Kansas GeoMaps

Don W. Steeples and Rex Buchanan

Kansas Geological Survey
Educational Series 4
1983

Cover Photo

The photograph on the cover was taken from 600 miles above Kansas by the LANDSAT satellite. However, it is not an exact photographic representation of the view of Kansas, but an image taken using infrared sensors so that healthy vegetation shows up as red, rather than green. Most rivers, for example, are outlined in red, representing the trees and plants near the streams. Also, the cover photo is a mosaic, or composite of a number of smaller images, pieced together to produce a single picture of the state. Jagged lines often occur where these smaller pictures are spliced together; the north-south lines in western Kansas are the result of this splicing process. This picture was taken in 1976, so newer features in the state, such as Clinton Reservoir near Lawrence, do not appear.

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(rev. 1984)

Contents

Maps

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Introduction

To most people, maps are simply two-dimensional diagrams of roads and highways, used to guide them from one place to another. But there's more to maps than pictures of roads. For hundreds of years, people have studied maps to learn more about, or to remember, the places they've been and to envision places they've never seen.

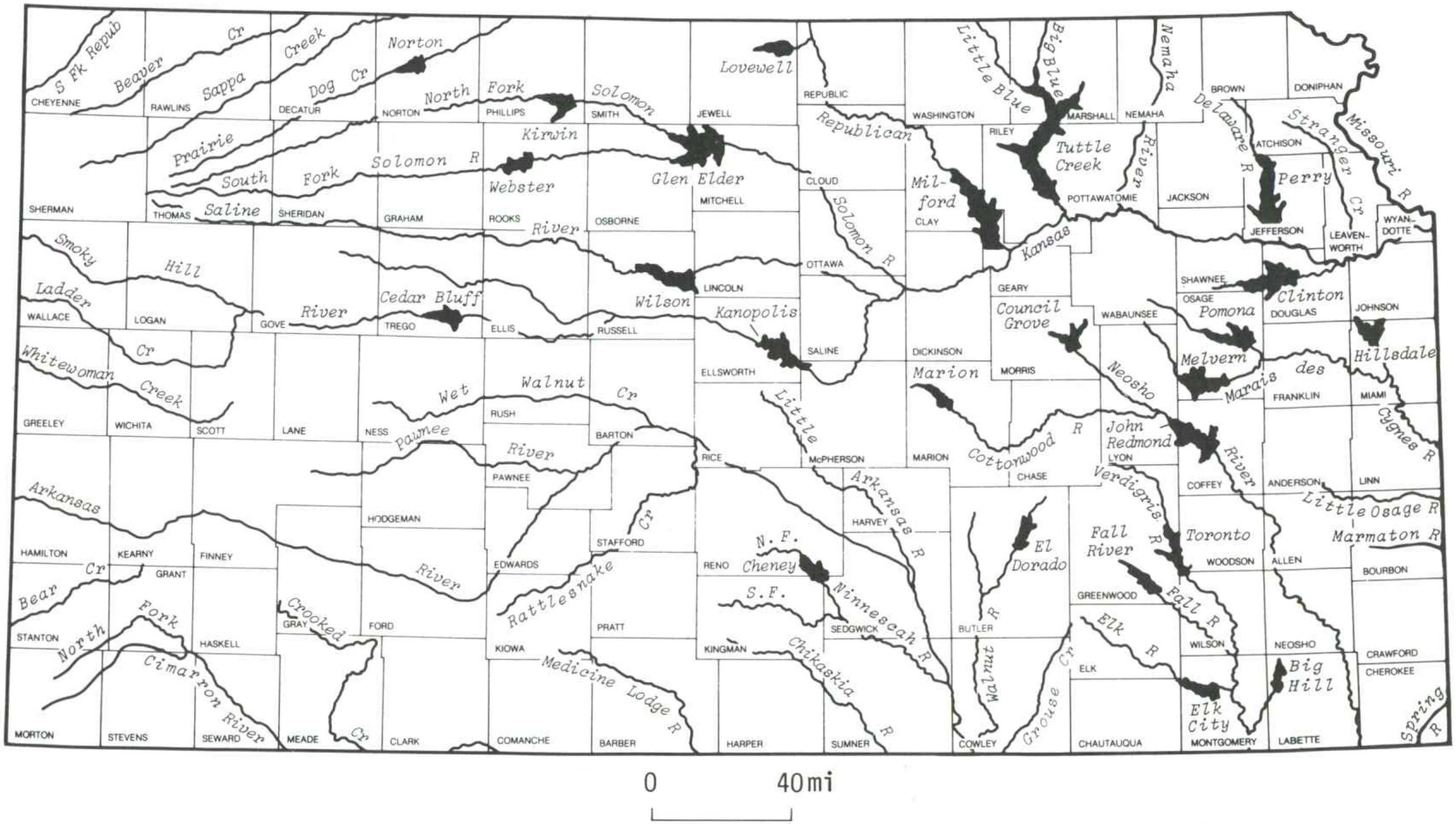
That is part of the reason for *Kansas GeoMaps*. "Kansas" is in the title because the booklet is about Kansas and written primarily for Kansans, although it should help others gain a new appreciation of the geologic and geographic diversity of the state. "Geo" is in the title because it is a Greek prefix describing those things that pertain to the Earth—such as geology, the study of the Earth. All the maps and discussions in this booklet describe the Earth in one way or another. "Maps," of course, are graphic representations of a part of the Earth's surface, in this case Kansas. And maps are the subject of this booklet.

In short, *Kansas GeoMaps* is written for readers who want to know more about the geologic and geographic qualities of Kansas. For students there is information about rock types, mineral deposits, energy sources, rivers, and lakes. For homeowners interested in using a ground-water-assisted heat pump, there is information about ground-water temperatures. For farmers information about ground-water availability, average annual precipitation, and the location of oil and gas fields is presented. And for earth scientists, samples of the types of geologic and geophysical maps available from the Kansas Geological Survey are included.

In some cases subtle, and not so subtle, relationships exist between maps. For instance, in central and western Kansas a strong relationship is found between oil and gas fields and the locations of holes drilled into the ground. In eastern Kansas, where our map of holes drilled is far from complete, the relationship to oil and gas fields is less evident. A correlation between oil fields and earthquakes also exists because many of the geologic structures that trap oil also contain one or more geologic faults where earthquakes occasionally occur. A relationship between physiography and the presence or absence of roads occurs, but this is complicated by the sparse population in extreme western Kansas, contributing to a lack of roads. More rivers and lakes are found in eastern than in western Kansas because more precipitation occurs in the eastern part of the state. Thoughtful readers will probably notice other relationships between these maps.

We hope that native Kansans, like the authors, will use these maps to develop a better appreciation of the complex nature of their home state. And we hope that those less familiar with Kansas will be surprised by the variety of geologic features here. Either way, enjoy *Kansas GeoMaps*.

Kansas with Rivers and Reservoirs



Generalized Geologic Map

One of the first lessons of Kansas geology is that nearly all the rocks on the surface of Kansas are sedimentary in nature, deposited by ancient seas, rivers, or the wind. These sediments were then compressed to form layers of sedimentary rock. Below these sediments is a layer of igneous rocks that underlies all of the state. In this generalized geologic map, the ages of the rocks found on the surface are shown in a variety of colors. The underlying igneous rock—once-molten rock that forms what geologists call the basement rock—is depicted in dark green as the Precambrian System. (A map of this basement rock is shown on page 23.) Precambrian rocks in Kansas are more than a billion years old, and they have been covered by younger sediments, which are depicted by the other colors on the map.

Another lesson of Kansas geology is that the rocks at the surface of the state are oldest in the east and, for the most part, younger in the west. The oldest rocks at the surface are found in extreme southeastern Kansas; they were deposited during the Mississippian Period of geologic history, about 350 million years ago. In eastern Kansas the most common rocks were deposited during the Pennsylvanian and Permian Periods, about 200 to 300 million years ago. One noteworthy Pennsylvanian-age rock is coal, which was formed in swamps and marshes and is today mined in southeastern Kansas. As you move west across Kansas, the rocks are much younger because these western Kansas formations were laid on top of the older sediments below and are responsible for the gradual rise in elevation across western Kansas. That is also why rock formations such as those of the Mississippian System, which holds oil in parts of eastern and western Kansas, are much deeper beneath the surface in western Kansas.

The light-green portion of north-central Kansas shows rocks of Cretaceous age, about 65 to 150 million years old. These rocks—predominantly limestones, shales, and chalk—were laid down at about the same time that dinosaurs ruled in North America. These Cretaceous rocks contain many fossils, including giant clams, sharks' teeth, and a number of swimming reptiles that were common in Cretaceous seas.

Western Kansas is covered by yellow and tan formations that represent much younger sediments that have been carried eastward from the Rocky Mountains, such as the sand dunes common around the Arkansas River. In northeastern Kansas, these younger sediments were deposited by glaciers that moved into the corner of the state about a million years ago, dropping the load of glacial rock debris they carried along with them from the north.

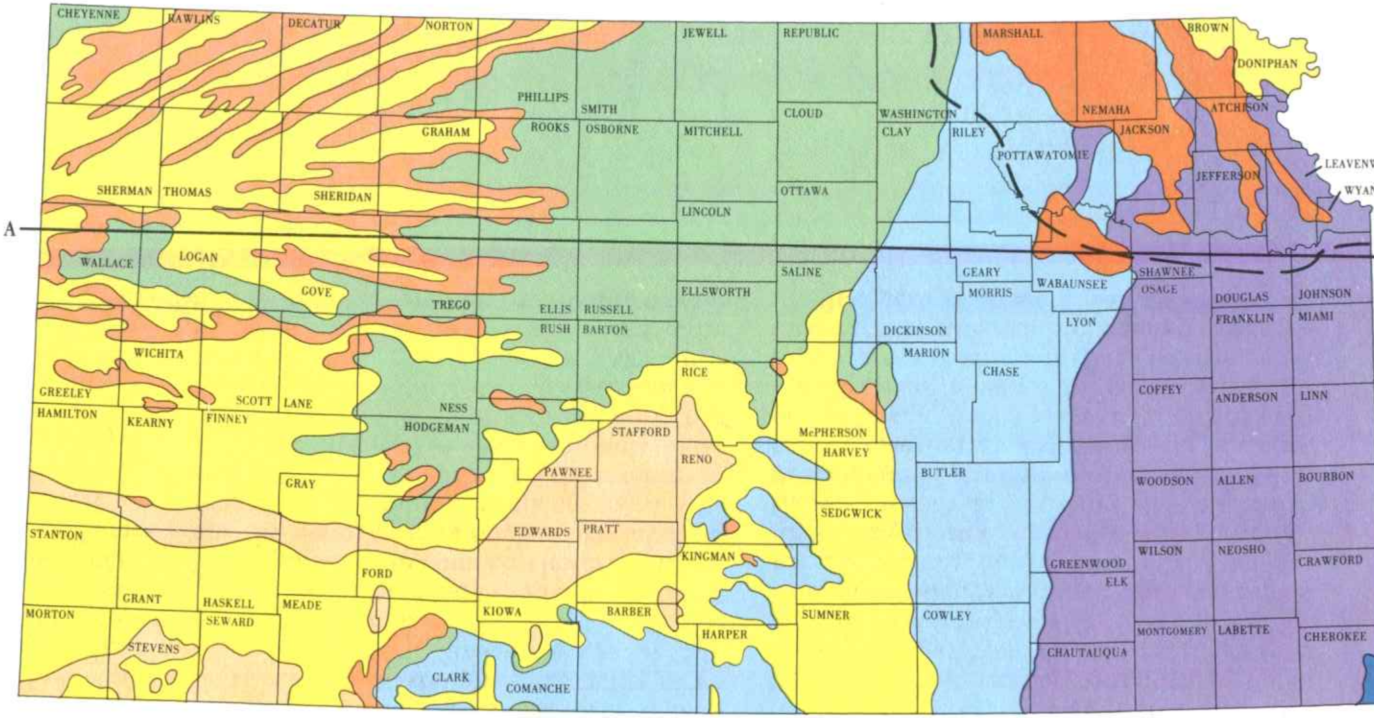
Generalized Geologic Map of Kansas

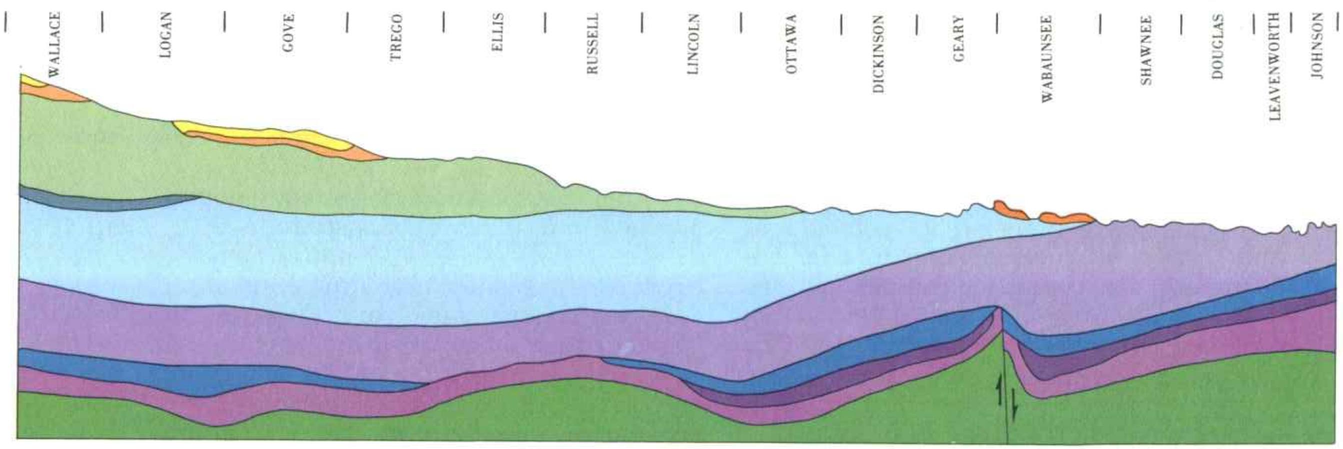
EXPLANATION

- QUATERNARY SYSTEM
  - Loess and river valley deposits
  - Sand dunes
  - Glacial drift deposits
- Limit of Kansan Glacier
- TERTIARY SYSTEM
- CRETACEOUS SYSTEM
- JURASSIC SYSTEM
- PERMIAN SYSTEM
- PENNSYLVANIAN SYSTEM
- MISSISSIPPIAN SYSTEM
- SILURIAN-DEVONIAN SYSTEMS
- CAMBRIAN-ORDOVICIAN SYSTEMS
- PRECAMBRIAN SYSTEM
- A—A′ Line of cross section

0 50 100 mi

0 50 100 km





Geologic cross section below I-70

Generalized Physiographic Map

This map is based on the land forms of Kansas, showing the natural physical geography and appearance of 11 different regions of the state. Much of the physical appearance of the land is related to the subsurface geology, shown on the geologic map of Kansas on the previous page.

The smallest of these 11 regions is the **Ozark Plateau** in the tip of southeastern Kansas, where beds of limestone and chert form hills similar to the Ozarks of Missouri and Arkansas. This region corresponds to the area of Kansas where the rocks are of Mississippian age. Also in southeastern Kansas are the **Cherokee Lowlands.** This area is relatively flat because the common rocks—shales, sandstones, and coal—are easily eroded. These lowlands form the major coal-producing area in Kansas. A large part of southeastern Kansas is in the region of the **Osage Cuestas** (pronounced KWE-sta), a landscape composed of parallel ridges. "Cuesta" is a Spanish word for hills characterized by a steep escarpment, or cliff, on one side and a gentle slope on the other.

Another distinctive region of southeastern Kansas is the **Chautauqua Hills,** a gently rolling upland of hills capped by limestone. To the west of the Chautauqua Hills are the **Flint Hills,** where beds of limestone and shale are interspersed with layers of flint or chert, allowing the hills to withstand erosion. Because those rocks also make cultivation difficult, the Flint Hills pastures are one of the largest areas of native grass in the United States. Most of the rocks in the Flint Hills were deposited during the Permian Period.

In northeastern Kansas is the **glaciated region** of Kansas, the distinctively hilly part of the state that was covered by glaciers about a million years ago. In places, these glaciers rearranged the landscape and dropped their load of rock debris, including huge red quartzite and granite boulders that were transported from the north, some from several hundred miles away. This debris is known as "glacial till" and it forms a deep, rich, heavy clay soil. In some parts of extreme northeastern Kansas, the glacial till is over 300 feet thick.

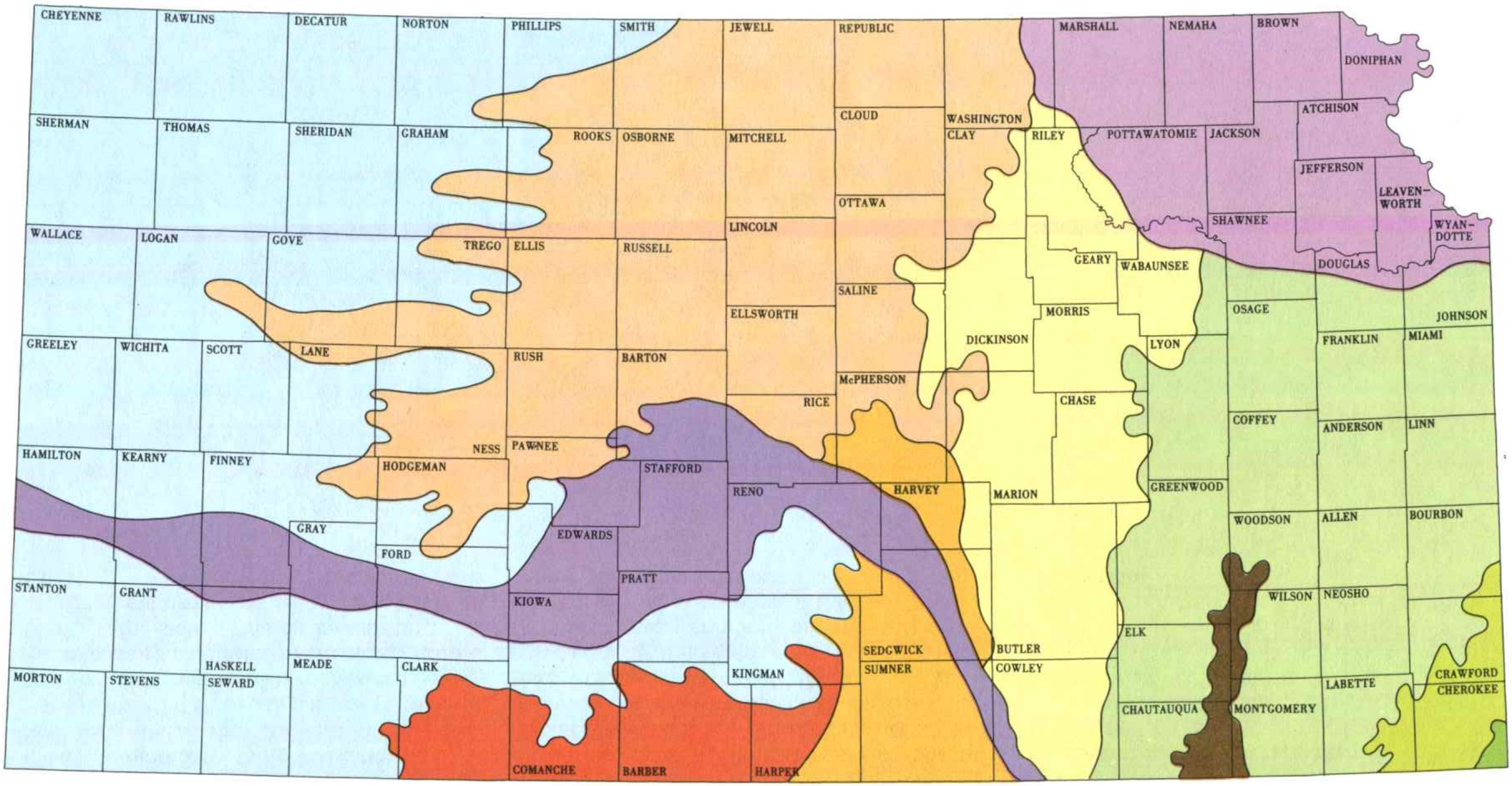
The area west of the Flint Hills, called the **Wellington-McPherson Lowlands,** was created by deposits from shallow Permian-age seas about 250 million years ago. Salt, gypsum, and shale, deposited when these ancient seas evaporated, are commonly found today. Along the south-central border of Kansas are the **Red Hills** of Kansas, an area that resembles Arizona or New Mexico as much as Kansas. The soils and rocks of the Red Hills are colored by iron oxide, or rust.

The **Smoky Hills** in north-central Kansas rival the Flint Hills in their beauty. Named because of the hazy appearance of their valleys, the Smoky Hills are largely Cretaceous formations (about 100 million years old) such as sandstone, chalk, and limestone. Included in the Smoky Hills is the "post rock country" to the north and Dakota sandstone outcrops in central Kansas.

To the west of the Smoky Hills are the **Kansas High Plains**, which were formed by erosion of the Rocky Mountains to the west. The eroded materials were carried east by streams, creating the wide, flat vistas of western Kansas. This material also formed an underground water-bearing rock formation called the Ogallala aquifer, and it contains much of the underground water that is rapidly being depleted by irrigation wells in parts of western Kansas.

Similar deposits form the **Arkansas River Lowlands,** an area where the Arkansas River transported eroded sediments into Kansas and, by meandering back and forth in its channel, created another flat, distinct surface. During an extremely hot and dry period about 6,000 years ago, this sandy material was blown into desert-type sand dunes, some of which can still be seen along the Arkansas River and in isolated instances in other parts of western Kansas.

Generalized Physiographic Map of Kansas



EXPLANATION

- HIGH PLAINS
- SMOKY HILLS
- ARKANSAS RIVER LOWLANDS
- WELLINGTON-MC PHERSON LOWLANDS
- GLACIATED REGION
- OSAGE CUESTAS
- FLINT HILLS UPLANDS
- RED HILLS
- OZARK PLATEAU
- CHEROKEE LOWLANDS
- CHAUTAUQUA HILLS

0 100 mi

Rural Roads

At first glance, a map of rural roads in Kansas might not seem particularly interesting. But take a closer look. This map reveals a great deal about the state's geography, its geology, and the relationship between the landscape and human activities.

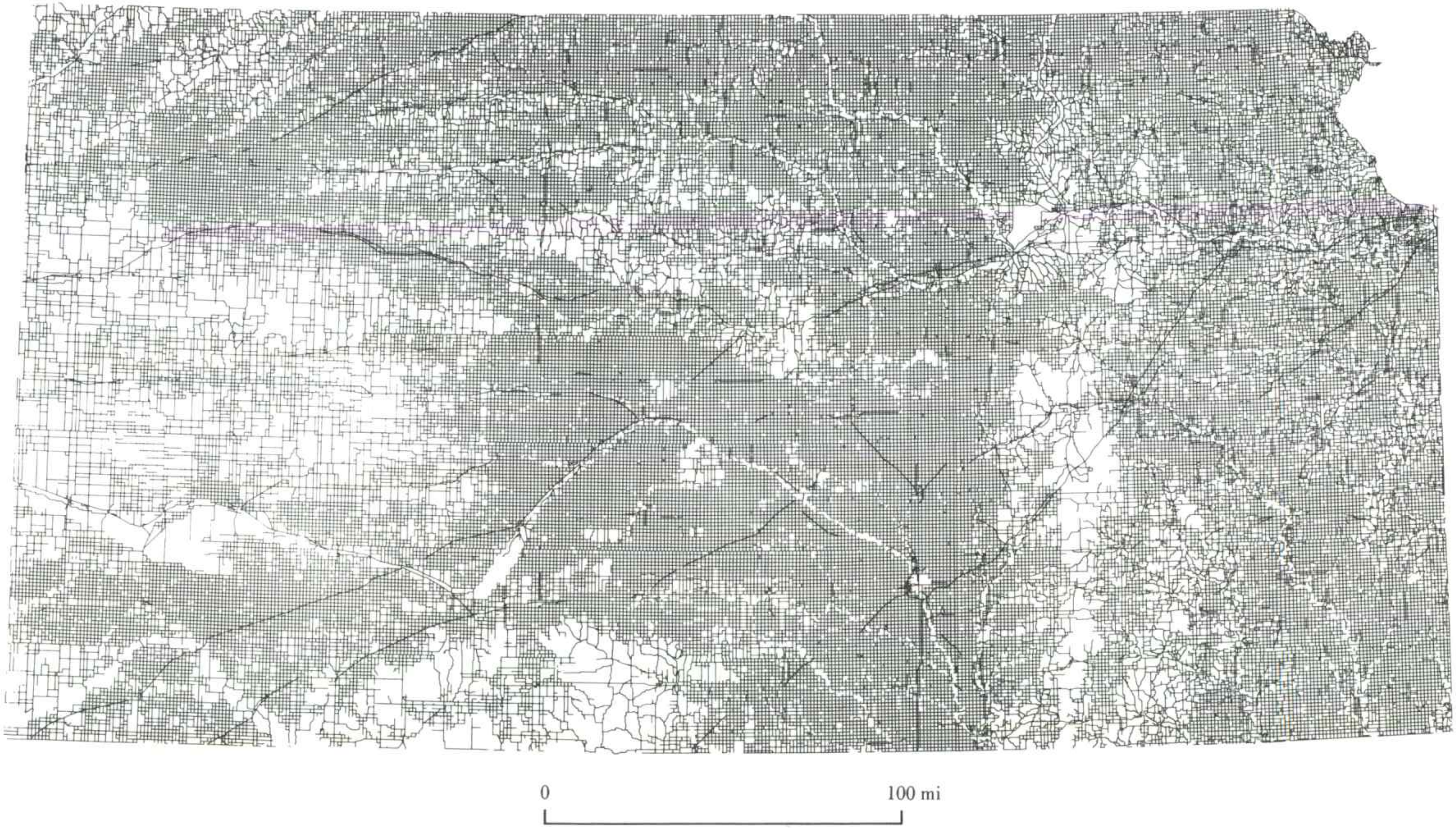
For example, in eastern Kansas the most noticeable feature is the lack of roads in the Flint Hills, which appear as a mostly blank stretch running north and south across the state. In the Flint Hills, rural roads have clearly adapted to their hilly terrain. The lack of roads in the Red Hills of southern Kansas and the unusual pattern of roads in the glaciated region of northeastern Kansas are two more examples of the adaptation of roads in the state's rugged topography.

River patterns also show up clearly on this map. The bend of the Cimarron River in extreme southwestern Kansas and the path of the Neosho River in southeastern Kansas are visible reminders of Kansas drainage patterns. The Cheyenne Bottoms Wildlife Refuge is apparent as an undeveloped area in central Kansas. Other features associated with drainage also are plainly visible; for instance, the blank areas south of the Arkansas River in southwestern Kansas are stretches of sand dunes that have not been penetrated by rural roads.

Kansas ranks third in the nation—behind Texas and New York—in number of miles of public roads, and most of those roads are laid out in section patterns. This is, rural roads divide areas into sections that measure a mile on each side and enclose 640 acres. But a surprising number of the state's roads don't obey that sectional division. In some regions, such as the Flint Hills and the Dakota sandstone country of north-central Kansas, that lack of regularly patterned roads seems to indicate that the land is used primarily as livestock pasture. In central Kansas, the regular pattern of sections seems to be found most often in areas where the land is extensively tilled. But in western Kansas, the roads rarely cut the land into parcels as small as a mile square, probably a result of lower population density and because farming in western Kansas is done on a larger scale.

Not all the features on the map result from people obeying nature's influence. The blank spot north of the Flint Hills, for example, is the largest roadless area in eastern Kansas. It outlines the Fort Riley Military Reservation.

All Rural Roads in Kansas



Ground-Water Availability and Precipitation

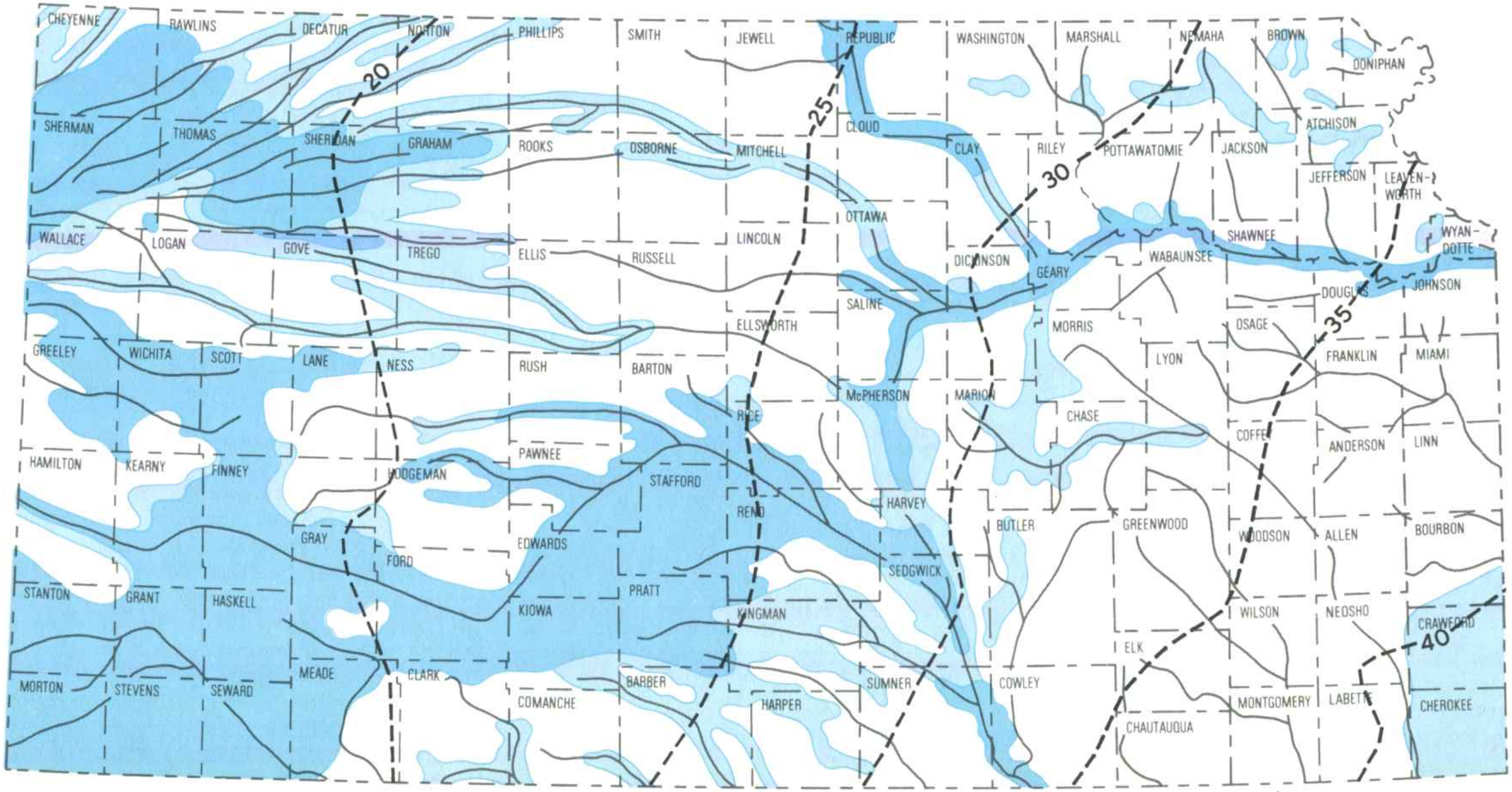
Few resources are as important to Kansans as their supply of ground water, the water found in rock formations under the ground. This map shows the typical availability of ground water and the average annual precipitation throughout Kansas. In much of western Kansas, ground-water yields of more than 100 gallons per minute are available from the Ogallala Formation, an extensive aquifer (or water-bearing rock formation) that provides irrigation water in parts of Nebraska, Colorado, Oklahoma, Texas, South Dakota, New Mexico, and Kansas. In much of the Ogallala, more than a hundred feet of the formation is saturated with water. This water accumulated slowly over the past several thousand years, mostly from precipitation filtering downward from the Earth's surface. While water levels in the Ogallala have dropped as much as 10 feet per year in some areas of extensive irrigation, the rate of recharge—the rate at which water trickles back into the aquifer—is usually only a few inches per year. Water clearly is being pumped out many times faster than it is being replaced by nature and in many areas it will be unprofitable, if not impossible, to produce water for irrigation by the year 2000. The federal government has studied ways to import water from the Missouri River or other sources to western Kansas, but imported water would cost several hundred dollars per acre-foot—not economic with today's farm-commodity prices.

Most of the state's large rivers dissect valleys that contain deposits of water-saturated sands and gravels. These sands and gravels, called alluvial aquifers, have long-term irrigation potential because they are recharged with water each time the river rises above normal. Many Kansas towns, especially in eastern Kansas, depend on wells in river valleys or on the rivers themselves for water supplies. Not coincidentally, many of the larger cities in eastern Kansas—such as Lawrence, Topeka, and Kansas City—are located along the banks of the Kansas River, an important and reliable water source. Except in times of severe drought, rivers and their valleys provide stable sources of water.

In extreme southeastern Kansas, limestone aquifers provide water supplies for towns, but little irrigation is possible because wells often must be 700 to 1,000 feet deep, making drilling and pumping too expensive for farmers. Besides, in a normal year, that area receives about 40 inches of precipitation—enough to raise crops without irrigation.

More detailed information about ground water is available from Survey staff members and in other Kansas Geological Survey reports and maps at the KGS publications offices in Wichita and Lawrence.

General Availability of Ground Water and Normal Annual Precipitation in Kansas



Yield of greater than 500 gallons per minute

Yield of 100-500 gallons of water per minute

Yield of less than 100 gallons of water per minute

Precipitation contours in inches per year

0 100 mi

Oil and Gas Fields

While Kansas has produced oil and natural gas for many years, deposits of these fuels are not distributed evenly across the state. This map outlines the oil and gas fields in Kansas—showing both the fields that are currently producing and those that have been pumped dry and abandoned.

This map shows areas of oil production, natural gas production, and combined oil and gas production. The light blue depicts fields where natural gas is stored in underground rock formations, and the yellow shows "shallow gas," natural gas that was discovered in a formation above a geologically older gas-producing formation. For example, the yellow area in central Kansas shows the Lyons Gas Area. This field produces gas from a rock bed that lies above an older formation that also produces gas.

Kansans first discovered oil in 1860 near Paola in Miami County, and early oil and gas development was concentrated in the eastern part of the state. Oil-bearing rocks in eastern Kansas are relatively shallow, some within a few hundred feet of the surface. Those shallow wells were easy to drill and the discovery of gas spawned an industrial surge in southeastern Kansas that lasted well into the 1930s, when gas supplies began to run out. A similar increase in oil drilling occurred, which attracted many major oil companies into southeastern Kansas.

Today many of the oil fields in southeastern Kansas have played out and most of the region's large fields have probably been discovered. Still, a few thousand new wells are drilled in eastern Kansas each year, although most of them are stripper wells, which produce less than 10 barrels of oil per day.

Farther west, oil production began in the early 1900s with discoveries near El Dorado in Butler County. Some of the first Butler County wells were dramatic "gushers" and many produced over a thousand barrels of oil per day. With the oil boom in south-central Kansas, the state's total oil production jumped from two million barrels in 1915 to over 45 million barrels just three years later. Oil from this area was discovered in a subsurface bowl-shaped sedimentary deposit that geologists call the Sedgwick Basin, and Butler County and Wichita remain major oil-producing and refining centers.

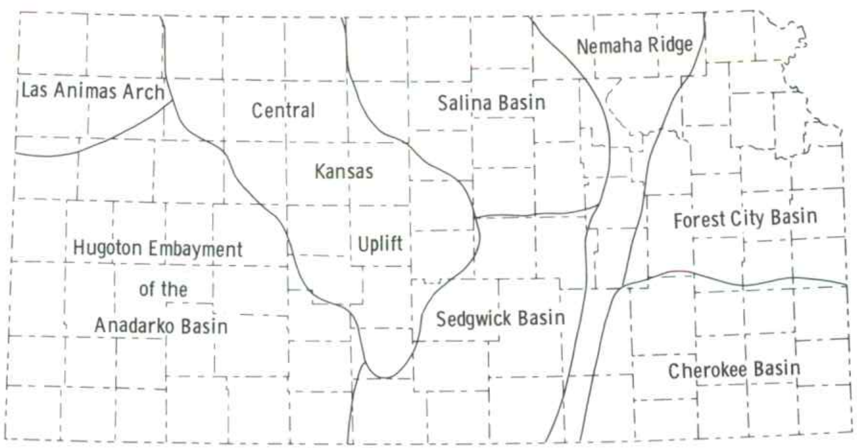
The diagonal trend running from northwestern Kansas to the central part of the state is known as the Central Kansas uplift, and it is the source of the vast oil production in Ellis, Russell, Rooks, and Barton counties, traditionally among the leading oil-producing counties in Kansas. Much of the oil in this area comes from relatively deep wells, most of them drilled into underground limestone formations, where oil is trapped between particles of rock. Geologists believe that much of the oil in this area matured from organic material, deep underground in Oklahoma. That oil then migrated northward until it reached the Central Kansas uplift, which acted as a barrier, trapping the oil and holding it in place where it was discovered in the 1920s.

Outlined in the nine counties in extreme southwestern Kansas is the Hugoton gas field, one of the largest gas fields in the world. Discovered in 1922, the Hugoton led to huge increases in gas production, especially from such counties as Grant, Kearny, and Stevens, each of which annually produces billions of cubic feet of natural gas.

Kansas oil production reached its peak in the 1950s, when the state annually produced more than 120 million barrels of oil. Since that time production generally has declined, until it hit a low of about 56 million barrels in 1978. The state's oil production has risen slightly during the past several years and drilling has been spurred by higher crude-oil prices.

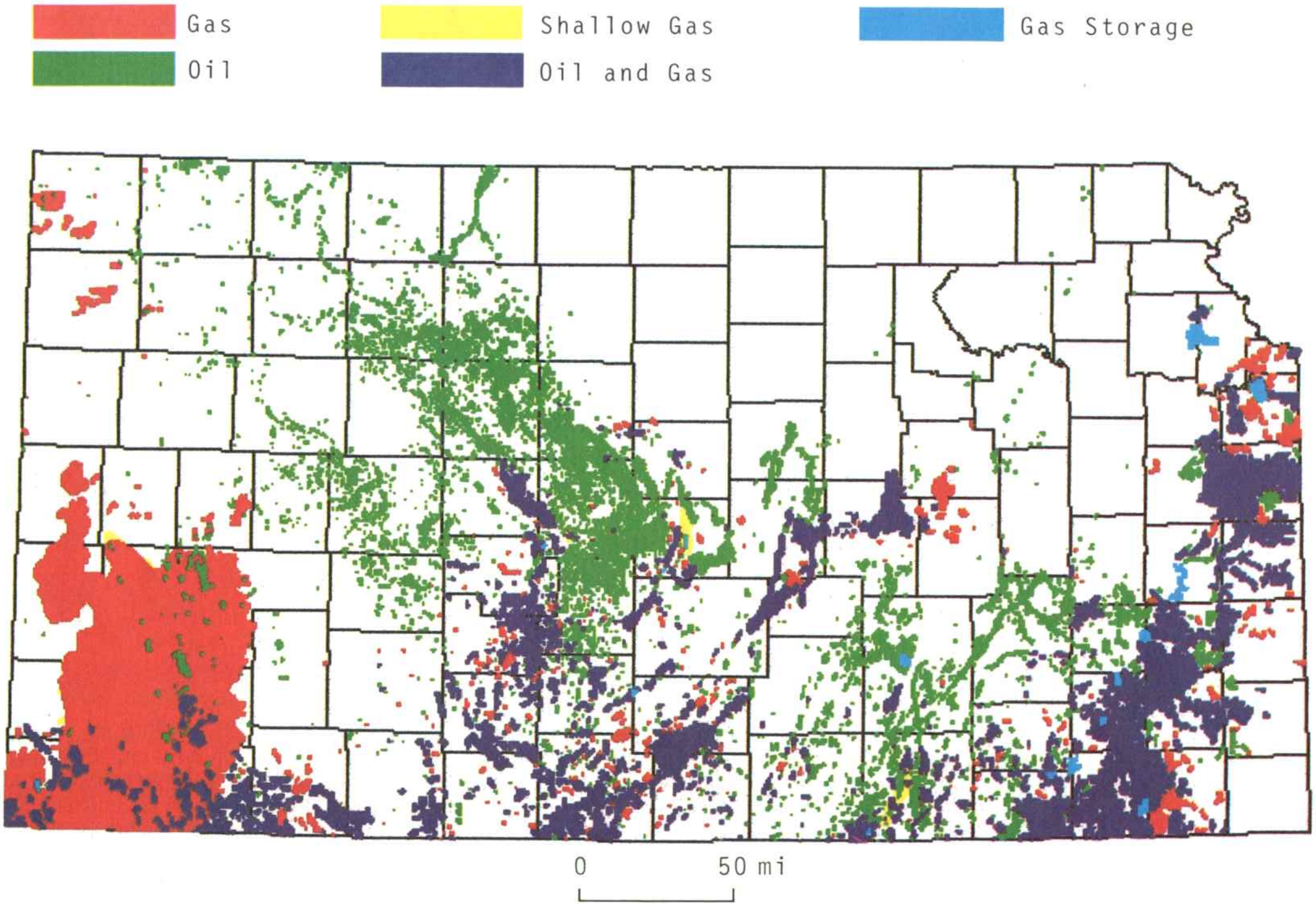
However, large parts of the state produce relatively little oil. Northeastern and north-central Kansas are largely blank spaces on this map, although oil explorationists are beginning to drill those areas more and more.

The oil and gas map below was created using the GIMMAP program and automated cartography unit of the Kansas Geological Survey.



Major subsurface geologic structures.

Oil and Gas Fields in Kansas



Holes Drilled for Oil and Gas

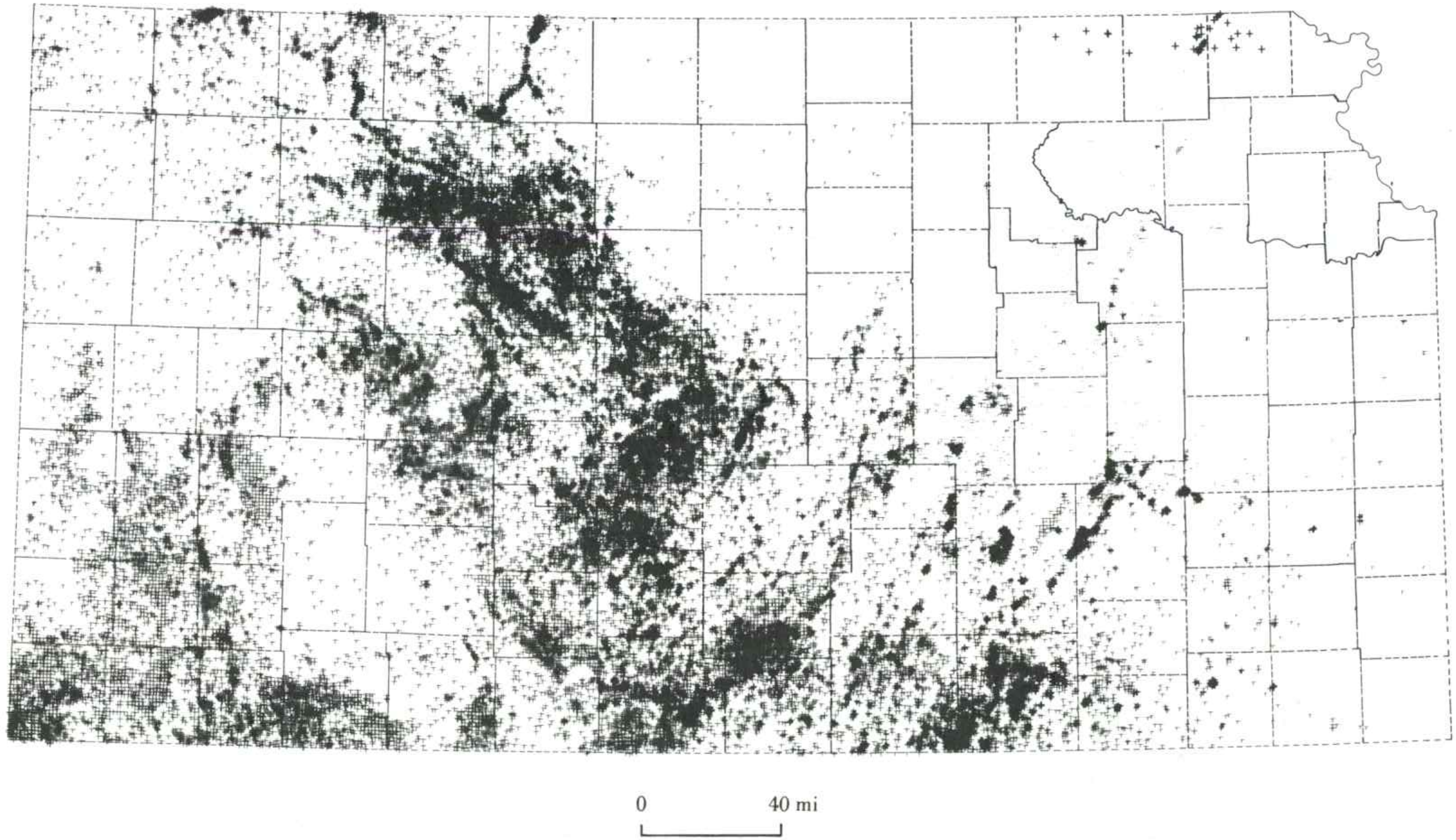
Kansas drillers have been poking holes in the state since the 1860s, when they first discovered oil in Kansas. The Kansas Geological Survey has extensive records for many of those wells, including 125,000 drillers' logs—notes made by geologists as they inspect the rock chips brought to the surface by the drill. The Survey also has geophysical logs—records made by electronic instruments lowered into a completed hole—for over 70,000 of those wells.

This map shows the location of the wells for which the Survey has geophysical logs. Because Survey files are far from complete, many wells are not represented on this map, especially in eastern Kansas where the earliest drilling took place.

There are similarities between this map and the oil and gas fields map on page 13. Dense drilling in the area from Wichita to northwestern Kansas—along a geologic structure called the Central Kansas uplift—has uncovered a number of oil fields in the region. Conversely, the area north of Saline County, called the Salina Basin, has few oil fields and little drilling, because the few wells drilled in the Salina Basin have been relatively unsuccessful. A drilling pattern from Nemaha County southward to Cowley County reflects the geologic structures associated with the Nemaha Ridge, a buried range of granite mountains (shown on the geologic cross section, page 5).

Data from only a few wells in extreme eastern Kansas are included in Survey files. However, the oil-field map shows that many small oil and gas fields have been discovered in that area.

Holes (with geophysical logs) Drilled in Kansas for Oil and Gas



Coal

About 300 million years ago, during the Pennsylvanian Period of geologic history, much of eastern Kansas was covered with a dense swamp. As plants in that swamp decayed and were buried under sediments, they formed layers of coal that now underlie much of the eastern third of Kansas.

This map shows the geographic location of coal deposits in Kansas. Parts of Kansas east of the dotted line are underlain by layers of coal. Some of these deposits of coal are thick enough for profitable mining, although in most cases those coal beds are thin and may be deeply buried.

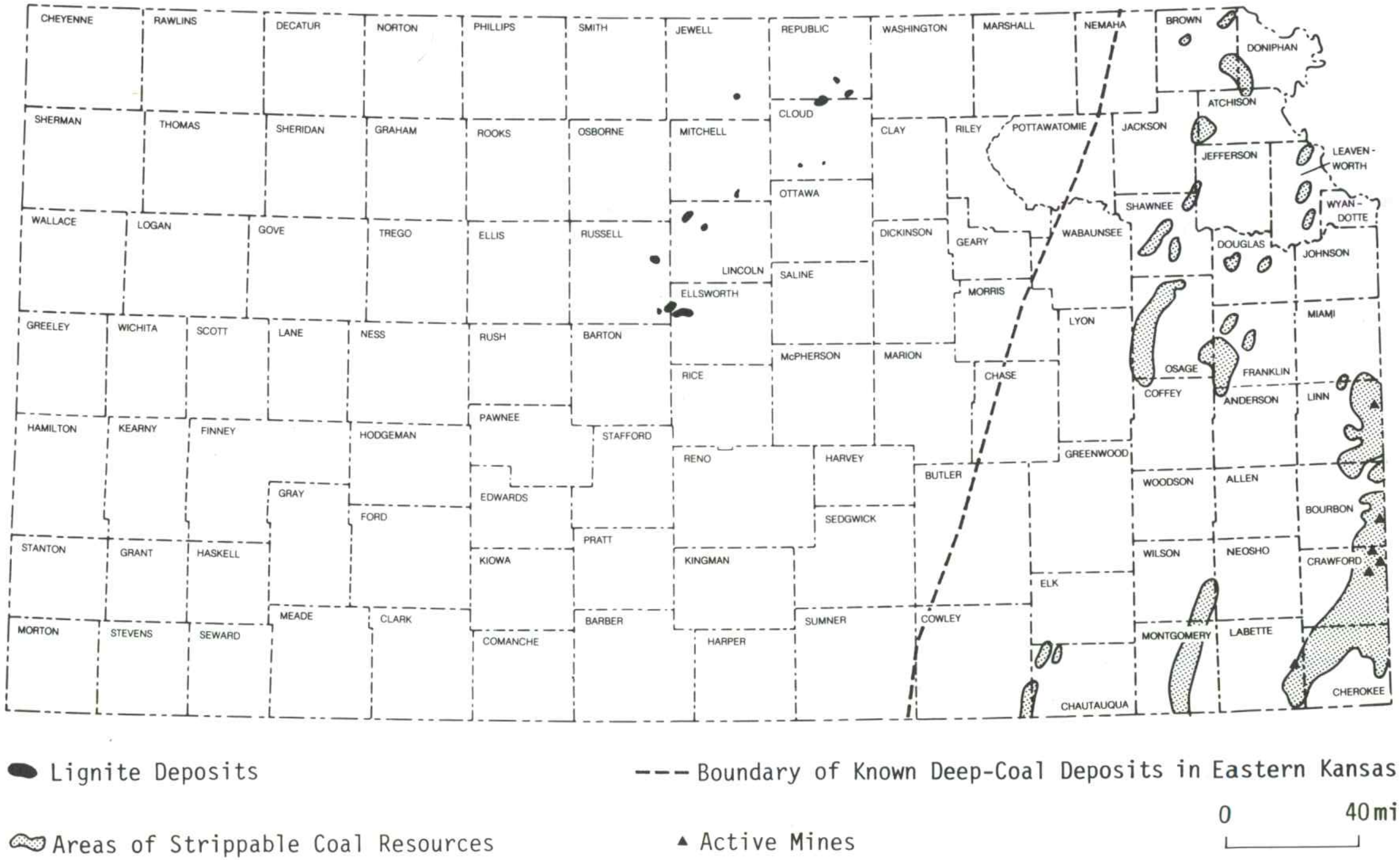
Coal mining began early in Kansas history. When pioneers first moved to the eastern part of the state in the 1850s, fuel was one of their primary concerns and they were able to dig coal in a number of areas, using both strip mines and deep-shaft mines. In Leavenworth County, one mine (about 700 feet deep) was tunneled under the Missouri River along a coal layer. Coal mining peaked in Kansas during World War I, when the state produced more than seven million tons of coal every year.

Today Kansas produces just over a million tons per year, all of it from strip mines in southeastern Kansas. The drop in production has been caused by relatively low coal prices and by the availability of other, cleaner sources of energy such as oil and natural gas. Also, most of the coal from Kansas is high in sulfur, which means it does not burn as cleanly as coal from other parts of the country.

The map also shows the locations of mines in north-central Kansas that once produced lignite, a low-grade form of coal. Kansas lignite was formed during the Cretaceous Period of geologic history, about 150 million years after coal was forming in eastern Kansas. While eastern Kansas coal is hard and black, lignite is soft and has a brownish color.

Early records show that lignite was mined in strip mines and shafts in Kansas as early as 1855, and the state was still producing the fuel as late as 1940. But because lignite is high in moisture and produces a great deal of ash when burned, it became less and less popular in Kansas. The peak of production was reached in 1891, when the state produced more than 28,000 tons of lignite.

Coal in Kansas



Mineral Products

When it comes to mineral products, Kansas is probably best known for its oil and natural gas. In 1980, Kansas produced about $3.75 billion worth of minerals, about 90 percent of which came from oil and gas sales.

But the state produces many other minerals and this map shows those mineral products and the locations that produce them. The most widespread of the nonfuel minerals from Kansas is sand and gravel, mined in open pits and dredged from rivers. Most sand and gravel comes from the Arkansas and Kansas Rivers, although some is produced from the Ogallala Formation in western Kansas. Nearly all Kansas sand and gravel is used in construction.

Other construction-related materials from Kansas are cement, produced in five counties, and crushed rock, produced throughout the state. Most of that crushed rock is limestone used for construction and in surfacing roads.

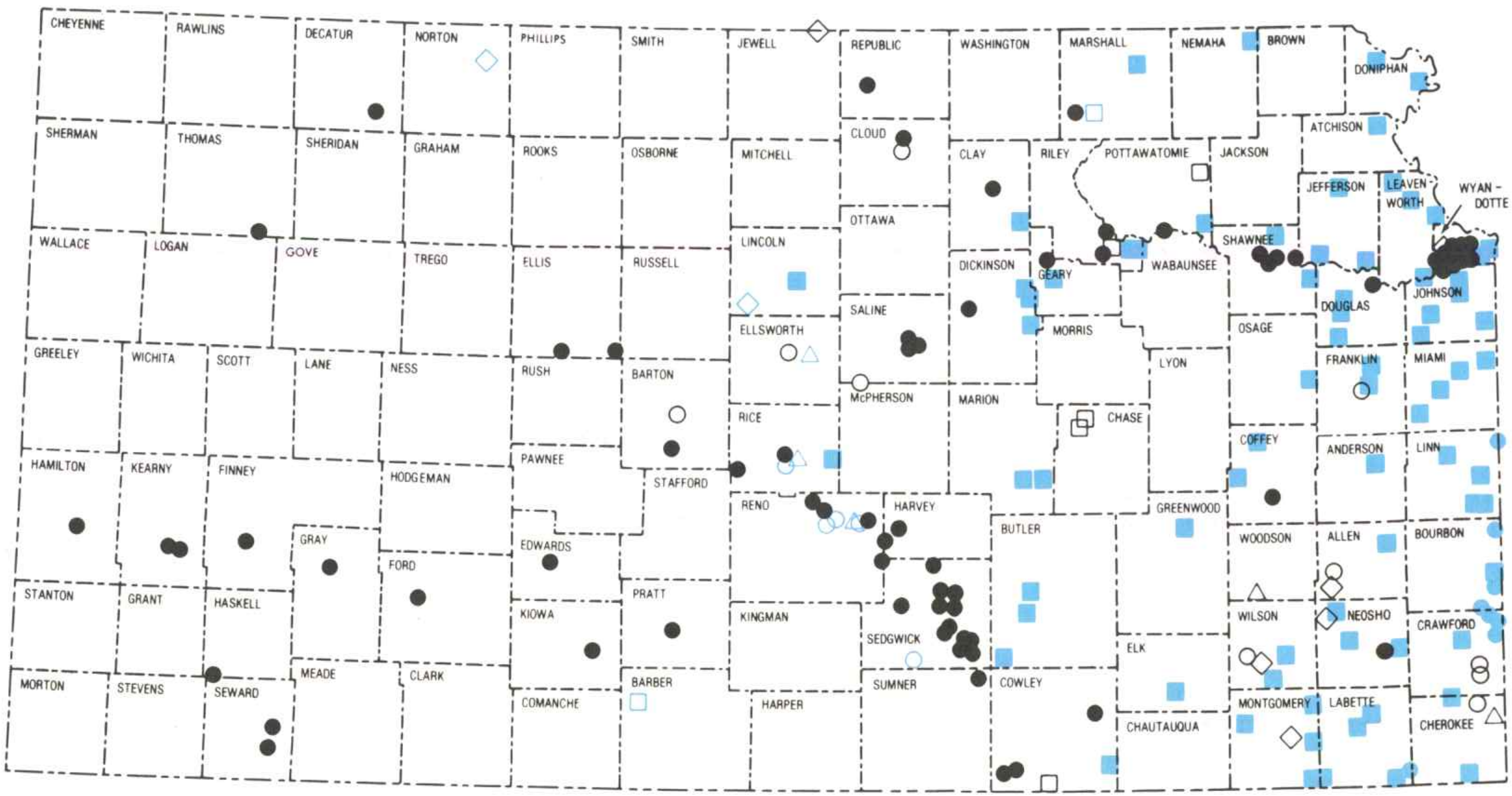
Most Kansans probably are less familiar with other minerals produced in their state. Gypsum, a white mineral used in plaster and sheet rock, is produced in Barber and Marshall counties, from shallow underground mines. Clay, produced commercially in north-central and southeastern Kansas, is used in making bricks, pottery, and other products. In 1980, Kansas manufactured more than $20 million worth of clay products.

Although Kansas is known for salt deposits, salt is mined in only eight locations in the state, all in central Kansas. Rock salt comes from underground mines in three locations, while other types of salt are solution-mined—by pumping down freshwater, which dissolves the salt away, and then pumping the brine back to the surface—in five other locations. All of the salt mined in Kansas comes from a thick salt bed called the Hutchinson Salt Member of the Wellington Formation, a layer of salt that was formed when an arm of a saline ocean evaporated during the Permian Period, about 250 million years ago.

One of the more unusual mineral products from Kansas is lightweight aggregate, a shale that is heated and expanded, making a lightweight rock that is used for decoration and construction. Much of the concrete in the terminals in Kansas City International Airport contains this lightweight aggregate, produced in plants near Ottawa and Marquette.

Volcanic ash—a gray, gritty material similar to ash produced by the Mount St. Helens eruption—also is mined in Kansas and has been used in everything from sink cleanser to bedding material for chinchillas. This ash is found in a number of deposits in Kansas, deposits that range in thickness from several inches to several feet. Kansas ash came from volcanoes that erupted at Yellowstone and in New Mexico several million years ago. That ash was thrown into the air, blown over Kansas, and then dropped over the state where lakes and streams concentrated the ash into thick deposits.

Kansas Mineral Products



EXPLANATION

- □ Building-stone quarry
- ◇ Cement plant with limestone quarry
- ○ Clay-product plant including clay pits
- △ Clay production
- ● Coal mine
- ■ Crushed-rock mine, quarry (>50,000 tons/year)
- □ Gypsum mine and plant
- ○ Salt (solution mine field)
- △ Salt (deep mine)
- ● Sand and Gravel pit or dredge (>50,000 tons/year)
- ◇ Volcanic ash pit

0 50 100 miles

0 50 100 kilometers

Earthquakes

While Kansas is famous for its tornadoes, occasional earthquakes do occur in the state. At least 25 earthquakes have been felt by residents of the state since 1867, the most serious occurring in the Wamego-Manhattan vicinity in 1867 and 1906. The 1867 quake broke dishes and windows, toppled chimneys, and cracked some building foundations. The most recent Kansas quake strong enough to be felt by local residents occurred in Russell County in September 1982.

Today the Kansas Geological Survey uses a seismograph network to study Kansas earthquakes that are too small to be felt by humans. These small earthquakes are called microearthquakes, and they generally rank lower than 3.0 on the Richter Scale. The network detects earthquakes by using seismometers—low-frequency, microphonelike devices—placed at the bottom of steel-encased holes in the ground. Seismometers pick up seismic waves, electronically amplify them a million times, then transmit the data to Lawrence using FM signals over standard telephone lines. The signals are then recorded by an ink pen on a revolving paper-covered drum. By studying the arrival times of the recorded signals, seismologists can determine the location, size, and origin time of earthquakes.

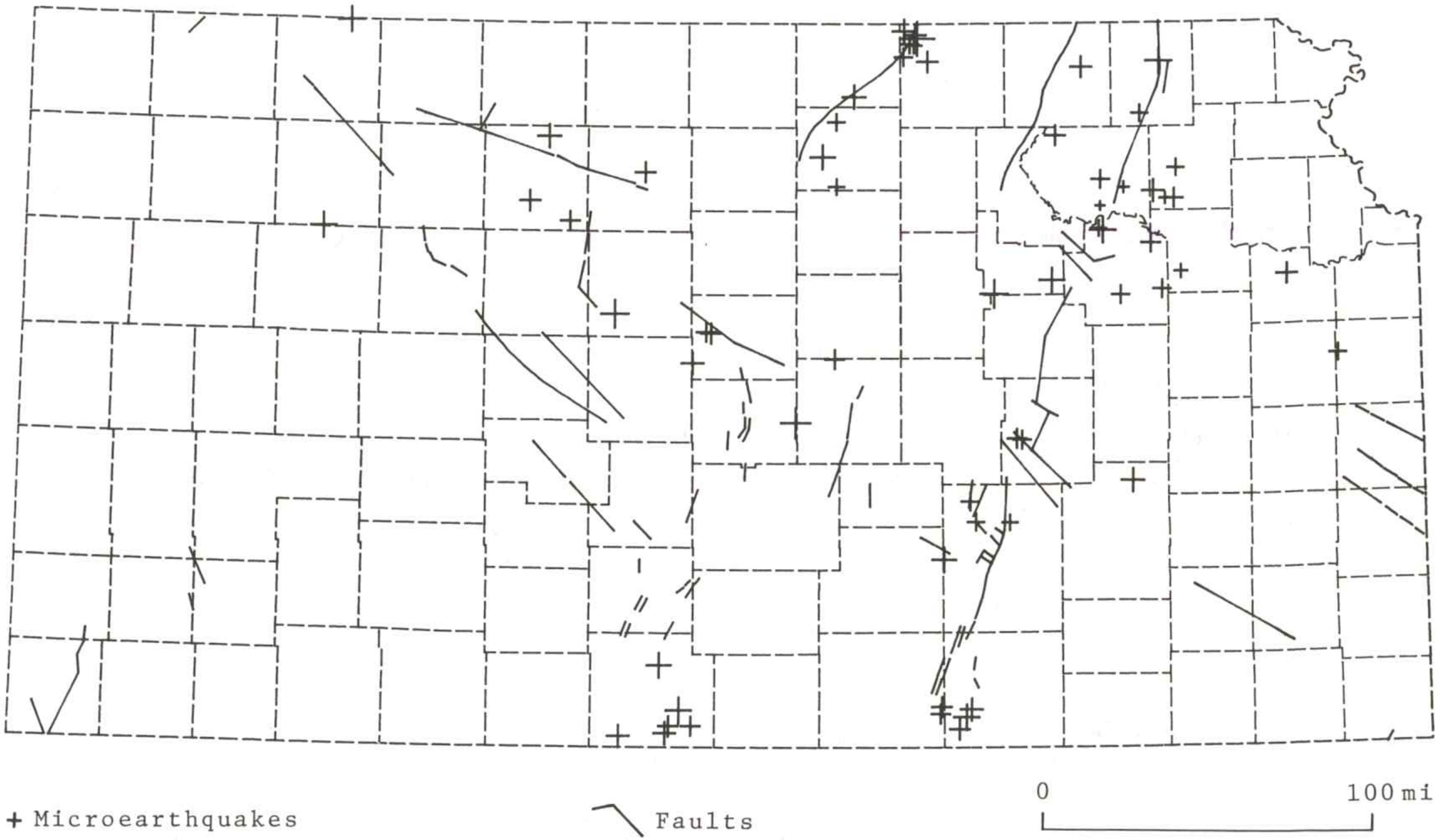
The Survey network can pick up ground movements as small as one millimicron or one 25-millionth of an inch—25,000 times smaller than the thickness of a human hair. The seismometers record not only Kansas earthquakes, but can even detect quarry blasts from as far away as Illinois, artillery from 30 miles away, and large earthquakes from places as distant as Japan and South America.

The Survey seismograph network began operating at its current level of sensitivity in December 1977, and in the following four years recorded about 80 small earthquakes. The largest of these earthquakes measured about 3.1 and the smallest 1.0 on the Richter Scale. The study of small earthquakes allows scientists to estimate how often we can expect larger earthquakes and to locate areas where they are likely to occur, information that is crucial in designing dams, power plants, and other structures so that they can withstand the earthquake's shaking. Most of the small earthquakes plotted on the map can be identified with known geologic structures or faults. For example, a number of the quakes in eastern Kansas are associated with the Humboldt fault zone, a major fault zone that crosses Kansas from Nemaha County in the northeast to Cowley County in the southeast. The Humboldt fault zone is associated with the east flank of the Nemaha Ridge, a buried granite mountain range that crosses the state.

Some earthquakes occur in the same vicinity as the Central Kansas uplift, a buried range of granite hills that extends from near Wichita, past Norton, across Nebraska, to the Black Hills of South Dakota. Other earthquakes are associated with the Midcontinent Geophysical Anomaly, a zone of dense igneous rock that extends from central Kansas near Abilene northeastward through Nebraska, Iowa, and Minnesota to Lake Superior.

The current level of earthquake activity is about what seismologists expected, so there is no reason for the public to be alarmed by earthquakes in Kansas. Kansans will continue to occasionally feel small to moderate earthquakes.

Microearthquakes and Faults in Kansas



Basement Configuration

As you may know, **sedimentary rocks**—such as limestone or sandstone—are the most common type of rock found on the surface in Kansas. These rocks came from blankets of sediments that were deposited by wind or water, then compacted and solidified to form rock layers.

But if you could somehow strip off that sedimentary cover and remove the limestones, sandstones, and shales, you would expose other vastly different types of rocks. This map depicts the appearance of the Kansas landscape if all those sedimentary rocks were removed. Geologists call this a basement map because it shows the formations that underlie the sedimentary rocks, much the way a basement underlies a house. On this map, the contours outline the top of the basement rock; the numbers show the distance, in feet, from sea level down to the surface of the basement rocks.

Without the cover of sedimentary rocks, the Kansas landscape would look drastically different than it does today. In eastern Kansas, for example, you would see a towering granite mountain range that extends from Nemaha County to Cowley County. If you approached these mountains—called the Nemaha Ridge—from the east, they would look something like the Front Range of the Rocky Mountains near Denver.

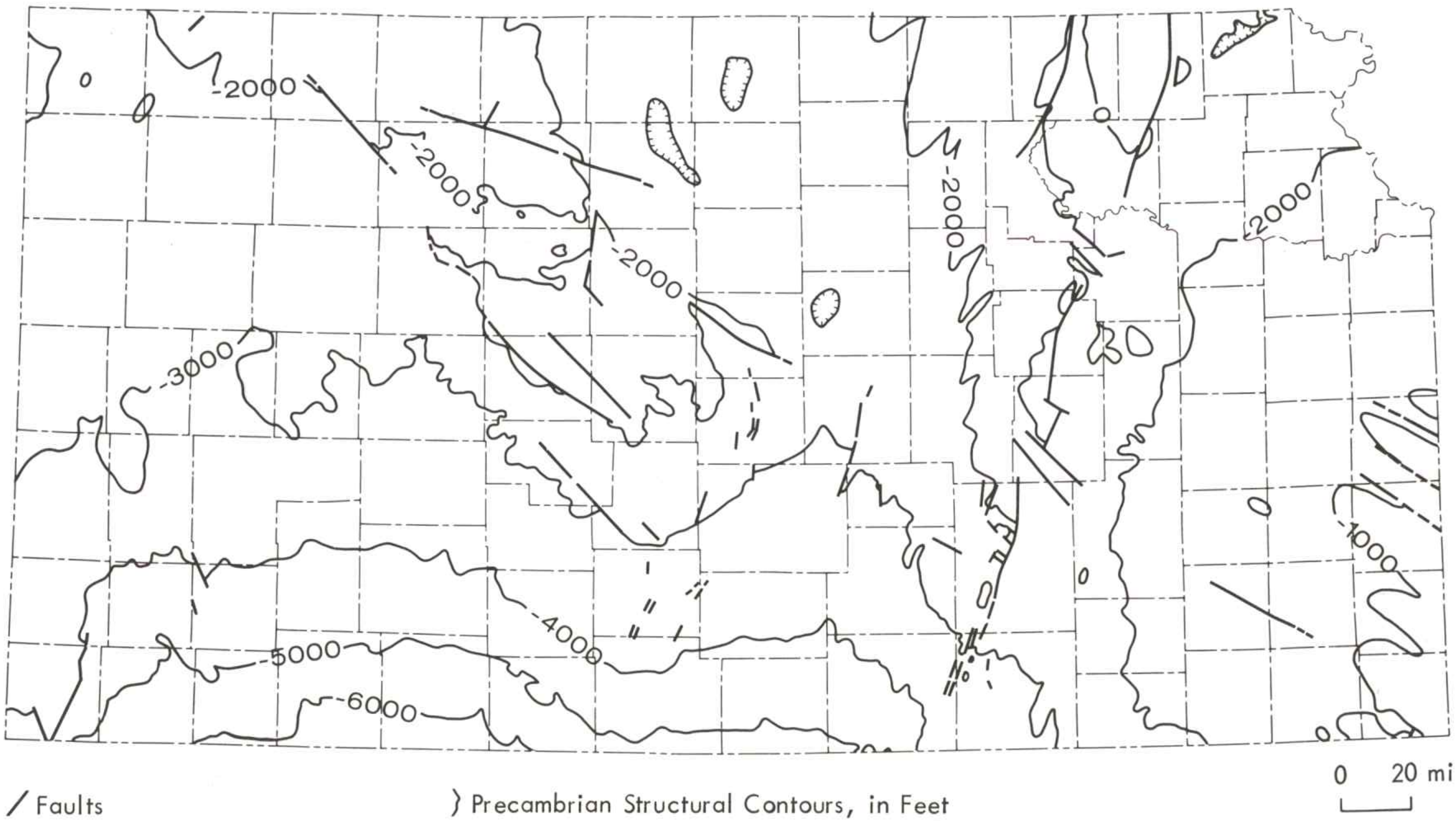
In central Kansas there is a less striking, lower range of now-buried mountains known as the Central Kansas uplift, which extends from near Hutchinson northwestward toward Norton and Decatur counties. This feature is responsible for many of the large oil fields in Barton, Ellis, Russell, and Rooks counties. In southwestern Kansas, where the surface of the basement drops to more than 6,000 feet below sea level, you could see a large basin, known as the Hugoton Embayment, which contains some of the largest natural-gas deposits in the world.

Because these basins and mountains are buried, geologists have never seen them, but scientists know they exist because samples of basement rock have been brought to the surface during drilling, mostly during oil and gas exploration. With modern geophysical technology, inferring the thickness of sedimentary rocks without having to drill holes is now possible. For example, seismic reflection techniques and analysis of gravity and magnetic measurements have led to the discovery of previously unknown sediments 10,000 to 15,000 feet thick in Clay, Riley, and Washington counties. The petroleum potential of these newly discovered rocks is likely to be explored by oil companies in the mid to late 1980s.

What kinds of rock form this basement? Most are igneous and metamorphic rocks that are more than a billion years old, formed during the Precambrian Era of geologic history when there was very little life on the planet. **Igneous rocks,** such as granite or basalt, were formed by molten lava or magma that cooled and then crystallized, **Metamorphic rocks** are sedimentary or igneous rocks that have been substantially changed by intense heat and pressure. For example, heat and pressure can transform granite, an igneous rock, into gneiss; limestone into marble; and sandstone into quartzite.

The most common basement rocks are granite in northern Kansas and rhyolite—a rock that cooled from lava with the consistency of stiff taffy candy—in southern Kansas. Basalt, quartzite, and schist are found in some places. In Riley, Marshall, Clay, and Washington counties a substantial area is underlain with basalt, a formation that extends northeastward to Minnesota and is called the Midcontinent Geophysical Anomaly, because of its unique signature on gravity and magnetic maps (see the aeromagnetic map on page 27).

Configuration of Kansas Basement



Temperatures at 1,000-Foot Depth

Most people associate geothermal power with geysers. But geothermal energy is any energy that can be extracted from naturally occurring steam or hot water. While Kansas has no geysers, the state does have low-grade geothermal energy resources. Because temperatures inside the Earth increase with depth, warm water may be under Kansas that could be used for space heating or in some industries.

The Kansas Geological Survey has been evaluating Kansas geothermal resources for the U.S. Department of Energy for the past several years. Though the Survey has discovered no high-temperature geothermal resources, the study's results may help homeowners and others to use warm ground water for space heating.

As the map shows, the temperatures at 1,000 feet deep are highest in northwestern and southeastern Kansas. In northwestern Kansas the higher temperatures are related to the movement of waters eastward and upward out of the Denver Basin, a bowl-shaped depression in eastern Colorado that is filled with sedimentary rocks. As water passes through the deepest part of the basin, it becomes warmer. Over thousands of years, the warmer water rises eastward underground along the edge of the basin, producing warmer-than-normal temperatures.

In southeastern Kansas, a similar process is occurring as warm waters gradually work their way northward from deeper sedimentary environments in Oklahoma.

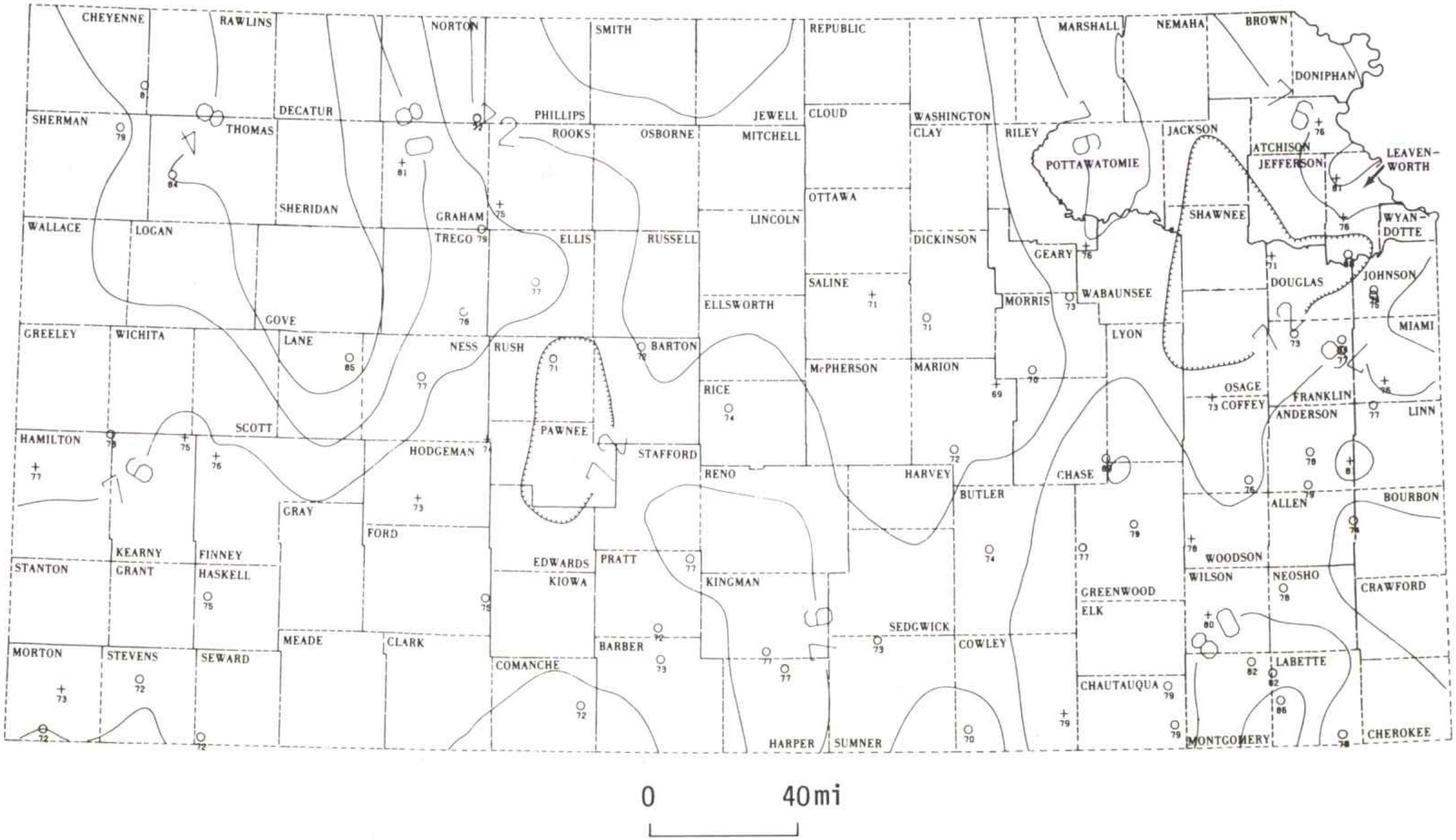
The temperatures shown on this map are probably accurate to within one or two degrees Fahrenheit. To calculate the temperature at a depth of less than 1,000 feet, use the following procedure:

1. Use the map to estimate the temperature (in degrees Fahrenheit) at the 1,000-foot depth at the location you are interested in.
2. Subtract 56 degrees Fahrenheit (the average annual temperature of near-surface ground water throughout the state).
3. Divide the depth of interest by 1,000.
4. Multiply the answer of step 2 by the answer of step 3.
5. Add 56 degrees Fahrenheit to the answer of step 4. The result is the temperature at the depth you are interested in.

For example, if you want to know the temperature of ground water 500 feet below Wichita, you begin by locating the temperature of Wichita at 1,000 feet deep: 73 degrees Fahrenheit. Then subtract 56 from 73 to get 17 (step 2). Divide 500, the depth you are interested in, by 1,000 to get ½ (step 3). Multiply ½ times 17 (step 4) to get 8.5. Add 56 to 8.5 (step 5) to get 64.5, the temperature of ground water in degrees Fahrenheit 500 feet below Wichita.

One important use of warm ground water may be in ground-water heat pumps, a sort of air conditioner working in reverse. The usefulness of these pumps depends upon the availability of at least a few gallons per minute of water. While the only way to know for certain about water availability is to drill a well, the general ground-water availability map in this booklet (p. 11) may be helpful. The Kansas Geological Survey has ground-water reports for many parts of Kansas, and local drillers, geologists, and engineering consultants are of great assistance in determining ground-water availability.

Temperatures at 1,000-Foot Depth



Aeromagnetic Map

In some ways, this is one of the most complex maps in this booklet. It does not show rock formations or geologic features, but does show variations of the Earth's magnetic field caused by the geologic features of Kansas.

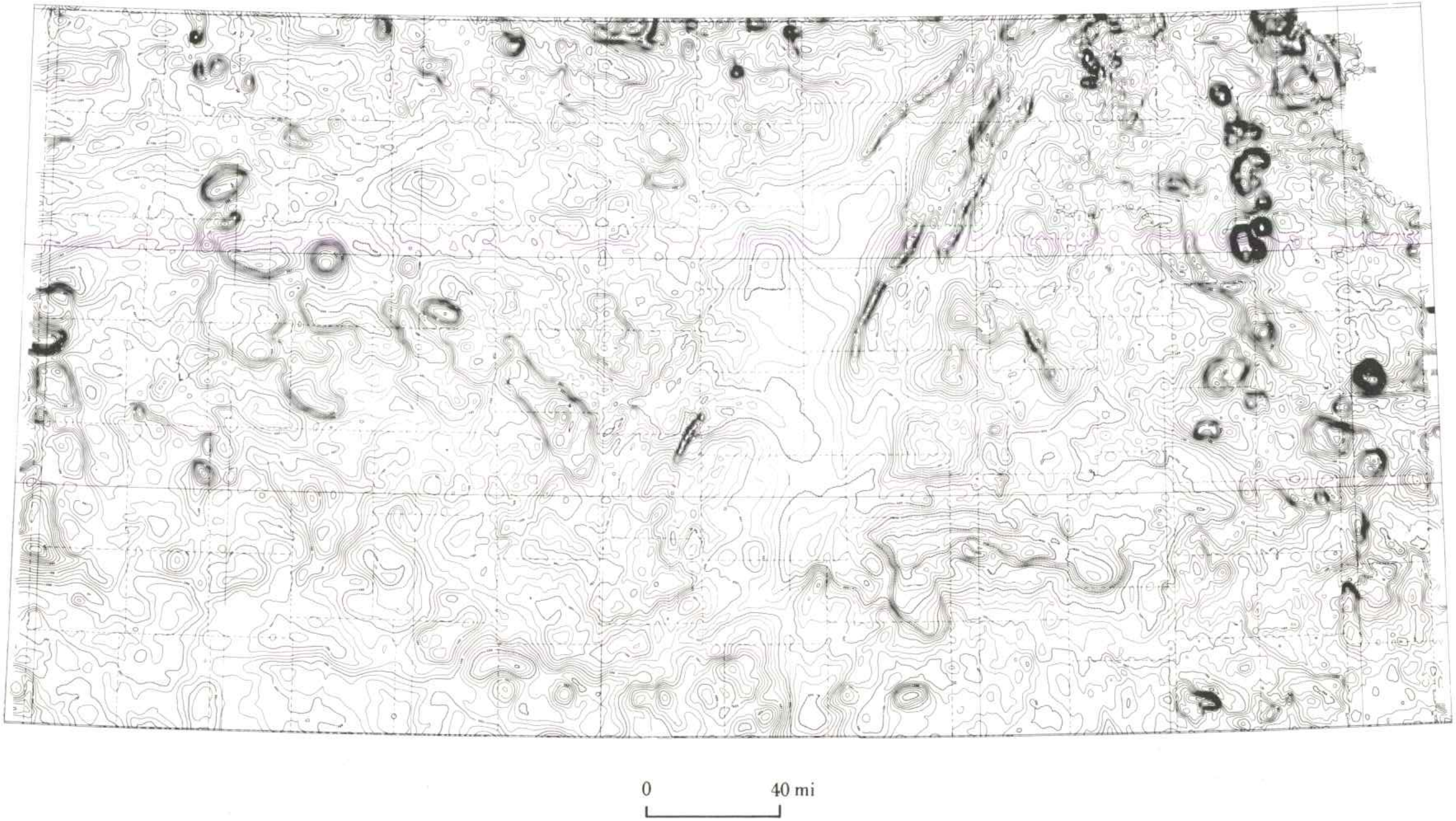
In essence, this map shows the magnetic levels in Kansas, which are determined by the magnetite content in the upper few miles of the Earth's crust. Magnetite, an iron oxide mineral that is naturally magnetic, has been known as a natural compass for centuries. It was known to the ancient Greeks as "lodestone" or "leading stone" because of those magnetic properties. Different rocks contain different amounts of natural magnetite. For instance, igneous rocks such as granite contain much more magnetite than do common sedimentary rocks such as shale or limestone. Thus, a magnetic map reveals clues about the location and position of various geologic features.

This map shows several variations in the Earth's magnetic levels. For example, the dark circular features in eastern Kansas represent areas where the magnetic levels are significantly higher than in much of the rest of the state. These higher readings probably are caused by shallow granite formations that have higher magnetic readings than the surrounding rock. The areas around Sedgwick County and in much of central Kansas have unusually low magnetic levels (as shown on the map), although scientists are not yet sure exactly why. Another notable feature extends from Washington County down into central Kansas. Called the Midcontinent Geophysical Anomaly, this magnetic high runs from Kansas, through Nebraska and Iowa, into the Lake Superior region. Geologists theorize that the MGA represents a rift system, an area where the continent began to split apart about a billion years ago. As that rift developed, igneous rock welled to the surface. After the rifting stopped, the igneous rock was covered by layers of sediments; that underlying igneous rock probably is responsible for the higher magnetic levels. The MGA probably also is responsible for recent earthquake activity in Washington County (see page 21).

The data for this map were gathered from a University of Kansas airplane that flew about 1,000 feet above the ground along east-west lines spaced two miles apart. The airplane towed a magnetic sensor behind it to measure the strength of the Earth's magnetic field. Data were transmitted onto computer tape in the airplane (along with latitude, longitude, and altitude information) for later analyses and plotting by computer.

The aeromagnetic ("aero" because data were gathered by airplane) map can be used (1) to estimate the thickness of sedimentary rocks overlying the igneous rocks, (2) to help determine what kind of igneous rocks lie beneath the sedimentary rocks, (3) to guide in the search for iron ore and other mineral deposits, (4) to locate geologic faults with potential earthquake hazards, and (5) to study ancient volcanic activity that has been hidden from view by the blanket of sedimentary rock.

Aeromagnetic Map of Kansas



Geologic Timetable

While the idea of geologic time is one of the simplest scientific concepts, it is just as difficult to appreciate the immensity of the time scale, with its billions of years, as it is difficult to grasp the concept of the U.S. federal budget, with its billions of dollars. Although it is not a map, this timetable is included to help explain the immensity of geologic time, a concept that is central to understanding geology.

To begin, compare the geologic time scale to a marathon footrace. Ten billion years—the approximate age of the known universe—corresponds to the total distance of a marathon, 26 miles and 385 yards. If we begin at the starting line and run toward the finish, the first 14 miles represent the time of the formation of the Sun and many of the older stars. Only the last 12 miles, or 4.7 billion years, represent the time after the Earth was formed, probably by the convergence of millions of meteorites or particles called "planetesimals." The oldest rocks brought back from the moon are about 4.5 billion years old.

Moving past the 15-mile line toward the finish, we reach the oldest known rocks on Earth, at slightly less than four billion years, and at the 18-mile line we reach the oldest known fossils. From this earliest beginning of life, 3.2 billion years ago, we move all the way to the 24-mile line before more modern life forms appear, about 600 million years ago. This period up to 600 million years ago is called the Precambrian Era on the timetable, and it is the longest era in geologic history.

Moving on, at the 25-mile line, or about 400 million years ago, fish are present during the Devonian Period of geologic history. Dinosaurs appear at about the 25.7-mile line and become extinct at the 26-mile line, during the Cretaceous Period.

The earliest recognizable human ancestors occur at about two million years ago, only 10 yards from the finish line. The last period of extensive continental glaciation in North America ended about 10,000 years ago, during the Quaternary Period, at about 1.4 inches from the finish line. At this scale, a human life of 70 years represents only one hundredth of an inch.

During this geologic history the Earth has undergone many changes; perhaps the most profound has been the change in position of the Earth's continents. For instance, geologists have established that South America was connected to Africa about 200 million years ago, before the Atlantic Ocean existed. Africa and South America (and Europe and North America) are still slowly moving apart at the rate of a few millimeters per year, as new oceanic rock material is produced in the middle of the ocean at the Mid-Atlantic Ridge. As new material is produced at this ridge, old crustal material is consumed at the oceanic trenches around the Pacific Ocean. Old material sinks into the mantle, where it is remelted, giving rise to volcanoes around the Pacific Ocean, such as Mount St. Helens in Washington State.

Geologists call the movement of the continents "plate tectonics." The concept of plate tectonics, a relatively new idea, has had a profound effect on geoscience, similar to the works of Einstein in physics or Darwin in biology. The interpretation of Kansas geology, in light of plate tectonics, is just beginning, and large-scale versions of the maps in this booklet will be of use to scientists participating in that new interpretation.

GEOLOGIC TIMETABLE AND KANSAS ROCK CHART

(Not scaled for geologic time or thickness of deposits)

ERAS	PERIODS	EPOCHS	EST. LENGTH IN YEARS*	TYPE OF ROCK IN KANSAS	MILLION YEARS PAST
CENOZOIC	QUATERNARY	HOLOCENE	10,000 +	Glacial drift; river silt, sand, and gravel; dune sand; wind-blown silt (loess); volcanic ash.	0.010
		PLEISTOCENE	1,990,000		2
	TERTIARY	PLIOCENE	3,000,000	River silt, sand, gravel, fresh-water limestone; volcanic ash; bentonite; diatomaceous marl; opaline sandstone.	5
		MIOCENE	19,000,000		24
		OLIGOCENE	14,000,000		38
		EOCENE	17,000,000		55
		PALEOCENE	8,000,000		63
MESOZOIC	CRETACEOUS		75,000,000	Limestone, chalk, chalky shale, dark shale, varicolored clay, sandstone, conglomerate. Outcropping igneous rock.	138
	JURASSIC		67,000,000	Sandstones and shales, chiefly subsurface. Siltstone, chert, and gypsum.	205
	TRIASSIC		35,000,000		240
PALEOZOIC	PERMIAN		50,000,000	Limestone, shale, evaporites (salt, gypsum, anhydrite), red sandstone; chert, siltstone, dolomite, and red beds.	290
	PENNSYLVANIAN		40,000,000	Alternating marine and nonmarine shale, limestone, sandstone, coal; chert and conglomerate.	~330
	MISSISSIPPIAN		30,000,000	Limestone, shale, dolomite, chert, oölites, sandstone, and siltstone.	360
	DEVONIAN		50,000,000	Subsurface only. Limestone, predominantly black shale; sandstone.	410
	SILURIAN		25,000,000	Subsurface only. Limestone.	435
	ORDOVICIAN		65,000,000	Subsurface only. Dolomite, sandstone.	500
	CAMBRIAN		70,000,000	Subsurface only. Dolomite, sandstone, limestone, and shale.	~570
PRECAMBRIAN			1,930,000,000	Subsurface only. Granite, other igneous rocks, and metamorphic rocks.	
			1,100,000,000 +		3,500

KANSAS GEOLOGICAL SURVEY

Eons not shown.

*U.S. Geological Survey, Geologic Names Committee, 1980

Other Information Available from the Kansas Geological Survey

The Survey has produced and makes available other publications that are related to the maps in this booklet.

For example, *Contemporary Kansas Maps*, by Tom McClain (1977), describes the variety of Kansas maps that are available and where you can order them. This booklet is not a map atlas; rather it contains detailed information about the maps produced by governmental agencies and other sources.

Kansas Landscapes: A Geologic Diary, by Frank W. Wilson (1978), describes the highlights of the Kansas landscape, how they were formed, and where best to see them. Nontechnical and illustrated with color photographs from throughout the state, this book will interest native Kansans as well as visitors to the state.

Kansas Rocks and Minerals, by Laura Lu Tolsted and Ada Swineford (1957), is a brief introduction to the state's geologic history, different types of rocks and minerals, and where they are found in Kansas. It includes a table for identifying specimens.

Ancient Life Found in Kansas Rocks, by Roger B. Williams (1975), serves as an introduction to Kansas fossils, describing the common fossils and the creatures that were the source of the fossils. Maps, diagrams, and numerous color photographs help familiarize readers with ancient life forms.

Earthquakes, by Don Steeples (1978), is a nontechnical discussion of earthquakes, both around the world and in Kansas. This pamphlet also includes a discussion of the Survey's study of small Kansas earthquakes. A related booklet, *List of Earthquake Intensities for Kansas, 1867-1977*, by Susan M. DuBois and Frank W. Wilson (1978), gives a nontechnical description of the 25 earthquakes that have rumbled through Kansas in the past 110 years and of the minor damage they caused. The result of searching through old newspapers, reports, and other records, this publication is part of the Survey's ongoing study of Kansas earthquakes.

The Survey produces annual data reports on oil and gas production and on enhanced oil-recovery projects in the state. A directory of Kansas mineral producers, which includes information on the quantities of nonfuel minerals produced at various locations in Kansas, also appears periodically.

The Survey also has published a number of more technical books that might be of interest. They include Daniel E. Merriam's *The Geologic History of Kansas* (1963), a detailed, technical description of the geology of the state, and *The Stratigraphic Succession in Kansas* (1968), edited by Doris Nodine-Zeller and including a formal description of all the rock formations found in Kansas and their positions in relation to one another.

In addition to books and reports, the Survey regularly produces new and updated maps similar to the ones that appear in this booklet. For instance the Survey has larger, more detailed versions of the geologic map of Kansas, the aeromagnetic map, the map of oil and gas fields, geothermal resources, and the map of ground-water availability. The Survey also has a map of the surface features of Kansas, by Raymond C. Moore, that is a hand-drawn depiction of the chief topographic features of the state, along with an explanatory text, drawn in 1930.

The Survey also produces maps jointly with the United States Geological Survey, including detailed topographic maps of Kansas that are used extensively in planning, mining, and recreation. The 7½-minute topographic maps provide the most detailed coverage of the state, depicting 7½ minutes of longitude and latitude per side, or about 8.6 miles by 7.7 miles. One inch on the map equals about one-third mile of actual distance on the ground. In many cases, you can locate your own home on these maps and identify roads, streams, and reservoirs, as well as determine local elevations to within 10 feet.

Sixteen generalized topographic maps provide coverage for the entire state with less detail. More recently, the Kansas Survey and the U.S. Geological Survey have begun to cooperatively produce a series of county topographic maps. These maps show the usual surface features as well as elevations in meters. Each map covers an entire county, and one inch on the map equals about 1.6 miles.

In addition to these, the Survey has available many technical and general-interest publications and maps, and new ones are being published regularly. For a list of currently available publications—or to order any of the items listed above—contact the Publications Sales Department at the Kansas Geological Survey, The University of Kansas, 1930 Constant Avenue, Lawrence, Kansas 66046 (913-864-3965).

Kansas Geological Survey, The University of Kansas, Lawrence, Kansas