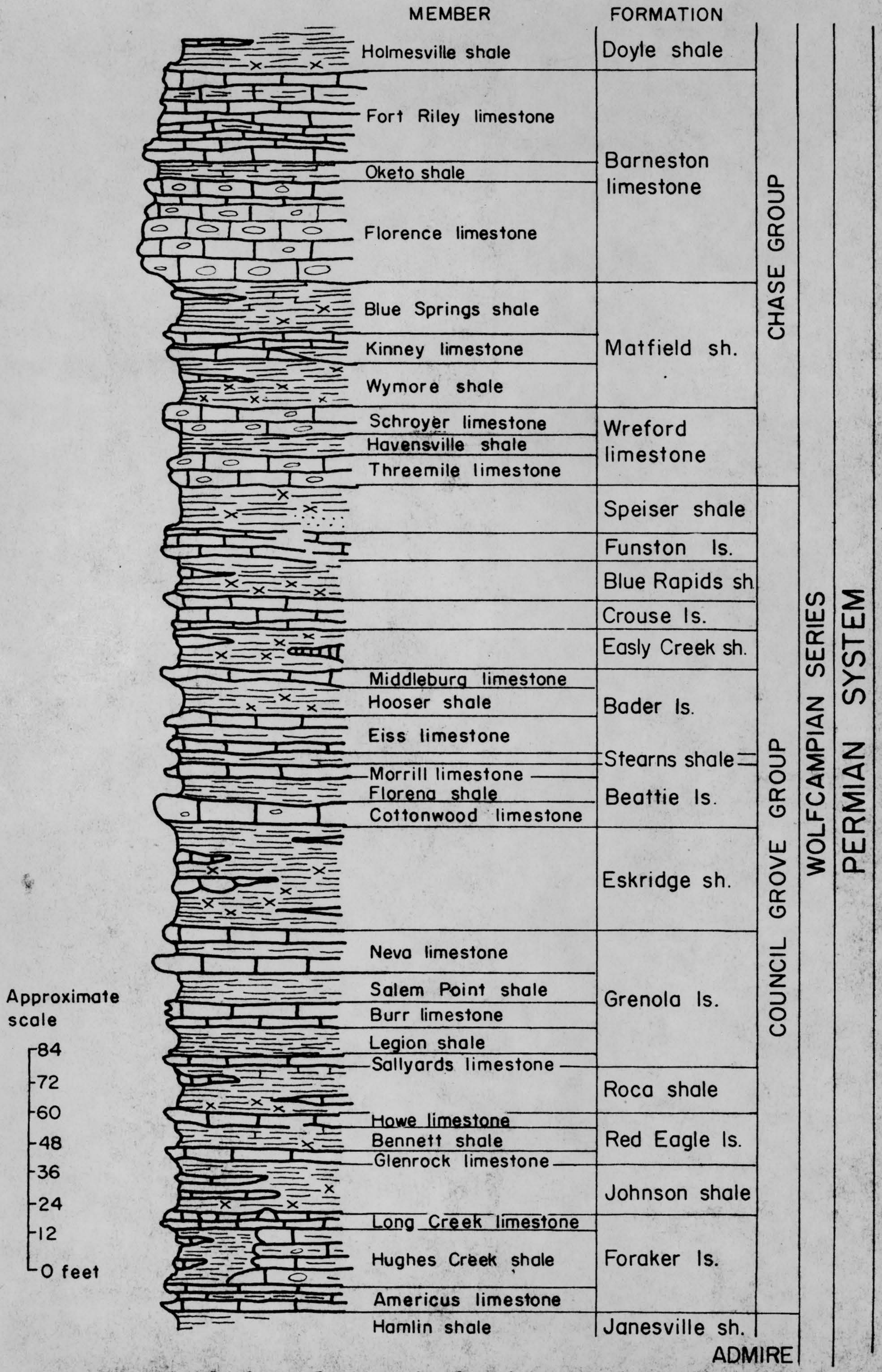
(Wreford Limestone)
Schroyer Limestone member
Havensville Shale member
Threemile Limestone member
Council Grove Group
Speiser Shale
Funston Limestone
Blue Rapids Shale
Crouse Limestone
Easly Creek Shale
Bader Limestone
Middleburg Limestone member
Hooser Shale member
Eiss Limestone member
Sterns Shale
Beattie Limestone
Morrill Limestone member
Florena Shale member
Cottonwood Limestone member
Eskridge Shale
Grenola Limestone
Neva Limestone member
Salem Point Shale member
Burr Limestone member
Legion Shale member
Sallyards Limestone member
Roca Shale
Red Eagle Limestone
Howe Limestone member
Bennett Shale member
Glenrock Limestone member
Johnson Shale
Foraker Limestone
Long Creek Limestone member
Hughes Creek Shale member
Americus Limestone member
Admire Group
Janesville Shale
Hamlin Shale member
Five Point Limestone member
West Branch Shale member
Falls City Limestone
Onaga Shale
Hawxby Shale member
Aspinwall Limestone member
Towle Shale member

PENNSYLVANIAN SYSTEM

Virgilian Series

Wabaunsee Group
Wood Siding Formation
Brownville Limestone member
Pony Creek Shale member
Grayhorse Limestone member

(Wood Siding Formation cont'd.)
Plumb Shale member
Nebraska City Limestone member
Root Shale
French Creek Shale member
Jim Creek Limestone member
Friedrich Shale member
Stotler Limestone
Grandhaven Limestone member
Dry Shale member
Dover Limestone member
Pillsbury Shale
Zeandale Limestone
Maple Hill Limestone
Wamego Shale member
Tarkio Limestone member
Willard Shale
Emporia Limestone
Elmont Limestone member
Harveyville Shale member
Reading Limestone member
Auburn Shale
Bern Limestone
Wakarusa Limestone member
Soldier Creek Shale member
Burlingame Limestone member
Scranton Shale
Silver Lake Shale member
Rulo Limestone member
Cedar Vale Shale member
Happy Hollow Limestone member
White Cloud Shale member
Howard Limestone
Utopia Limestone member
Winzeler Shale member
Church Limestone member
Aarde Shale member
Bachelor Creek Limestone member
Severy Shale
Shawnee Group
Topeka Limestone
Coal Creek Limestone member
Holt Shale member
DuBois Limestone member
Turner Creek Shale member
Sheldon Limestone member
Jones Point Shale member
Curzon Limestone member
Iowa Point Shale member
Hartford Limestone member
Calhoun Shale



Generalized column of outcropping Permian rocks along conference route (June 7, 1958) in Flint Hills area. Adapted from "Graphic Column of Kansas Rocks", by R. C. Moore and others, 1952.

SELECTED PUBLICATIONS OF THE STATE GEOLOGICAL SURVEY
UNIVERSITY OF KANSAS

The State Geological Survey, University of Kansas, has issued several hundred reports and maps during the last half century. Some of these publications are general in geologic or in geographic coverage; others are restricted to specific subject matter or to local areas. A few of the publications that are of general interest or are statewide in scope are listed below. Some publications that may have particular interest to residents of the Flint Hills region are included.

Geology of the El Dorado Oil and Gas Field (Bull. 7), by A.E. Fath. OUT OF PRINT.

The Geology of Cowley County, Kansas (Bull. 12), by N.W. Bass. OUT OF PRINT.

Ground-Water Resources of Kansas (Bull. 27), by Raymond C. Moore, with chapters by S.W. Lohman, J.C. Frye, H.A. Waite, T.G. McLaughlin, and Bruce Latta. OUT OF PRINT.

The Geology of Riley and Geary Counties, Kansas (Bull. 39), by John M. Jewett. OUT OF PRINT.

Kansas Mineral Resources for Wartime Industries (Bull. 41, Part 3), by J. M. Jewett and Walter H. Schoewe. OUT OF PRINT.

Subsurface Reconnaissance of Glacial Deposits in Northeastern Kansas (Bull. 86, Part 6), by John C. Frye and K. L. Walters. 25 cents.

The Kansas Rock Column (Bull. 89), by Raymond C. Moore, John C. Frye, J. M. Jewett, Wallace Lee, and Howard G. O'Connor. $1.00.

Coal Resources of the Permian System in Kansas (Bull. 90, Part 3), by Walter H. Schoewe. 25 cents.

Geologic Structures in Kansas (Bull. 90, Part 6), by John Mark Jewett. 75 cents.

Pleistocene Geology of Kansas (Bull. 99), by John C. Frye and A. Byron Leonard. $1.00.

Oil and Gas in Eastern Kansas (Bull. 104), by John Mark Jewett. $1.50.

Geology and Ground-Water Resources of Marshall County, Kansas (Bull. 106), by Kenneth L. Walters. $1.00.

Chemical Composition of Eastern Kansas Limestones (Bull. 119, Part 3), by Russell T. Runnels and John A. Schleicher. 25 cents.

Depositional Environment of the Wreford Megacyclothem (Lower Permian) of Kansas (Bull. 124), by Donald E. Hattin. $1.00.

The Precambrian Rocks of Kansas (Bull. 127, Part 3), by O. C. Farquhar. 75 cents.

The Mineral Industry in Kansas in 1956 (Bull. 127 Part 6), by Walter H. Schoewe. 50 cents.

Oil and Gas Developments in Kansas During 1956 (Bull. 128), by Edwin D. Goebel, A. L. Hornbaker, P. L. Hilpman, and D. L. Beene. $1.00.

Geology, Mineral Resources, and Ground-Water Resources of Chase County, Kansas (Vol. 11), by R. C. Moore, J. M. Jewett, H. G. O'Connor, and R. K. Smith. 75 cents.

Geology, Mineral Resources, and Ground-Water Resources of Lyon County, Kansas. (Vol. 12), by Howard G. O'Connor, Edwin D. Goebel, and Norman Plummer. 75 cents.

Kansas Rocks and Minerals, by Laura Lu Tolsted and Ada Swineford. Mailing charge, 5 cents.

The Kansas Scene, by Grace Muilenburg. Free

Geologic Map of Kansas (map size, 40 x 51 inches; scale approximately 8 miles equal 1 inch). 50 cents; by mail 75 cents.

Surface Features of Kansas (map and text; sheet size, 23 x 26 inches) by Raymond C. Moore. Mailing charge, 10 cents.

Kansas Mineral Resources (map size 31 1/2 x 45 inches). 50 cents; by mail, 75 cents.

Topographic Maps of some areas in Kansas have been published by the State and Federal Geologic Surveys. These maps are available for 30 cents a sheet; an index map showing areas covered may be obtained free.

- - - - - - - -

Publications marked OUT OF PRINT may be consulted in public libraries.

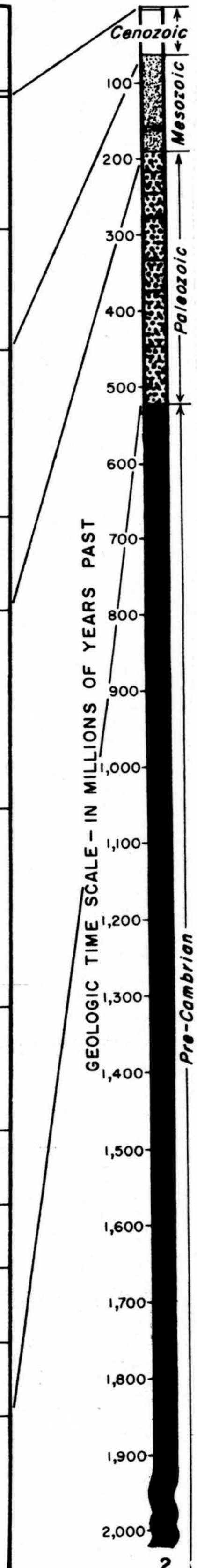
A complete list of State Geological Survey publications may be obtained free from the State Geological Survey, University of Kansas, Lawrence, Kansas.

GEOLOGIC TIMETABLE AND KANSAS ROCK CHART

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.
	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.
	JURASSIC	25,000,000	*Sandstones and shales, chiefly subsurface.*	
	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.
	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.
	MISSISSIPPIAN	30,000,000	*Mostly limestone, predominantly cherty.*	Oil, zinc, lead, gas, chat and other construction materials.
	DEVONIAN	55,000,000	*Subsurface only. Limestone, black shale.*	Oil
	SILURIAN	40,000,000	*Subsurface only. Limestone.*	Oil
	ORDOVICIAN	80,000,000	*Subsurface only. Limestone, dolomite, sandstone, shale.*	Oil, gas, water.
	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.

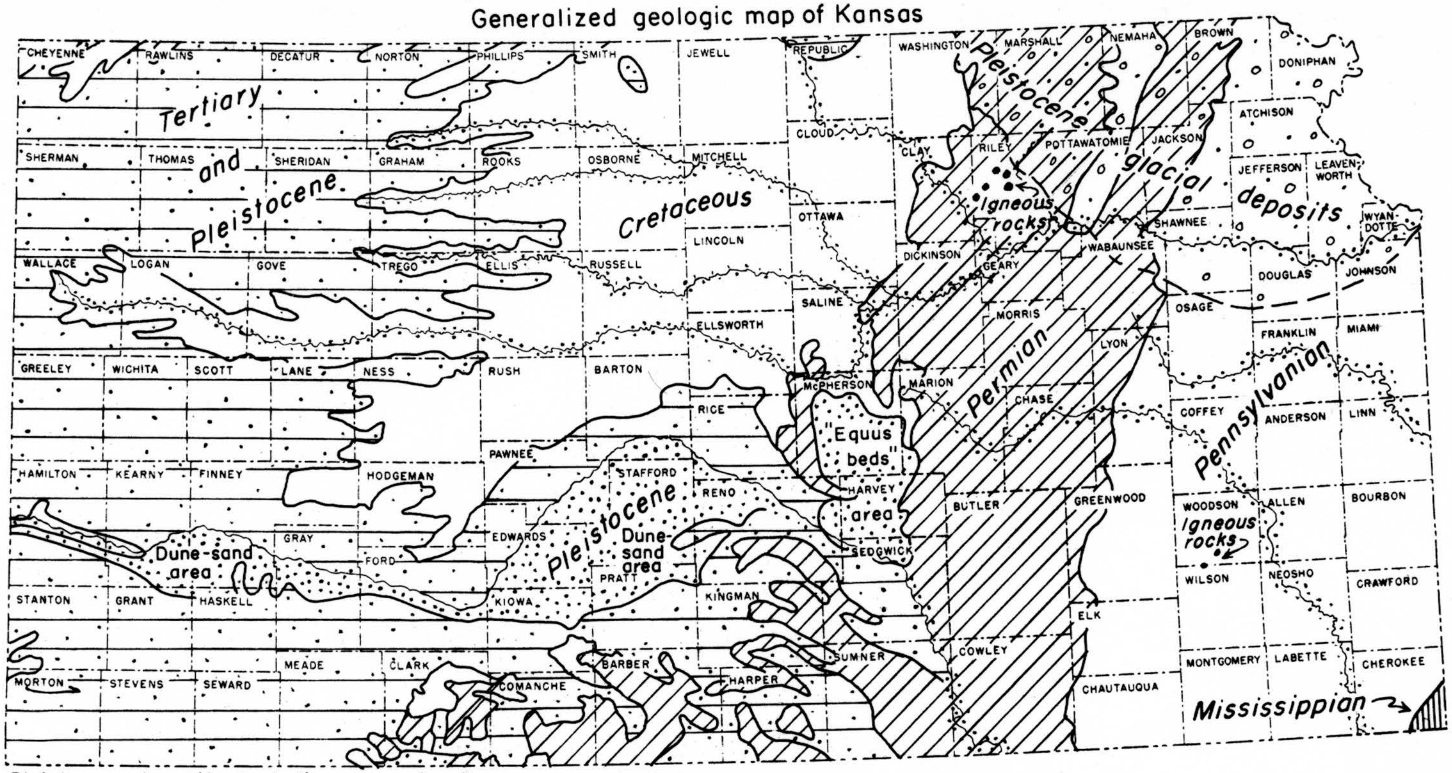
(Not scaled for geologic time or thickness of deposits)

*Committee on Measurement of Geologic Time, National Research Council

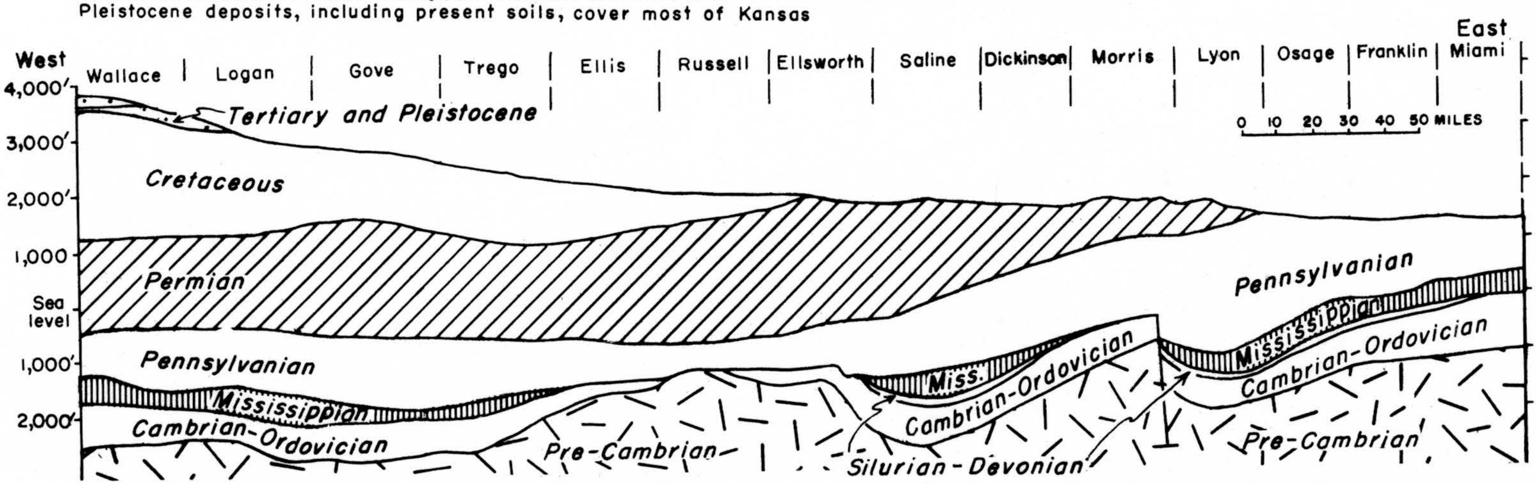


State Geological Survey of Kansas

Generalized geologic map of Kansas

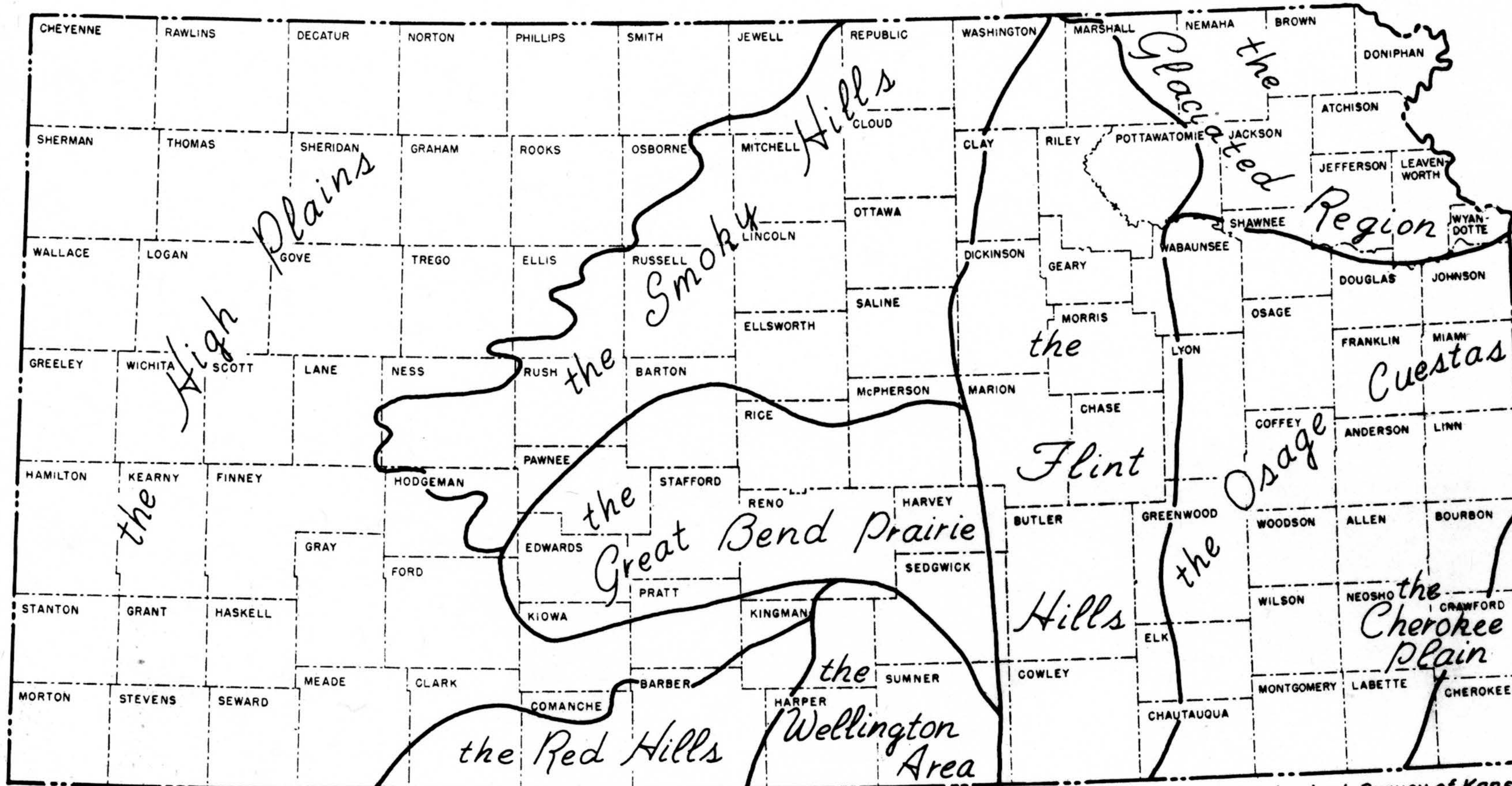


Pleistocene deposits, including present soils, cover most of Kansas



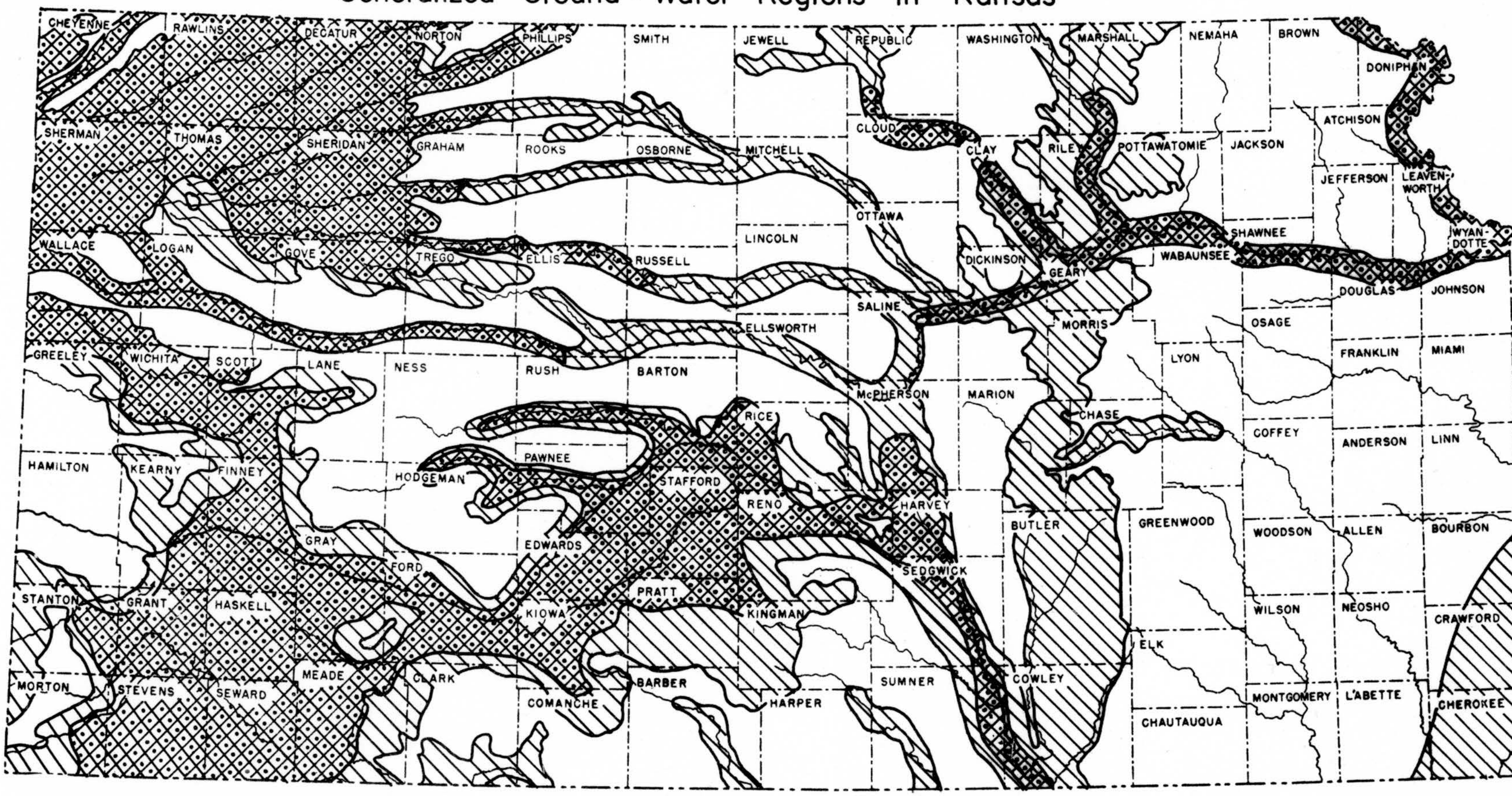
Generalized cross section of Kansas rocks

—State Geological Survey of Kansas



State Geological Survey of Kansas

Generalized Ground-Water Regions in Kansas



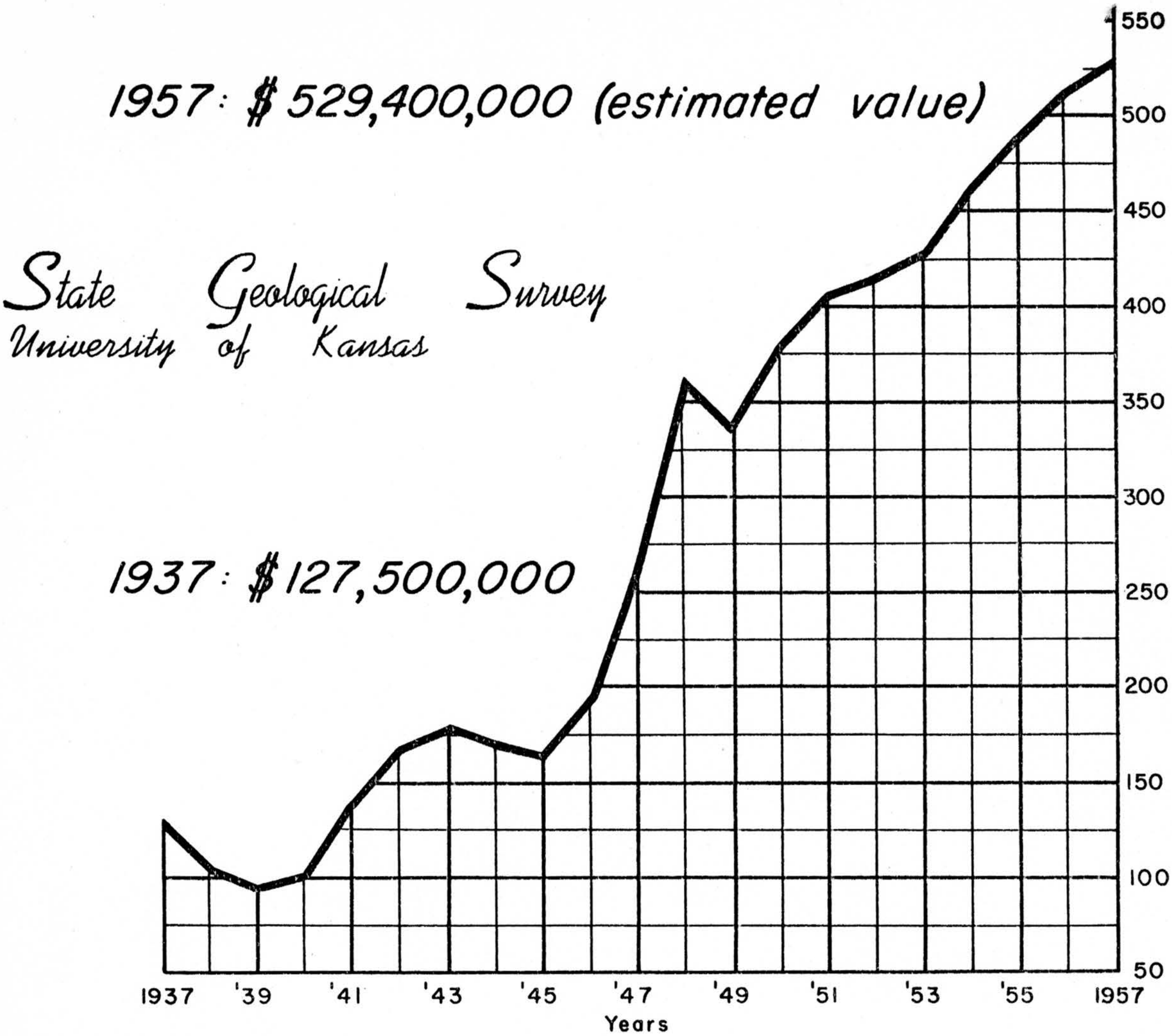
Areas in which yields of 500 gallons of water a minute are generally available.

Areas in which yields of from 50 to 500 gallons of water a minute are generally available.

Areas in which yields of less than 50 gallons of water a minute are generally available.

Map prepared by the Federal and State Geological Surveys, in cooperation with the State Boards of Agriculture and Health.

Mineral Wealth in Kansas



Estimated Value of Mineral Production in Kansas.....1957

Cement (portland and masonry)	$ 24,000,000
Clay and clay products	10,000,000
Coal	3,700,000
Lead	1,000,000
Natural gas	59,100,000
Natural gasoline and LPG	10,000,000
Petroleum, crude	378,700,000
Salt	9,000,000
Sand and gravel	8,000,000
Stone (building stone, crushed rock, ag. lime, etc.)	14,500,000
Zinc	2,100,000
Miscellaneous (gypsum, volcanic ash, natural cement, carbon black, helium, diatomaceous marl, etc.)	9,300,000
	$529,400,000

Each January the State Geological Survey makes mineral-production estimates to cover the year just ended. These estimates are based on figures and trends obtained from producers and other sources: trade journals, State Mine Inspector, State Corporation Commission, and U. S. Bureau of Mines, with which agency the Geological Survey has a cooperative agreement in getting statistical information other than for petroleum, coal, and metals.