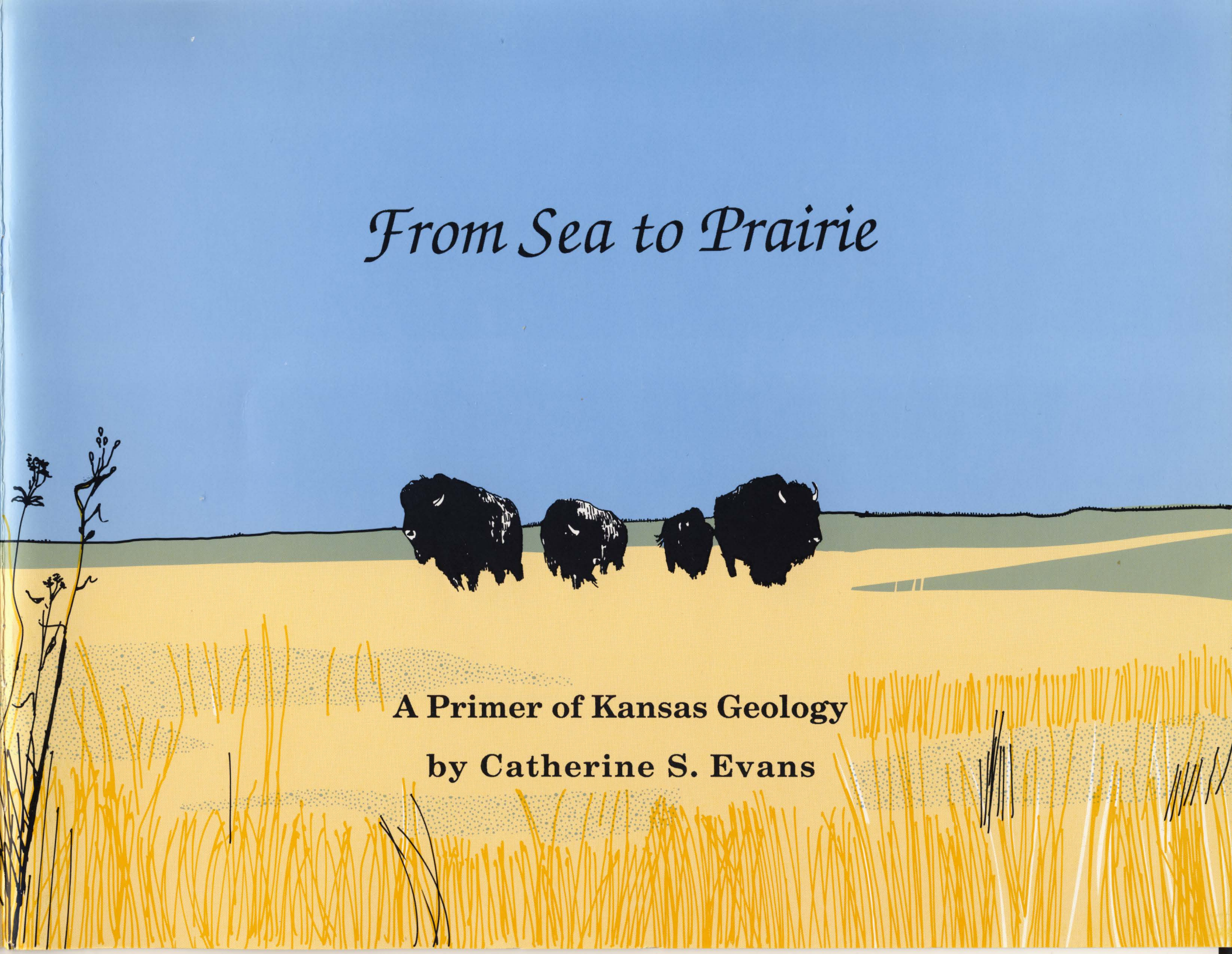
From Sea to Prairie



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by Catherine S. Evans

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From Sea to Prairie: A Primer of Kansas Geology

by Catherine S. Evans

Kansas Geological Survey
Lawrence, Kansas
1988, reprinted 1995

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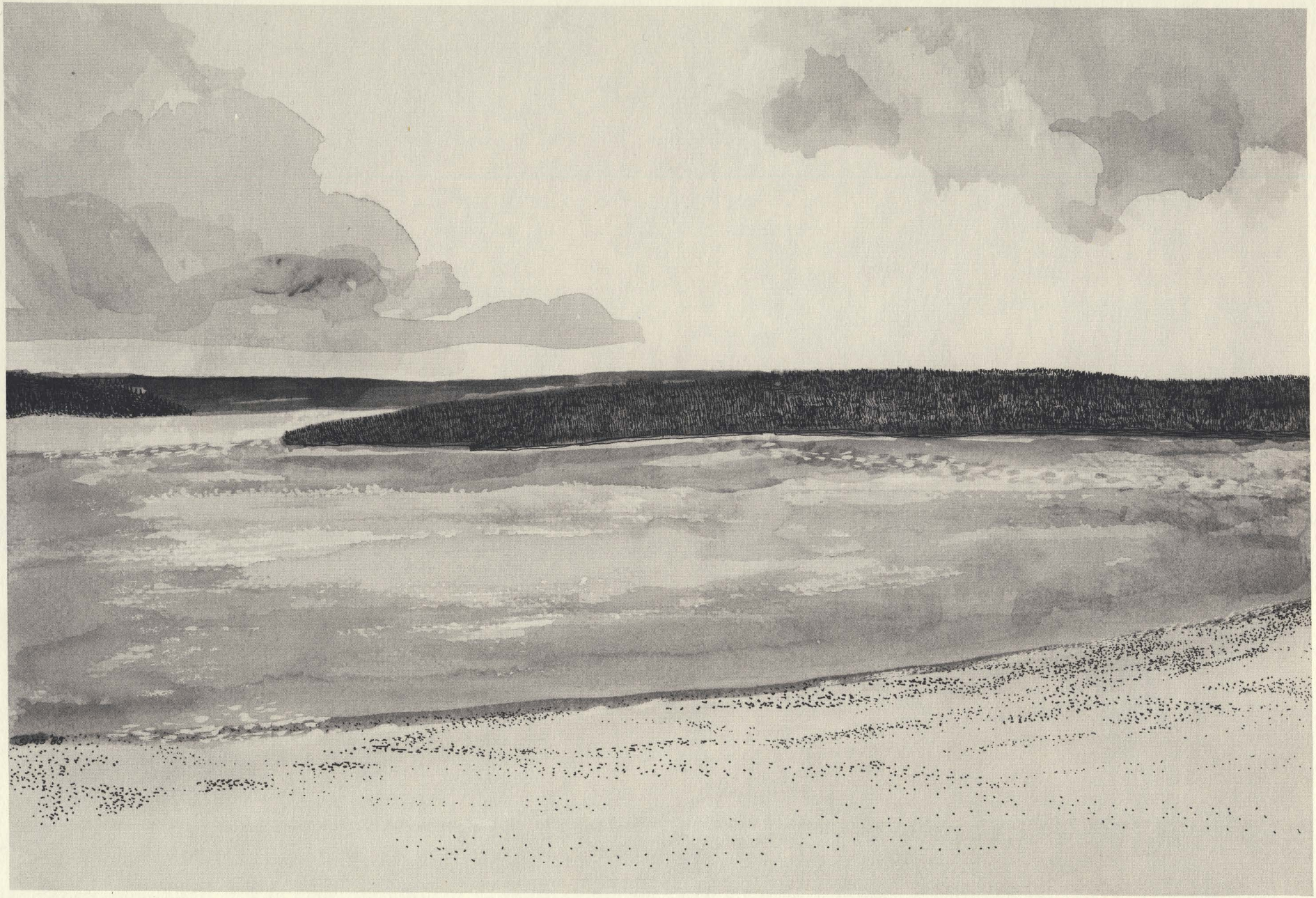


INTRODUCTION

Imagine it's a nice summer day and you decide to take a walk in the Kansas countryside. Being in an adventuresome mood, you get off the road and head through open country. In the distance is a large body of water. From the shore it looks bigger than any lake you've ever seen in Kansas. You can't even see the other side.

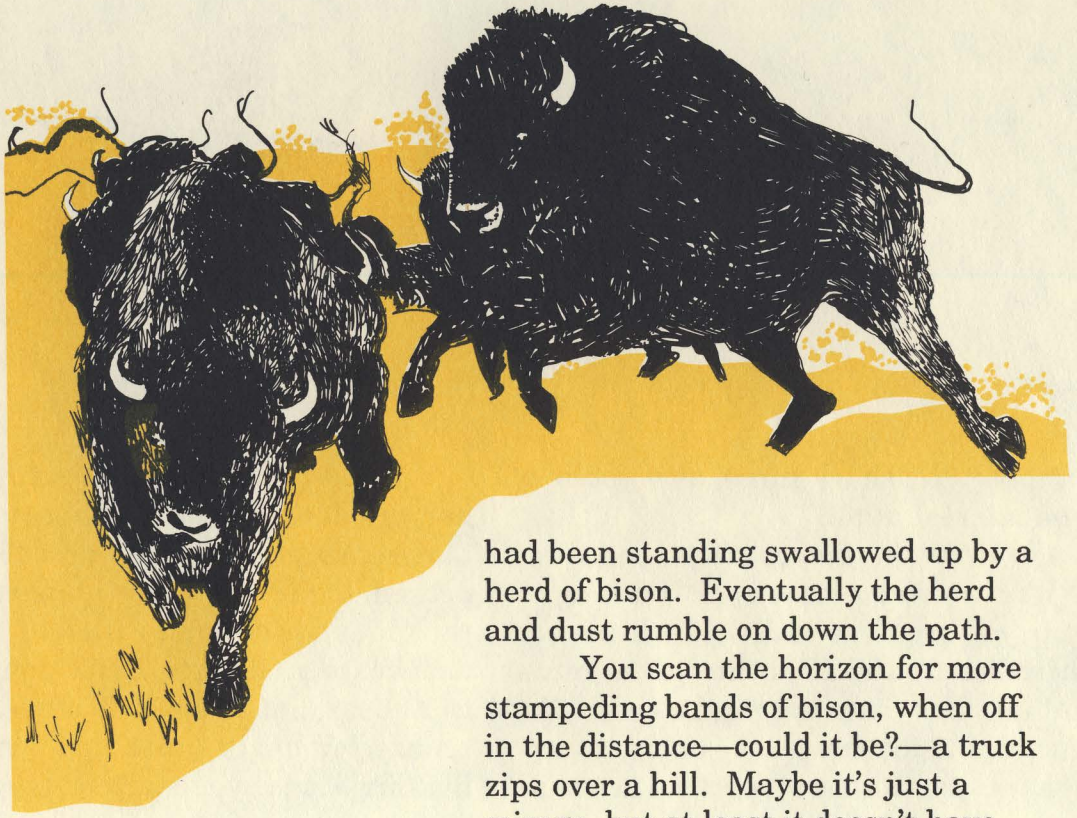
Strolling along the shore picking up seashells, you decide to take off your shoes and wade in. Suddenly, a fin splits the water and cuts rapidly and silently toward you. A giant mouth filled with sharp teeth pops out of the water and you're nose to nose with one long, sharp shark snout. You can hardly lift your feet out of the oozy mud as you turn and slowly struggle through the water with a mean and hungry shark on your tail. Just when you think you'll be shark supper, the shark turns, as if you're of no interest at all.

As you recover on the beach, a giant shadow passes over. Looking up, you see huge featherless birds circling around. But they're not birds at all. They're giant reptiles with nearly 20-foot wings. Grabbing your shoes, you don't wait around to see what else this beach has to offer. You run for miles before stopping to check where you are. By now you're hopelessly lost.

Down the road the scenery turns into rolling grasslands, broken by an occasional clump of trees. This scene doesn't seem too unusual for Kansas, but the hippopotamus wallowing in the pond to your left looks out of place. To your right a camel stares as you pass. Things are definitely a little strange.

Soon you're heading across a hot, dry desert covered with sand dunes. As quickly as the desert appeared, the temperature plunges and the ground is covered with ice. Sudden weather changes aren't unusual in Kansas, but this is ridiculous. You realize you haven't seen any people or buildings since you started this trip, and, by the way, this really isn't what Kansas is supposed to look like.

Just when you think you'll never see civilization again, the ice is gone and you're heading across a grassy plain. You come across a well-worn path and turn down it. Ahead a large cloud of dust appears. It's moving rapidly toward you—closer and closer. Suddenly, large, hairy animals come roaring out of the dust. Scrambling up a nearby hill, you turn to look just in time to see the spot where you



had been standing swallowed up by a herd of bison. Eventually the herd and dust rumble on down the path.

You scan the horizon for more stampeding bands of bison, when off in the distance—could it be?—a truck zips over a hill. Maybe it's just a mirage, but at least it doesn't have sharp teeth or huge, flapping wings, and it's not headed toward you with a hungry look on its grill, so you figure it's worth checking out. When you reach the spot where you sighted the truck, a road appears and things begin to look a little familiar again. Heading down the highway, you eventually find your way home for a good night's sleep.

In the morning, you wake up and hesitantly open the curtains. Everything is the way it should be. Running to the library, you search for information on Kansas landscapes and wildlife. You find that Kansas has grasslands, hills and trees, and many farms, towns, cities, and about two million people. Also a variety of animals including coyotes, deer, skunks, and many birds and fish are now found in Kansas, although none from the shark family and definitely no large flying reptiles.

But where are the sea, the desert, the massive ice fields, the hippopotamus, camel, and bison that you saw? Reading on, you discover that in the past, Kansas has had all of these landscapes and has been home to all of these animals at one time or another. You have been on a trip—not only through Kansas, but through time.

CHANGING KANSAS

Long before people were on Earth, Kansas was here. Of course, it wasn't called Kansas because no one was around to call it anything, and it didn't always look the way it does today. Over the years, many changes have taken place.

The Earth is billions of years old. In Kansas, hills were formed that were later buried or worn away by wind and water. Seas covered parts of the state, then disappeared. Giant sheets of ice called glaciers moved into northeast Kansas, then melted. Rivers changed their courses. The climate changed—sometimes hot, sometimes cold, sometimes wet, sometimes dry.

These changes are what made Kansas look the way it does today.

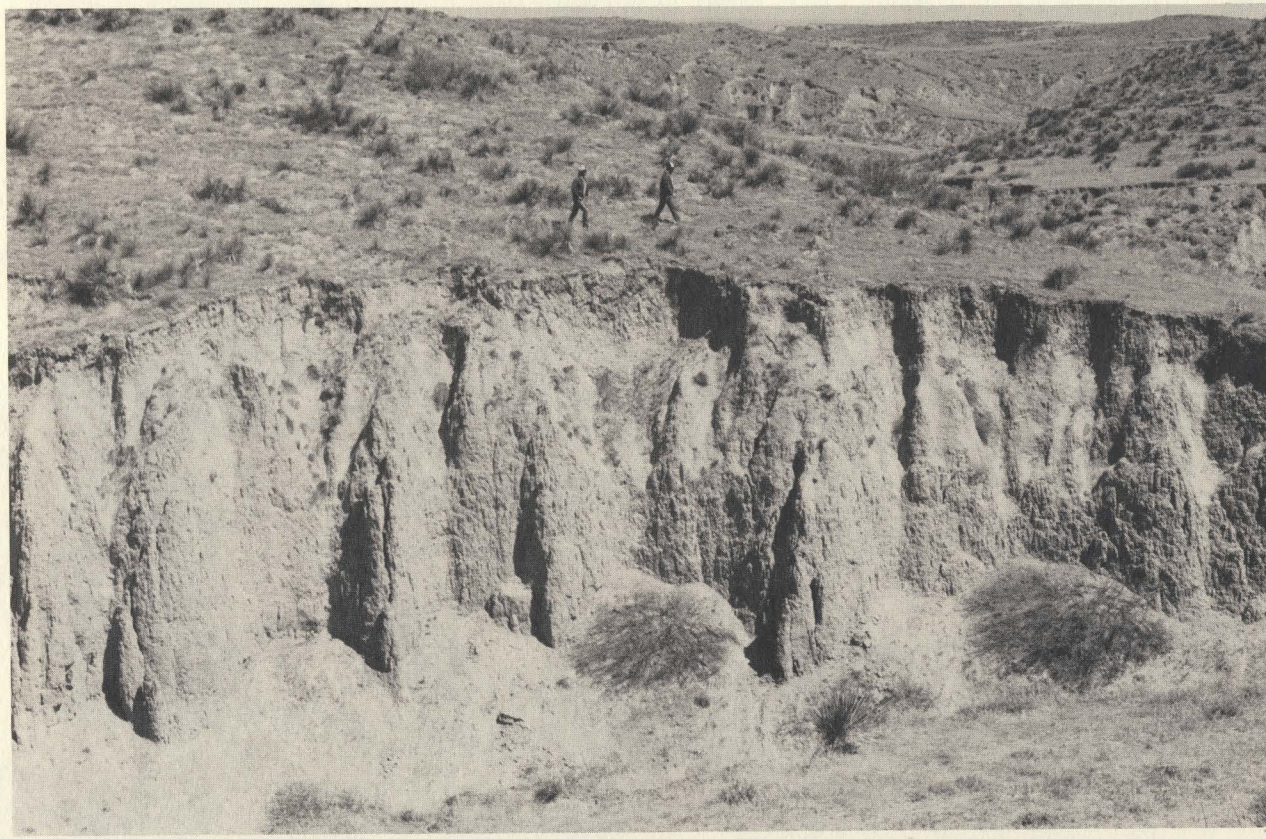


FIGURE 1. THIS BLUFF WAS FORMED when soil was eroded by water in Cheyenne County in northwest Kansas.

FIGURE 2. CASTLE ROCK IS A NATURAL CHALK SCULPTURE in Gove County in western Kansas. In this photograph, taken in the late 1800's, Castle Rock had two spires taller than the rest. One of the spires eventually toppled—see figure 3 (photo courtesy of the Kansas Historical Society).

Looking around, it's hard to believe that changes are still taking place. We rarely notice them because they happen so slowly. But every time it rains or the wind blows, dirt and rock are worn away from hills, valleys, and plains. This process of wear and tear is called erosion. Over just a few years or even a few hundred, it's hard to tell that things are changing, but over millions of years whole mountains may erode away or be buried.

Sometimes changes happen more quickly. Floods can cause rivers to change course almost overnight. The Missouri River, which is the state line in northeast Kansas, has changed course several times. Small areas of land that were once on the Kansas side of the river are now on the Missouri side. Missouri has also lost some land to Kansas.

Wind and water are just two of the many forces that are changing the world around us. The force of gravity, which holds us to the Earth, causes eroded rocks to roll off mountains and hillsides into valleys and river beds.

Unstable conditions inside the Earth also cause changes. Volcanic eruptions, such as Mount St. Helens in Washington in 1980, can cause immediate changes. When Mount St. Helens erupted, the top of the mountain blew off and volcanic ash was carried thousands of miles by the wind. Millions of years ago, active volcanoes in New Mexico, Wyoming, and California erupted and large quantities of ash were carried into Kansas. Today, volcanic-ash deposits can be found in western Kansas.

Earthquakes, which accompany volcanoes or the shifting of underground rocks, can change the environment. Most earthquakes in Kansas

FIGURE 3. TODAY CASTLE ROCK ONLY HAS ONE TALL SPIRE. The other one collapsed due to erosion by wind and water.

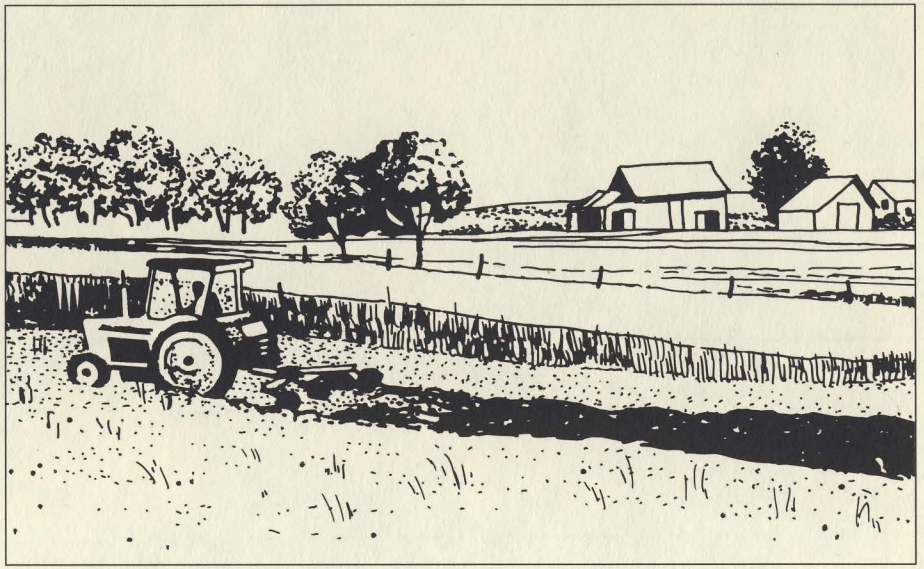


Figure 4. PEOPLE ALSO HAVE CHANGED THE ENVIRONMENT by building cities and roads, cutting trees, using water, and farming.

are small and can only be detected by sensitive equipment. However, some have been intense enough to cause damage. In 1867 an earthquake in northeast Kansas shook buildings, knocked over chimneys, and cracked walls. Most changes caused by earthquakes are underground and not as obvious as changes caused by volcanoes. But, over time, earthquakes help to change the way the surface of the Earth looks.

People also have greatly changed the environment by plowing fields, quarrying rocks and minerals, building cities and roads, and damming rivers. Try to imagine what Kansas would look like without farms, buildings, roads, and cities—without people.

How do we learn about geologic changes over time? Without people to write books or take pictures, the only records we have of the Earth's early history are hidden in the land around us. Since the Earth isn't talking, scientists must search for answers. The study of what the Earth is made of and how it changes over time is called geology. Scientists who study the Earth are called geologists.

GEOLOGIC TIME

After years of studying the rocks, minerals, and features of the Earth, geologists have learned much about its geologic history. They have determined that the Earth is approximately 4 1/2 billion years old, give or take a few million years. The Earth is so old, no one knows its exact age.

Because 100 years seems like a long time, something billions, even millions, of years old is almost impossible to imagine. To make it easier to understand geologic history, scientists have divided all the time since the Earth was formed into four eras (see figure 6).

The first era, called the Precambrian, was much longer than any of the others. It lasted almost 4 billion years, or 88 percent of the Earth's history. Although the Precambrian Era includes much of that time, we know very little about it. Rocks formed during the Precambrian have gone through many changes; in Kansas and many other places, these rocks can only be found hundreds and even thousands of feet underground, making them difficult to study.

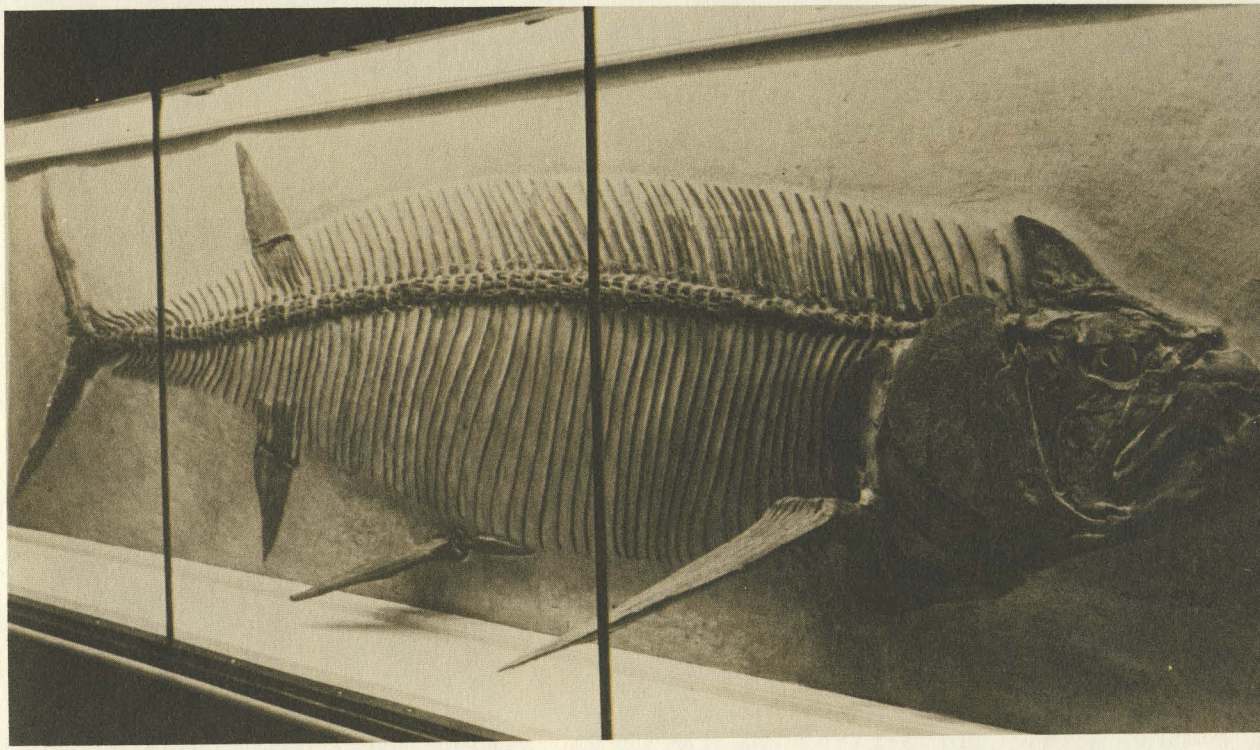


FIGURE 5. *XIPHACTINUS* WAS A TYPE OF FISH that lived in the sea that covered western Kansas in the Cretaceous Period of the Mesozoic Era. This one, which is about 13 feet long, was found in the late 1800's and is on display at the University of Kansas Museum of Natural History (photo courtesy of the University of Kansas Museum of Natural History).

After the Precambrian Era, more plant and animal species began to develop. During the Paleozoic Era, which followed the Precambrian and lasted 245 million years, plants and reptiles began moving from the sea to the land. The era has been divided into seven smaller units of time called periods. Several times during the Paleozoic Era, seas appeared and disappeared in Kansas. Rocks from the last three periods in the era, called the Mississippian, the Pennsylvanian, and the Permian periods, can be found at the surface in central and eastern Kansas.

KANSAS GEOLOGIC TIMETABLE

(Not scaled for geologic time or thickness of deposits)

ERAS	PERIODS	EPOCHS	EST. LENGTH (YEARS) *	DESCRIPTION	MILLION YEARS PAST
CENOZOIC	QUATERNARY	HOLOCENE	10,000+	Early, the land was stable with some erosion. Glaciers moved into the northeast at least twice. Later the climate was dry. Sand dunes were formed by wind in the west. Volcanic ash was blown in from California, New Mexico, and Wyoming.	1.6
		PLEISTOCENE	1,590,000		
	TERTIARY	PLIOCENE	3,700,000	Rocks found are part of the Ogallala Formation (sand, gravel, and porous rock), which contains a large quantity of ground water and occurs only in the western third of the state. No rocks were formed in eastern Kansas.	
		MIOCENE	18,400,000		
		OLIGOCENE	12,900,000		
		EOCENE	21,200,000		
		PALEOCENE	8,600,000		66.4
MESOZOIC	CRETACEOUS		77,600,000	Much of the western half was covered by seas. Limestone, sandstone, and chalk formed from sea deposits. Fossils can be found in these rocks, which crop out in central and western Kansas.	144
	JURASSIC		64,000,000	Most rock in Kansas is underground in the west. A few small outcrops are found in the southwest corner.	208
	TRIASSIC		37,000,000	No rocks have been found in Kansas.	245
PALEOZOIC	PERMIAN		41,000,000	Much of Kansas was covered by several seas. As they rose and fell, limestone, shale, and chert were deposited. The Flint Hills were formed. When the seas dried up, salt and gypsum were left behind. Salt, now underground, is mined in central Kansas. The Red Hills were formed from deposits of shale, siltstone, sandstone, gypsum, and dolomite.	286
	PENNSYLVANIAN		34,000,000	For much of the period the land was flat. Seas and swamps came and went; coal formed in swamps from dead plants. Shale, limestone, sandstone, chert, and conglomerates were deposited. Two ridges of hills, the Nemaha uplift and the Central Kansas uplift, appeared; both are now buried. Pennsylvanian rocks are found at the surface in eastern Kansas.	320
	MISSISSIPPIAN		40,000,000	Repeated layers of limestone, shale, and sandstone indicate that seas rose and fell. Mississippian rocks are the oldest found at the surface and are in the southeast corner; elsewhere these rocks are only underground.	360
	DEVONIAN		48,000,000	Seas covered Kansas during much of the period. Limestone, shale, and sandstone deposits are only underground.	408
	SILURIAN		30,000,000	Land was uplifted and seas disappeared. Limestone deposits are found only underground.	438
	ORDOVICIAN		67,000,000	Seas covered parts of Kansas during much of the period. Dolomite and sandstone are only underground.	505
	CAMBRIAN		65,000,000	Early, the climate was dry and many rocks eroded. Later, parts of Kansas were covered by seas. Dolomite, sandstone, limestone, and shale are now underground.	570
PRECAMBRIAN			3,930,000,000	These rocks are the oldest on earth. In Kansas, they are only found deep below the surface and not much is known about them. Many are igneous and metamorphic and have gone through many changes.	4,500?

Eons not shown

* Decade of North American Geology 1983 Geology Time Scale, Geological Society of America

Kansas Geological Survey Lawrence, Kansas 1988

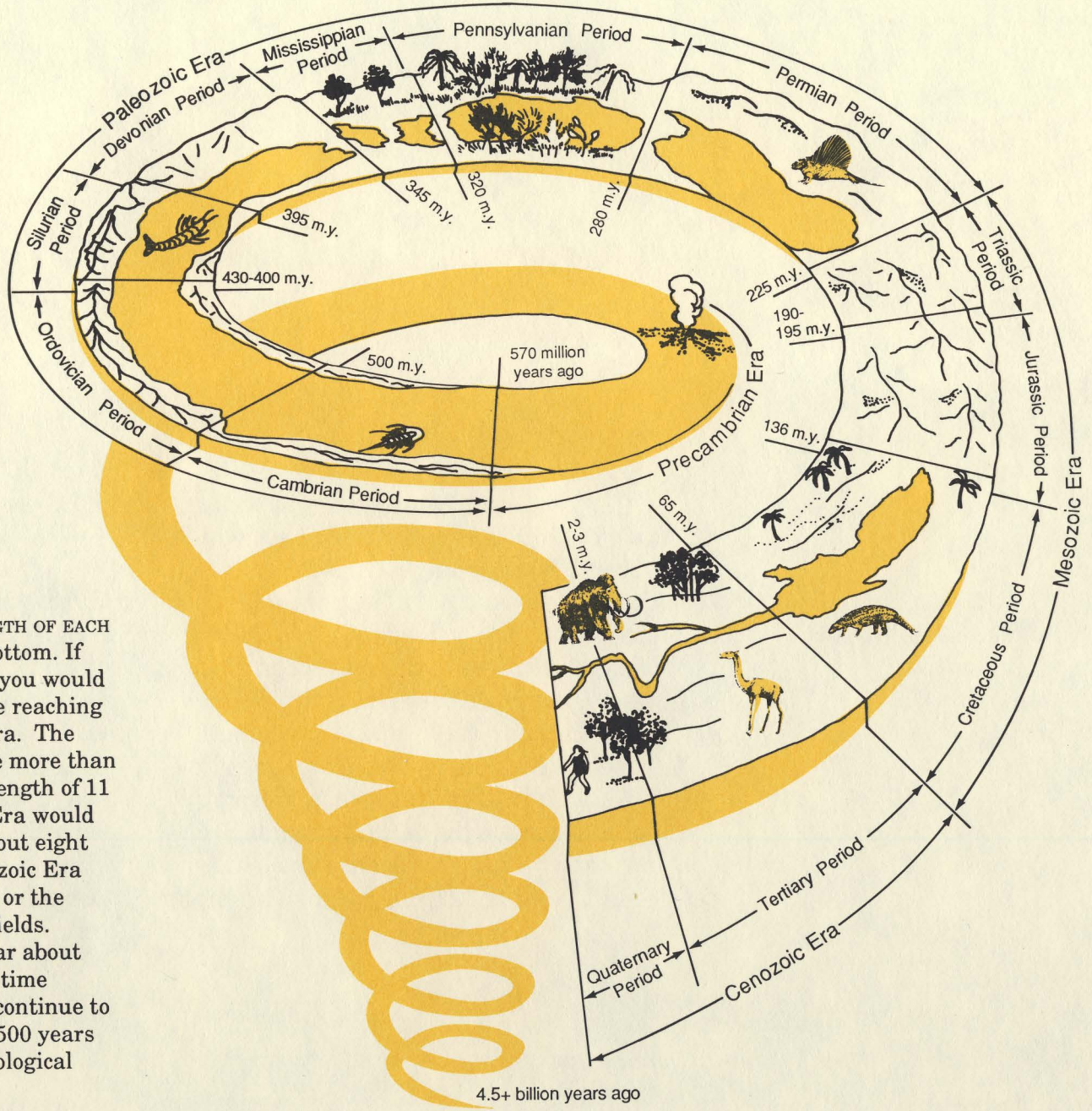
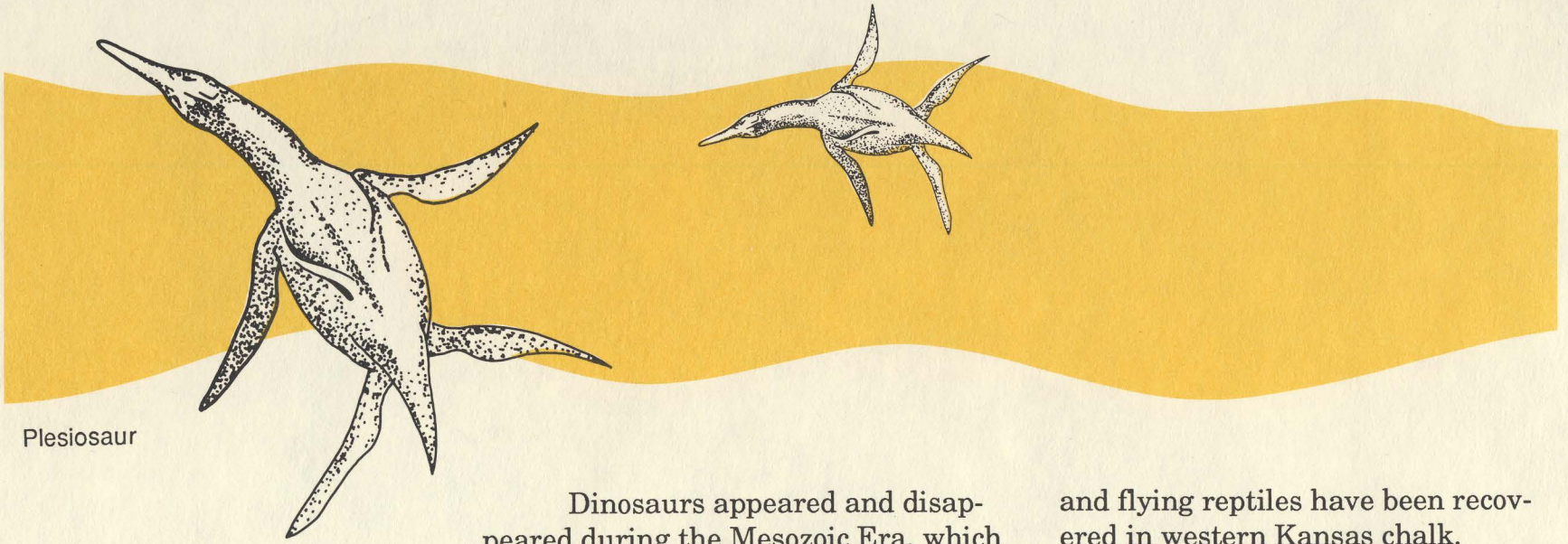


FIGURE 7. THIS SPIRAL SHOWS THE LENGTH OF EACH ERA AND PERIOD. Start at the bottom. If the spiral were 10 miles long, you would travel nearly nine miles before reaching the end of the Precambrian Era. The Paleozoic Era would be a little more than half a mile long or about the length of 11 football fields. The Mesozoic Era would be less than half a mile, or about eight football fields long. The Cenozoic Era would only be 200 yards long, or the length of a couple of football fields. People in Kansas would appear about two inches from the edge. As time passes, the spiral will slowly continue to grow, about one inch every 7,500 years (after Geologic Time, U.S. Geological Survey publication).



Plesiosaur

Dinosaurs appeared and disappeared during the Mesozoic Era, which lasted 160 million years. Not many dinosaur fossils have been found in Kansas. During the first part of the Mesozoic, much of the surface in Kansas was being eroded. If dinosaurs lived in Kansas then, they weren't preserved. Later in the era, in the Cretaceous Period, much of the state was covered by seas. Because the land was under water, not many dinosaur fossils have been found, but bones from giant swimming and flying reptiles have been recovered in western Kansas chalk.

We're now in the Cenozoic Era, which began about 63 million years ago. Because it is the most recent era, we know the most about it. The glaciers that moved into Kansas from the north came during this era. Later, giant dust storms carried the soil away from some areas and deposited it in other places. As mountains were formed by volcanic activity in the western United States, layers of volcanic ash were deposited in Kansas.

ROCKS AND MINERALS

Rocks are one of the main sources of information for geologists. By comparing rocks and minerals and their locations, geologists can estimate approximately how old the rocks and minerals are. They can tell if a rock was formed on dry land, on an ocean floor, or deep inside the earth.

Other people besides geologists have found rocks and minerals useful. The Indians used native stone to make tools, weapons, and pottery. Early settlers constructed buildings, bridges, and fences out of limestone and sandstone. Indians and settlers used natural caves for protection and rock outcrops for lookouts; and they carved pictures, called petroglyphs, in the rock walls.

Kansas also has had its share of fortune hunters. More than once people have traveled through the state seeking valuable minerals such as gold and silver.

In 1541 the Spanish explorer Francisco Vazquez de Coronado was told of an Indian land named Quivira where gold and other riches were abundant. His desire to find Quivira led him into a territory that is now part of Kansas. But Coronado and his men went away disappointed. They never located gold, which apparently existed only in Indian legends.

More than 300 years later in the 1880's, hundreds of prospectors flocked to Logan County in western Kansas hoping to find silver. Thousands of dollars were spent to stake claims, but only traces of nickel ore were found. Scientists who visited the area didn't think conditions were right for either silver or nickel to form. The traces of the minerals were probably found in rocks from outer space, called meteorites, which had collided with Earth.

FIGURE 8. ANCIENT CARVINGS ON ROCK EXPOSURES ARE CALLED PETROGLYPHS. This one was carved in sandstone by Indians in Ellsworth County in central Kansas.

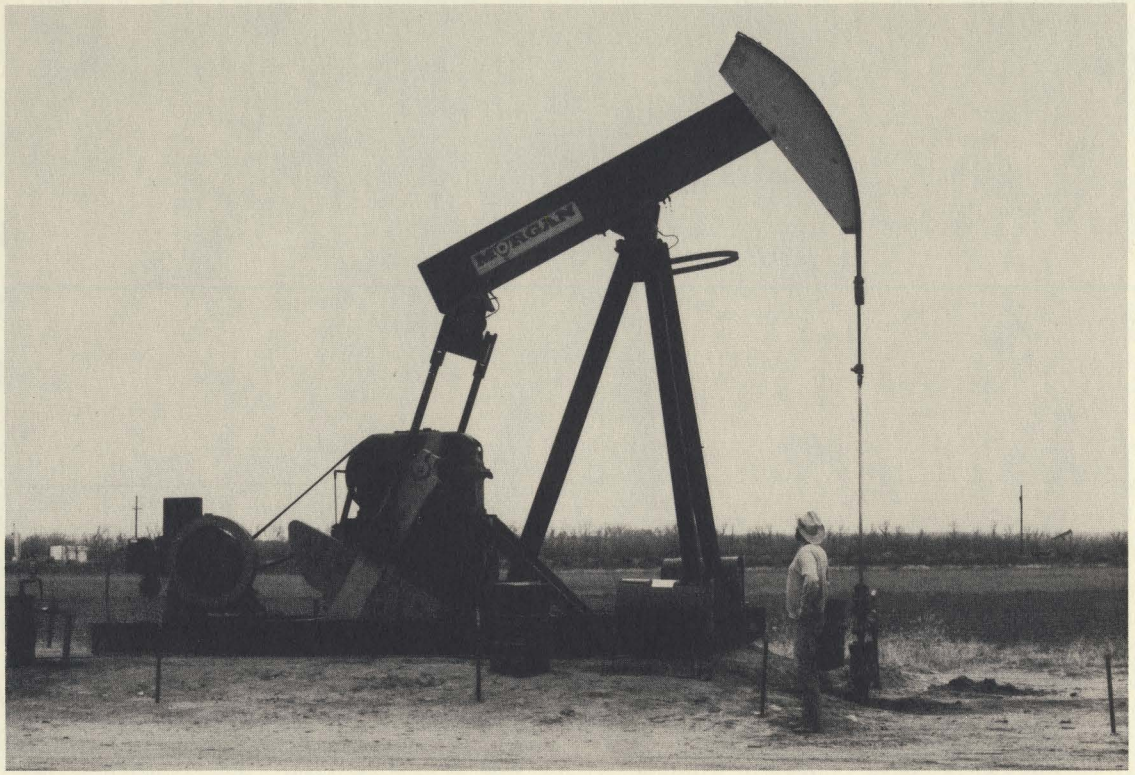


FIGURE 9. OIL AND GAS WERE FIRST DISCOVERED IN KANSAS IN THE 1860'S. Wells, such as this oil well in Comanche County in southwest Kansas, are now located throughout the state.

Although not much gold or silver has been found in Kansas, coal, gypsum, lead, zinc, chalk, salt, volcanic ash, limestone, sandstone, clay, sand, oil, and gas have all been found and used to make various products. Because of their many uses, rocks, minerals, and other natural resources add to the wealth of Kansas. They bring money and jobs. They also add to the environmental wealth. Undisturbed rocks and minerals add color, form, and beauty to the landscape.

We know that rocks and minerals are all around us, but what are they?

Minerals

Minerals occur naturally in the Earth. They are not made by people. They also are inorganic. This means they are not made from living material; no part of a mineral was ever alive.

All minerals are made of smaller units called elements. A few minerals, such as gold and silver, are made of only one element. These minerals are called native elements. Sulfur is the only native element found in Kansas. All other minerals are a combination of two or more elements.

Minerals can be identified by their color and hardness. The scale for hardness ranges from 1 to 10; the harder a mineral is, the higher its number. A diamond, which is very hard, rates a 10. Garnet is one of the hardest rocks found in Kansas. It is a 7 and is so hard it can scratch window glass.

Pyrolusite, another Kansas mineral, is at the lower end of the hardness scale. It is a 1 or 2 on the

scale and is soft enough to leave a black streak when rubbed on a piece of paper.

Galena, sphalerite, pyrite (fool's gold), halite (salt), calcite, anhydrite, gypsum, mica, and quartz also are found in Kansas. Many other minerals occur in the state, but none in large quantities.

Rocks

A rock is usually made of one or more minerals. Most rocks we see on the Earth's surface have been broken up into small pieces. Sand, gravel, clay, and silt are all made of particles worn from rocks.

Rocks that are buried are called subsurface rocks because they are located below the Earth's surface. Subsurface rocks are often found in large slabs called beds. Beds are sometimes seen at the surface, but often in Kansas they are covered by soil. They can be several feet thick, extend for many miles, and be layered one on top of another. Unless the beds are disturbed by forces such as earthquakes or volcanoes, the deeper beds are usually older than the ones closer to the surface (see figure 12).

FIGURE 10. GEODES ARE FORMED WHEN GROUND WATER DEPOSITS MINERALS IN ROCK CAVITIES. They measure from 1 to 12 inches (2–27 centimeters) in diameter.

Sometimes rocks that were once underground are exposed by erosion. These exposures are called outcrops. In some places, the hills have been cut away to make roads more level. Areas cut away for roads are called roadcuts.

Rocks are organized into three categories depending on the way they are formed. These categories are sedimentary, igneous, and metamorphic.

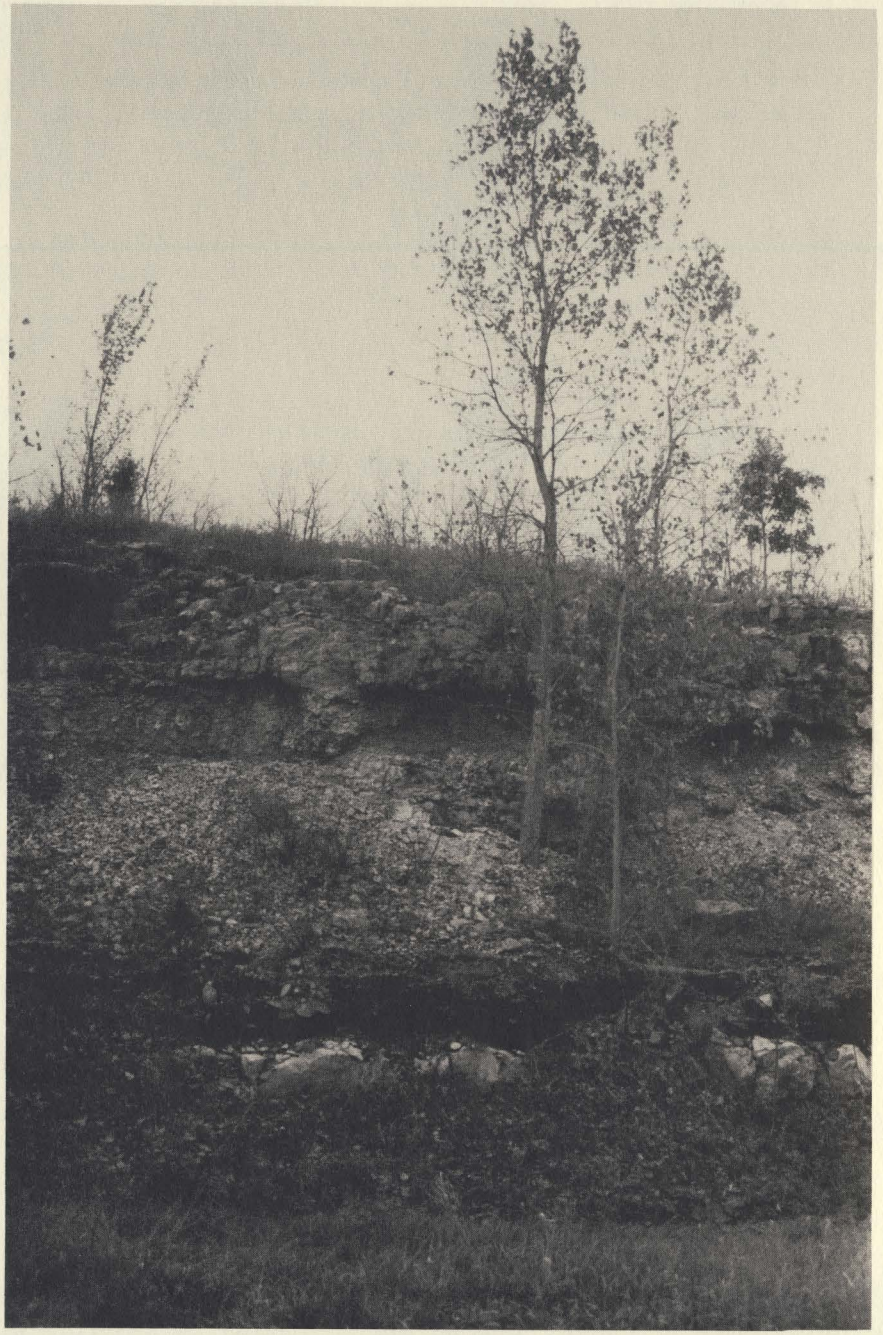
SOME MINERALS FOUND IN KANSAS

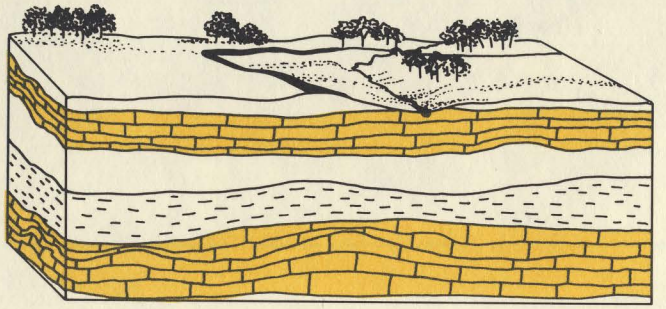
Mineral	Hardness	Color	Description
SULFUR	1-1/2 to 2-1/2	Bright yellow	Sulfur is the only native element found in Kansas, but not in large enough quantities for mining. It is so soft it can be scratched with a fingernail.
MICA 	1-1/2 to 3	White, golden yellow, brown, colorless, green, or black	Several minerals, muscovite, biotite, phlogopite, and vermiculite, are in the mica group. Micas can be split into thin, flat, flexible sheets. Flat, shining mica flakes can be found in sandstones, siltstones, and shales throughout Kansas and in metamorphic and igneous rocks in Riley and Woodson counties.
GYPSUM	2	Colorless, white, light gray, and occasionally bright red	Found throughout Kansas, gypsum is mined in Barber and Marshall counties. It is used in plaster of Paris, Portland cement, wall plasters and mortars, wallboard, and fertilizer.
GALENA	2-1/2	Lead-gray (often metallic)	Galena is heavy but soft and leaves a mark when rubbed on paper. In the late 1800's and early 1900's, galena was mined in southeast Kansas. The lead in galena has many industrial uses.
HALITE (common table salt) 	2-1/2	Colorless and transparent when pure. Also red, blue, or yellow	Halite tastes salty and dissolves rapidly in water. Salt is dissolved by rain and river water at the surface. Underground salt is protected from water by hard rock above and below it. An underground salt bed in central Kansas contains 13 trillion tons of salt. One million tons of salt is produced each year from mines in Hutchinson, Kanopolis, and Lyons.
CALCITE	3	Usually white or colorless. Also tinted gray, red, green, or blue	Calcite is the main constituent in limestone. A knife will scratch calcite, but a fingernail won't. Calcite sometimes acts as a cementing material in sandstone. It is used in cements, limes for mortar, the chemical industry, and fertilizers.
ANHYDRITE	3 to 3-1/2	Light gray	Like gypsum and halite, anhydrite is an evaporite. Anhydrite has a glassy luster and is translucent. It can be scratched with a knife but not with a fingernail. Many of the Red Hills in Barber and Clark counties are capped with anhydrite and gypsum.

FIGURE 11. KANSAS HAS MANY MINERALS, but most are found only in small quantities. Minerals vary in color and hardness. The hardness of each mineral is rated on a scale from 1 to 10, with 1 being the softest and 10 being the hardest; most minerals fall somewhere in the middle.

Mineral	Hardness	Color	Description
BARITE	3 to 3-1/2	Usually colorless or white. Also light blue, yellow, or red	Barite is common in many areas of Kansas but not in large enough quantities to make it worth mining. It resembles gypsum, celestite, and calcite and can be scratched with a knife but not a fingernail.
DOLOMITE 	3-1/2 to 4	White, gray, greenish-gray, brown, or pink	Dolomite has a glassy to pearly luster and is the main component in the rock dolomite. It can be scratched easily with a knife. Dolomite is common in the lead and zinc mines in southeast Kansas but is also found throughout the state.
SPHALERITE	3-1/2 to 4	Colorless when pure. Also brown, dark red, black, or yellow	Like galena, sphalerite was once mined in southeast Kansas. The zinc in sphalerite is often combined with other metals for industrial use. It can still be found around the old mines in Cherokee County and also in Pennsylvanian shale in eastern Kansas.
OPAL	5 to 6	White, yellow, red, brown, green, gray, blue, or colorless	Opal, found in the Ogallala Formation in western Kansas, cannot be scratched with a knife. Precious opal, highly prized as a gemstone, is not found in Kansas.
PYRITE 	6 to 6-1/2	Brass yellow	Pyrite is brittle, has a metallic luster, and is so hard it can scratch glass. Also called fool's gold because it is shiny and yellow, pyrite is harder than gold. Small quantities can be found in many places in Kansas, but most often with coal, lead, and zinc.
GARNET	6-1/2 to 7	Usually red to brown. Also black, green, or colorless	One of the hardest minerals found in Kansas, garnet has a glassy luster and is hard enough to scratch window glass. It has been found near kimberlite outcrops in Riley County.
QUARTZ 	7	Colorless when pure. Also yellow, pink, purple, brown, green, blue, gray, or black	Quartz, the most common mineral, has a glassy to greasy luster. It can easily scratch glass. Nearly all sands and sandstones are composed of tiny particles of quartz worn off quartz outcrops. Flint, or chert, which is common in the Kansas limestones, is a type of quartz. Agate, a type of quartz that is often used for decoration, was carried into northeast Kansas by glaciers hundreds of thousands of years ago.

OTHER MINERALS ARE FOUND IN KANSAS IN SMALL QUANTITIES: chalcopyrite, greenockite, marcasite, hematite, ilmenite, psilomelane, magnetite, limonite, siderite, smithsonite, aragonite, cerrusite, hemimorphite, goslarite, celestite, malachite.





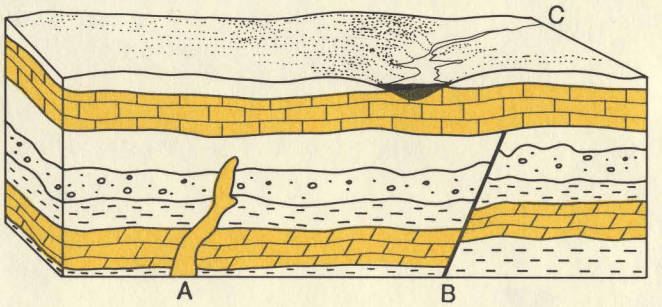


FIGURE 12. LAYERS OF SEDIMENTARY ROCKS OFTEN FORM IN FLAT BEDS. Sediment deposited on the Earth's surface compresses earlier deposits into hard rock. When beds are formed in this way, the deepest ones are the oldest (above, top).

FIGURE 13. SOMETIMES WIND AND WATER CARVE HILLS AND VALLEYS into the surface that are later buried. Magma also may force its way up from deep inside the Earth. When magma cools, a solid rock is formed within the layers of rock already there. This type of formation is called an intrusion (A). Rocks inside the earth may break and shift along a fault (B). These shifts, if big enough, may cause earthquakes (above).

FIGURE 14. UNDERGROUND ROCK BEDS, formed over millions of years, were exposed when part of a hill was cut away for a road (left).

SEDIMENTARY ROCKS

Sedimentary rocks, the most common rock at the surface in Kansas, can be found throughout the state. They may be formed from other rocks that were worn down by erosion into small pieces, such as sand and gravel, called sediment. A solid rock may be formed if the sediment is covered by great thicknesses of other sediment and rocks and pressed together, or if it is cemented together by minerals.

Organic material, which is anything that was once alive, may also be pressed together into a solid mass. Fossils of shells and tiny microscopic plants and animals, left behind when ancient seas dried up, are found in much of the Kansas chalk and limestone. Other common sedimentary rocks in Kansas are clay, shale, bentonite, silt, siltstone, sand, sandstone, dolomite, salt, and coal.

FIGURE 15. BRICKS MADE OF CLAY PAVE THIS SIDEWALK IN LAWRENCE.

Clay, Shale, and Bentonite

Clay is composed of very fine particles eroded from rocks and minerals. These particles are so finely worn that they can only be seen with a microscope. Clays may be a variety of colors—white, gray, black, red, yellow, tan, or green—and are often mixed with larger particles of other sediment such as sand and pebbles. Bricks, dishes, and other ceramic products are made from clay, which is molded and then hardened by heat.

When clay and silt are compacted into a solid rock, it is called

FIGURE 16. WIND AND WATER HAVE SHAPED THIS SAND DUNE near the Arkansas River in Kearny County in southwest Kansas.

shale. Shale erodes easily into clay when exposed in outcrops and roadcuts. Like clay, shale can be many different colors and is common in Kansas and throughout the world. It is used to make bricks and as an ingredient in cement.

Bentonite is a type of clay formed from altered volcanic ash. Most types of bentonite swell when they absorb water. Deposits of bentonite have been found in several locations in western Kansas.

Silt and Siltstone

Silt consists of particles larger than clay particles but smaller than sand particles. It is deposited by wind and water. Loess (pronounced lus) is a windblown silt found in many areas of Kansas. Thick loess deposits occur in northeast Kansas where rocks and gravel were ground down by glaciers and water. Later the dried mud was picked up by the wind. Much of it settled near the margins of the glaciers. But loess also covers much of the surface in western Kansas where it was spread around by ferocious dust storms.

When silt is compacted and cemented together, it forms a rock called siltstone, which is found in eastern Kansas.

Sand and Sandstone

Sand particles vary in size and can easily be seen without a microscope. Sand often contains eroded particles of rocks and minerals carried downstream by rivers and creeks. Two minerals, quartz and feldspar, are commonly found in sand.

Sand deposits are widespread in the state, especially along streams

and river valleys and in old river deposits. Sand hills also cover large areas of south-central and southwest Kansas.

When sand is cemented together, it is called sandstone. Sandstones in Kansas range in color from a light tan to brown to reddish-orange to bright orange. The different colors are caused by a variety of minerals and impurities. Sandstone deposits are found throughout Kansas, and buildings made of sandstone blocks can be found in areas where it is most abundant.

Limestone

Limestones are common in Kansas. They are usually found where seas once covered the land. They also can be formed from deposits in freshwater or on dry land, but nonmarine limestones are less common.

Most of them were formed from accumulations of marine plants and animals after they died and sank to the sea floor. If conditions were right, millions of tons of plant and animal debris were deposited and eventually compacted together. When the sea dried up, large slabs of rock were formed, often stretching for hundreds

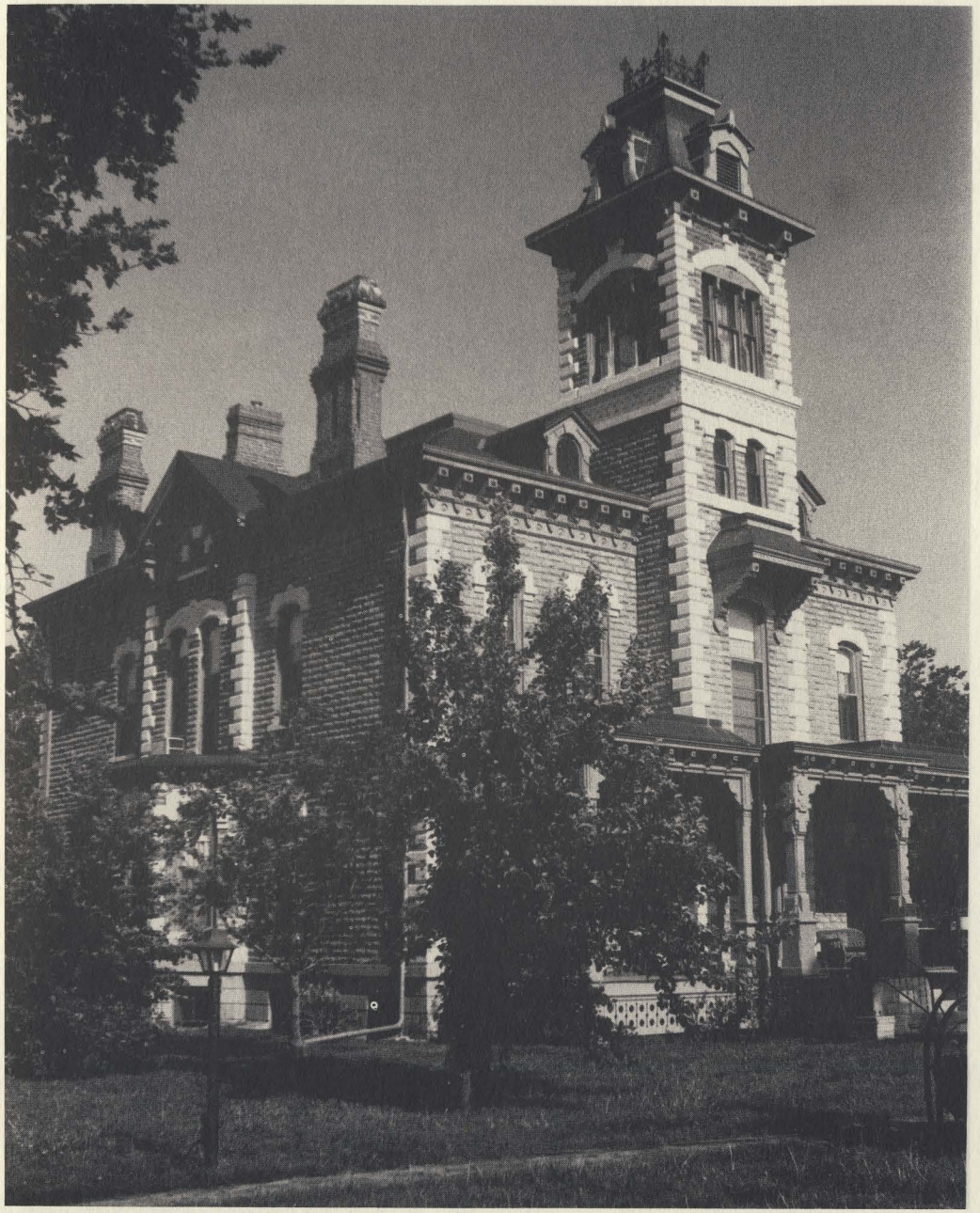


FIGURE 17. THE LEBOLD–VAHSHOLTZ HOUSE IN ABILENE was completed in 1880, and was built of limestone brought from more than 100 miles away in Russell and Ellis counties.

FIGURE 18. A LIMESTONE BRIDGE CROSSES DIAMOND CREEK IN CHASE COUNTY.

FIGURE 19. THIS CHARACTER, CARVED IN LIMESTONE, guards the front door of the Marion County courthouse in Marion.

of miles in every direction. Some plant and animal remains, such as shark's teeth and dinosaur bones, have been preserved as fossils in limestone.

Sea or freshwater shells, plants, or animals such as algae, corals, clams, oysters, brachiopods, bryozoans, fusulinids, and crinoids are sources of calcite, which is the main mineral found in limestone. Thick deposits of these plants and animals form limestone.

Limestones containing only one mineral–calcite–are white. But most limestones contain other minerals, for example iron oxide (rust), and organic remains. These cause limestone to vary in color, especially when the rocks are exposed to weathering elements such as air and water. Limestones in outcrops and roadcuts are usually off-white, tan, or yellow, and may be streaked with other colors.

Some buildings are made of limestone. Crushed limestone also is used to surface roads and is an ingredient in cement. Limestones are found at the surface in many parts of eastern Kansas but are not as common in central and western Kansas. However, chalk, which is a type of limestone, is found in some central and western areas.

Chalk

Chalk is a type of limestone often formed from the shells of small, single-celled animals called foraminifera. Pure chalk is fairly soft and white, but it usually has impurities that cause it to be different colors. Many fossils have been found in the chalk beds of western Kansas, among the most extensive chalk beds in the world.

Dolomite

Dolomite is similar to limestone; however, it is composed chiefly of a mineral also named dolomite, rather than calcite. Calcite and dolomite are often found together. The rock they form may be called dolomitic limestone or dolomite, depending on the quantities of calcite and dolomite it contains. Dolomite, which is found in some areas of southern and central Kansas, has many of the same uses as limestone.

FIGURE 20. GEOLOGISTS EXPLORE A WALL OF CHALK IN GOVE COUNTY.

FIGURE 21. COAL IS MOST LIKELY TO FORM FROM DEPOSITS IN SWAMPY AREAS with heavy vegetation. Coal takes millions of years to form.

Coal

When plants die in a swamp, their decaying remains are buried in mud. As they become buried deeper in the Earth, the decaying plants are pressed together and heated, forming a firm, brittle rock called coal. Coal can be burned to produce heat or to generate electricity. Before they had electricity, people often heated their homes and other buildings by burning coal. Early steam engines were fired by coal, but today trains run on diesel oil.

METAMORPHIC ROCKS

Rocks that have been changed from one kind of rock to another by heat and pressure are called metamorphic, which is Latin for "changed form." Limestone changes to marble; shale to slate, schist, and gneiss; and sandstone to quartzite. Marble, slate, and quartzite are much harder rocks than limestone, shale, and sandstone. Metamorphic rocks are rare in Kansas. Quartzite, which is found in a small area in Woodson County, is the only native metamorphic rock found at the surface.

Quartzite boulders can be found throughout northeastern Kansas, but they were not formed there. Glaciers

carried the rocks in from South Dakota, Iowa, and Minnesota. They are red, brownish red, or purple.

IGNEOUS ROCKS

Igneous rocks are formed when a hot liquid, called magma, cools and changes from a liquid state to a solid state. They may form slowly underground or rapidly at the Earth's surface. When magma reaches the surface, it is called lava. Lava flows out of a volcano and quickly hardens after an eruption. Although most lava reaches the surface through volcanoes, it may also flow out of deep cracks in the earth without building a mountain.

Kansas doesn't have an active volcano, but lava did flow onto the surface as recently as 90 million years ago when dinosaurs still roamed the Earth. Hot magma forced its way up from over 100 miles below the Earth's surface in two small areas of eastern Kansas. The hot liquid, which spread upward through cracks in other underground rocks, cooled and hardened, forming a rock called lamproite in Woodson and Wilson counties and one called kimberlite in Riley County.

In one area of Riley County, lava flowed onto the surface but a volcanic cone was never formed. The

FIGURE 22. COAL WAS USED TO FUEL THIS TRAIN AS IT TRAVELED THROUGH KANSAS AROUND THE TURN OF THE CENTURY (photo courtesy of the Kansas Historical Society).

kimberlite formed from the lava is now buried. Lamproite and kimberlite found at the surface in Kansas were exposed when the rock above was eroded away. Diamonds have been found in kimberlites and lamproites in other parts of the world, but none has been found yet in Kansas.

Granite, another type of igneous rock, has been found mixed with lamproite in Woodson County. It is older than the surrounding surface rocks and was formed deep in the Earth. Lamproite magma carried it toward the surface, where it is now exposed.

Some igneous and metamorphic rocks have traveled into Kansas from other places. Volcanic ash, basalt, granite, and quartzite have been carried in by wind, glaciers, and water.

METEORITES

One type of rock found in Kansas was not formed anywhere on Earth. Meteorites have the most unusual origin of any sediment carried—or, in this case, dropped—into Kansas. Meteors are rocks in outer space that usually vaporize before reaching the Earth's surface. As they enter the atmosphere and begin to disintegrate, meteors are seen as streaks of light called shooting or falling stars. The few meteors that do reach the Earth's surface are called meteorites.

Identifying meteorites in Kansas is easier than in other places, because they don't look like other Kansas rocks. Meteorites usually have a burned appearance, are pitted, and are denser than other rocks. Iron meteorites, consisting of heavy metals, iron, and nickel, are the easiest to identify. Stony meteorites are harder to identify because they look like volcanic rocks. Because Kansas has few volcanic rocks and lots of wide-open spaces, many meteorites have been found in the state.

FOSSILS

Over millions of years Kansas has been home to a variety of plants and animals. As the climate changed, different types of plants and animals moved in and out. Elephants, camels, tigers, large flying and swimming reptiles, sharks, 20-foot fish, and even three types of dinosaurs have all lived in Kansas at one time or another. Some descendants of these animals have survived and now live in other parts of the world. Others, such as the dinosaur, have become extinct. There are no dinosaurs today anywhere in the world.

We would never have known which animals had lived in Kansas if there were no fossils. Fossils are the remains of plants or animals that have been preserved in rock. Body parts, especially bones and teeth, may be preserved. Impressions or outlines of plants and animals are also found in some rocks. Sometimes the only evidence of an early animal is a footprint or track that has become hardened in rock. All of these—bones, teeth, impressions, outlines, footprints, and tracks—are fossils.

Fossils help geologists learn about the Earth. Another scientist, the paleontologist, specializes in studying fossils and life in the past.

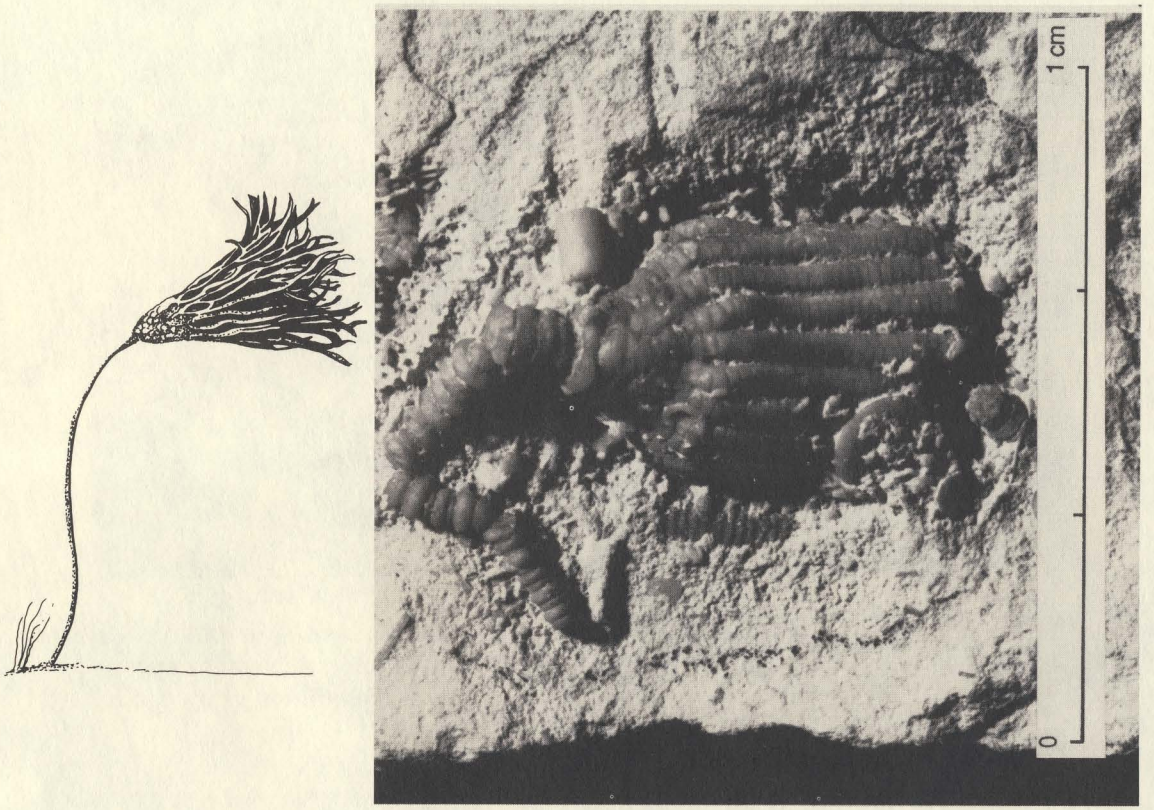


FIGURE 23. THE DRAWING SHOWS WHAT CRINOIDS IN THE ANCIENT KANSAS SEA LOOKED LIKE. The crinoid fossil was found in limestone, millions of years after the animal died and was fossilized.

Both geologists and paleontologists explore the Earth's surface and subsurface to learn more about its history.

Through fossil finds, paleontologists can piece together evidence of earlier life and landscapes. On one expedition in 1885, a footprint was found in a subsurface sandstone dug from a well in Ellsworth County. The sandstone was formed from sand deposited during the Cretaceous Period. Because of the position of the toes, scientists decided the impression was probably made by a bird.

Not far from where the footprint was found, impressions of leaves

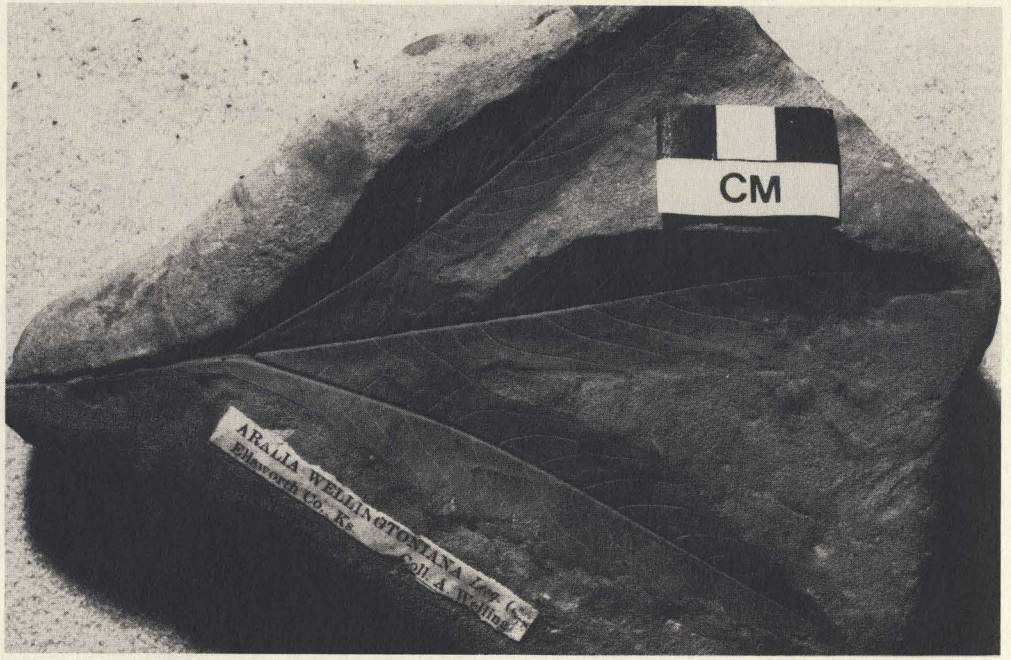


FIGURE 24. A FOSSIL LEAF FOUND IN DAKOTA SANDSTONE, which was deposited about 100 million years ago in Ellsworth County.

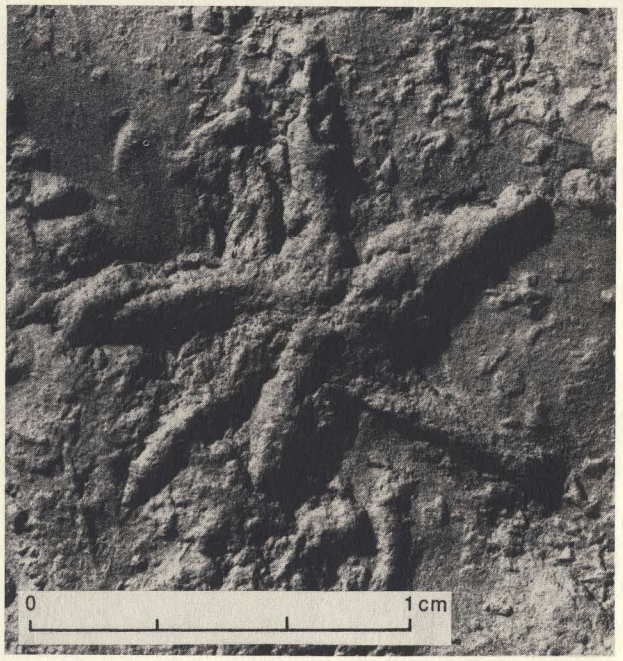


FIGURE 25. THIS FOSSIL WAS FORMED FROM A STARFISH THAT LIVED ABOUT 300 MILLION YEARS AGO in the Pennsylvanian Period.

were found in the same layer of sandstone. The leaves came from trees similar to modern-day oaks, willows, poplars, laurels, sarsaparillas, magnolias, and sassafras trees. None of these trees is native to Ellsworth County today, although people have planted some of them in the area. They grow naturally in other areas of the world where the temperatures are warmer. In the same sandstone surrounding the area where the leaves were found, fossils of marine fish and seashells were found.

By putting all of these fossil finds together, we know that a sea covered Ellsworth County millions of years ago. In this sea was at least one small island that was covered with beautiful trees and inhabited by birds. Insects also lived on the island because the leaves showed signs of insect attacks. The types of trees that were able to grow indicate the climate was probably warmer and wetter than it is today.

Before and after 1885, many other fossils have been discovered in Kansas and throughout the world. By studying fossils and rocks, scientists are able to determine what plants and animals lived during different periods and what their environments were like.

Fossils form only under certain conditions. Very few plants and animals are fossilized. Dead plants and animals must be buried quickly and not exposed to harsh weather and running water. Deltas, marshes, swamps, and shallow seas are ideal places for fossils to form. Because Kansas has been covered with marshes and seas several times in the past, it has a good supply of fossils.

The most common Kansas fossils are marine animals found in rocks formed in the Pennsylvanian, Permian, and Cretaceous periods. Few fossils of plants and animals that lived before the Mississippian Period have been found in Kansas. As the rocks changed over time, many of the fossils were destroyed. Also, many early animals had soft bodies. Most animal parts that are preserved are hard, such as bones, teeth, and shells.

But the main reason for few early fossil finds in Kansas is that no rocks formed before the Mississippian Period are found at the surface in Kansas. Fossils of tiny single-celled plants and animals from earlier periods have been found in rocks brought up from hundreds, even thousands, of feet underground when oil and water wells were drilled. The chance of finding larger fossils by this method is not good because the rock brought up

FIGURE 26. A CLAM-SHELL FOSSIL FROM THE PENNSYLVANIAN PERIOD.

FIGURE 27. BRACHIOPODS, SMALL-SHELLED MARINE ANIMALS, were abundant in Kansas seas more than 250 million years ago.

from underground during drilling is usually crushed into small pieces. Also, only a narrow cylinder of rock—about two to four inches in diameter—is ever removed from the hole. Much of what we know about life before the Mississippian Period comes from fossils found in areas outside of Kansas.

Nonmarine plant and animal fossils also have been found in Kansas, but they are not as common because plants and animals often decay on dry land before they can be fossilized. Usually only fragments of bones or teeth are fossilized, and only a small number survive over millions of years.

Paleontologists compare new fossil finds to other fossils and to living animals. This helps them determine what animals looked like millions of years ago.

Sea Fossils from Ancient Kansas

A variety of marine-animal fossils have been found in Kansas, including corals, bryozoans, brachiopods, crinoids, clams, snails, squid, jellyfish, trilobites, eurypterids, turtles, fish, and sharks. You may not be familiar with some of these animals even though many of them have living relatives. Numerous sea plants and animals today are rarely seen because they spend their lives crawling on or attached to the ocean floor.

Like their descendants, Kansas corals, bryozoans, and crinoids attached themselves to the sea floor or each other and rarely moved. Although they look more like plants, all of these are really animals. Shelled animals, such as brachiopods, clams, and snails also spent their lives deep underwater on the floors of the Kansas seas.

Besides stationary animals, the ancient Kansas seas also had active crawlers and swimmers. Trilobites were present in the Pennsylvanian seas in eastern Kansas. Several types existed at one time, but they are now all extinct. Another extinct sea dweller, the eurypterid, grew up to six feet long in the Kansas seas. Its living relative, the horseshoe crab, can still be found in many parts of the world today.

Several types of sharks and fish lived in the Pennsylvanian and Permian seas. An even greater variety of fish fossils have been found in rocks formed in the later Cretaceous sea that covered western Kansas. These fish shared the sea with the bottom dwellers and large swimming reptiles.

Two types of swimming reptiles, the mosasaur and the plesiosaur, have been found in Cretaceous sea deposits. From the looks of their large fossilized skeletons, they must have been a frightening and probably unwelcome sight to their smaller neighbors. Both reptiles had long bodies, sharp teeth, and paddlelike limbs. Although mosasaurs and plesiosaurs are extinct today, many of their smaller relatives, including snakes and lizards, are still common.

Dinosaurs and other Land Dwellers

No evidence of land-dwelling animals on earth before the Devonian Period—410 million years ago—has been found. Plants showed up on land a little earlier in the Silurian Period. Before this period, all known life lived in the water. Before and after land dwellers appeared, millions of species of plants and animals lived on the Earth. Some are extinct, but many are still around today.

Among the extinct animals are a number of giant reptiles, including the dinosaurs. Fossil evidence suggests that dinosaurs appeared during the Mesozoic Era and disappeared at the end of that era.

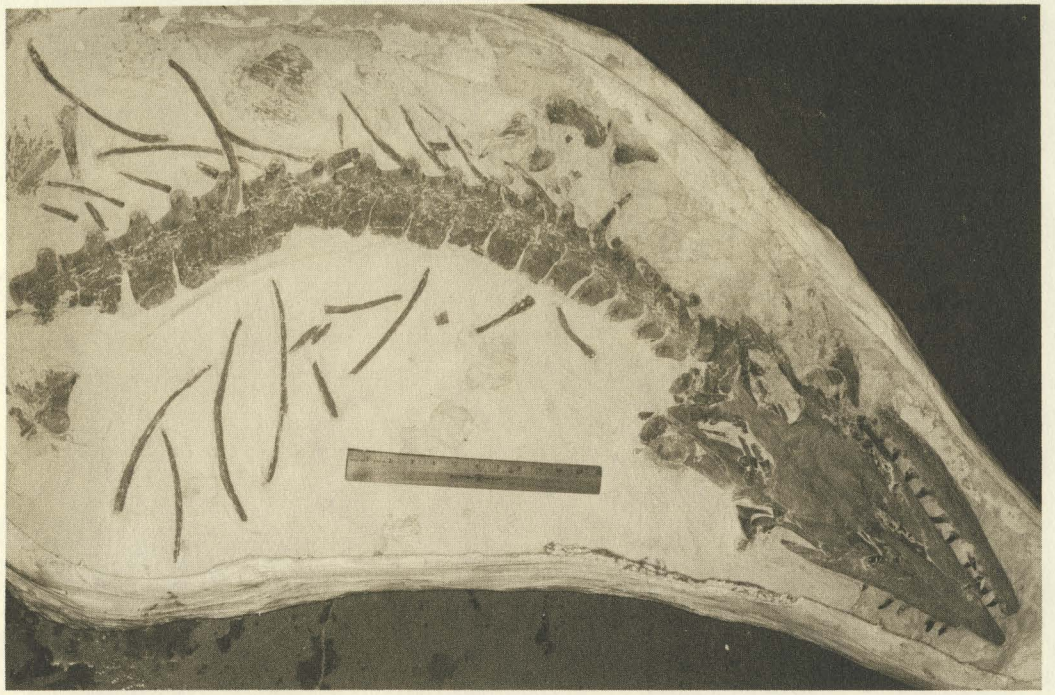
No one is certain what caused the extinction of the dinosaurs, other giant reptiles, and many plant and animal species. Many scientists now

believe the Earth's climate changed drastically. The change may have been caused by a meteor shower where millions of rocks and other debris from outer space collided with the Earth. Why some species were able to endure while others, such as dinosaurs, became extinct is not yet known.

Not many dinosaur fossils have been found in Kansas. During the early Mesozoic Era, erosion was fairly common in Kansas so not many animals or plants could be preserved as fossils. In the last part of the Mesozoic Era, the Cretaceous seas covered much of the state and most animals were of the marine variety. However, three types of dinosaurs did live along the Kansas shoreline. Fossils of Sylvisaurus, Heirosaurus, and Claosaurus have been discovered.

Sylvisaurus and Heirosaurus were armored dinosaurs. The Sylvisaurus grew to 10 feet in length and the Heirosaurus to 20 feet. The Claosaurus stood on its hind legs, grew up to 12 feet in height, and had a duck bill. Like many dinosaurs, the Sylvisaurus, Heirosaurus, and Claosaurus were herbivores, or plant eaters.

Another unusual reptile, the pterosaur, dominated the Kansas



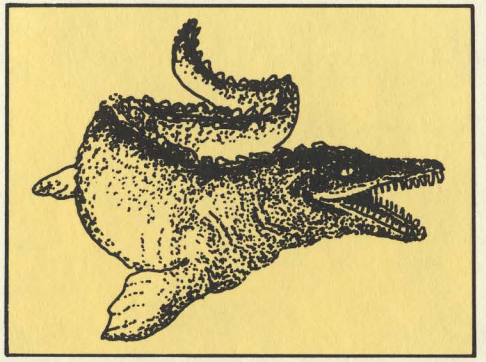
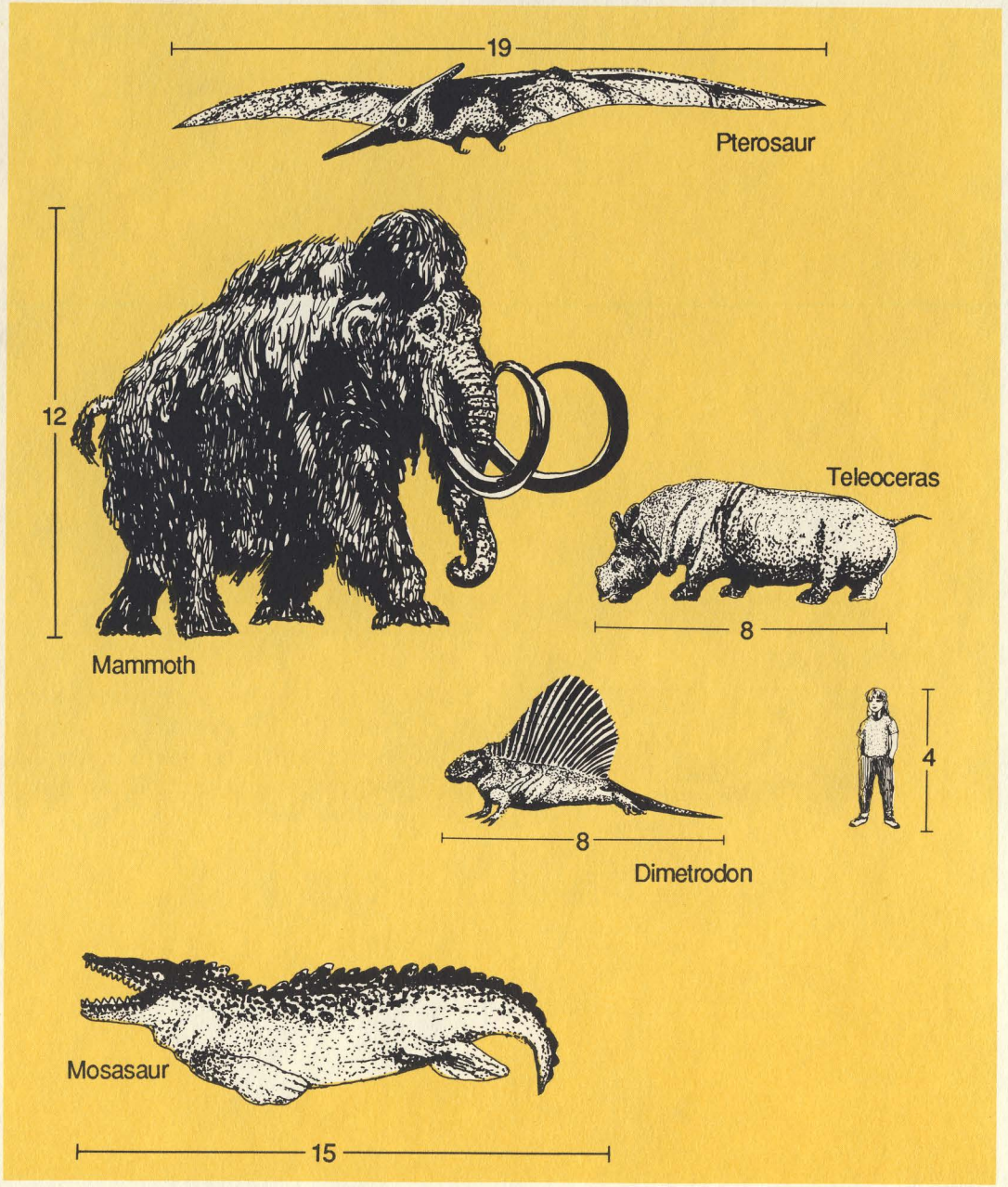


FIGURE 28. MOSASAURS, GIANT SWIMMING REPTILES, WERE UP TO 20 FEET LONG. The mosasaur fossil above, which includes the head and part of the spine and ribs, was found in western Kansas.

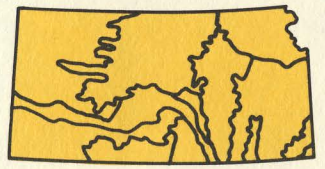


skies during the Mesozoic Era. Although the pterosaur could fly, it probably had hair rather than feathers on its wings. Fossils of pterosaurs found in Kansas have wingspans under 20 feet, but larger pterosaurs have been found in other places.

The plants and animals that were able to survive into the Cenozoic Era often are more familiar to us. Thousands of fossils of plants, insects, amphibians, reptiles, birds, fish, and mammals have been found in Cenozoic rocks in Kansas.

During the Cenozoic Era, large mammals began to appear. Mammals such as the mastodon, woolly mammoth (ancestor of the elephant), rhinoceros, camel, tiger, peccary (wild pig), and bison roamed through Kansas in the early part of the era. By the time people began making Kansas their home, many of these animals were extinct or had migrated to other parts of the world. The bison, one of the few large animals that did survive, almost became extinct when thousands were slaughtered by hunters in the 1800's. Even though an assortment of wild animals still live in Kansas, most seem tiny compared to the giant mastodons and mammoths.

FIGURE 29. THIS DIAGRAM SHOWS THE SIZE (IN FEET) OF SEVERAL ANIMALS THAT LIVED IN KANSAS at one time or another. Dimetrodon fossils have been found in Permian rock. Mosasaurs and pterosuars lived in western Kansas during the Cretaceous. The Teleoceras, a rhinoceros, lived in Kansas in the Tertiary Period, and mammoths traveled in herds on the plains during the early Quaternary Period.



LANDFORMS AND LANDSCAPES

Acansis, Canips, Caw, Ka An-jou, Kathasi, Kauzaus, Konga, Quaus, Ukasak. These are just a few of the ways early explorers spelled the name of an Indian tribe they found living in central North America. Because the Indians had no written language, their name had no official spelling. French explorers spelled it the way they thought it should be spelled in French, the Spanish based their spellings on Spanish, and the Americans used English. Later settlers named the territory after the Indians. They called it Kansas.

Just as Kansas has had many names, it also has many faces. Not all areas of Kansas are alike. Some areas are hilly, others are flat. Some parts have more rainfall and rivers, which means more trees and bushes. In areas with less rainfall, fewer trees and more prairie grasslands are found. In some areas the dirt is brown. In other parts it is red. Some places have water stored in rocks underground, while in other areas, ground water is not so plentiful.

The landscape in Kansas hasn't changed much in the past 4,000 to 5,000 years. The biggest changes have been made by the people who have made Kansas their home. Although the Indians did affect the environment, they lived more in harmony with nature. When settlers moved in, the big changes began.

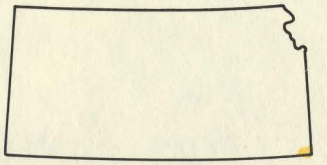
Farmers plowed the soil and the prairie grasslands began to disappear. Holes and ditches were dug in the earth in search of minerals and building materials. Roads and buildings were constructed, and cities and towns grew. Most of this happened in just the past 150 years.

Today the Kansas landscape is a combination of natural landforms and human-made features. Natural landforms are features of the Earth such as hills, mountains, valleys, slopes, canyons, sand dunes, plains, and plateaus.

The landscape looks the way it does because of geologic activities in the past. In some places limestone is the rock at or closest to the surface and in other places sandstone is on top. In some areas hills were carved out by rivers that eroded the land. In other places, large rivers meandered around and flattened out the land for miles in all directions. Large slabs of rock are near the surface in some regions, making the soil rocky, while other regions have several layers of soil and sediment above the rock.

The state has been divided into regions based on rock type and age, landscape, and landforms. Some regions look alike but the rocks and soil in the regions were formed at different times. Differences also are found within a single region. Hilly regions have flat areas and flat regions usually have a few hills. The variety of landscapes and landforms in Kansas may surprise you.

FIGURE 30. "CHAT" PILES NEAR GALENA.

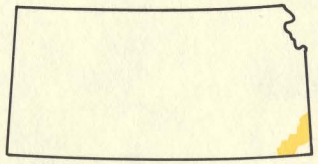


Ozark Plateau

Many people still form their opinion of Kansas by watching a Hollywood movie made in 1939. The *Wizard of Oz*, which, by the way, was not filmed in Kansas but in a Hollywood studio, depicts Kansas as hot, dry, dusty, flat, and tornado-ridden. The Ozark Plateau region, in the southeast corner of the state, doesn't come close to fitting this image.

This region of Kansas is the corner of the Ozarks, a hilly and densely forested region that covers a large area in Missouri, Arkansas, Oklahoma, and Kansas. The limestone and flint in this region were formed during the Mississippian Period, 350 million years ago. They are the oldest surface rocks in the state.

Two minerals, lead and zinc, were once mined in this area. Rocks were crushed to get the minerals out. The lead and zinc are no longer mined here, but big piles of crushed rock called "chat" were left behind.



Cherokee Lowlands

The region northwest of the Ozark Plateau, the Cherokee Lowlands, differs from the Ozark Plateau in appearance. The Lowlands aren't as hilly as the Plateau and don't have as many trees, but the two regions have similar mining and industry backgrounds.

In the late 1800's and early 1900's, business was booming in southeast Kansas. Growth was based on thriving industries, such as coal mining and the cement, glass, brick, and tile plants that popped up around the area. All of these industries used the natural resources such as coal, zinc, clay, and limestone. But by the 1930's, many of the industries closed because they were no longer profitable. Some industry still exists in southeast Kansas and coal is still mined, but the mineral-based industrial heyday is over.

In Kansas, coal is removed by strip mining. Large, mechanical shovels are used to dig long, deep ditches to reach the underground coal. One of the world's largest shovels, Big Brutus, was used in Cherokee County. Big Brutus is retired from mining now and is used as a museum.

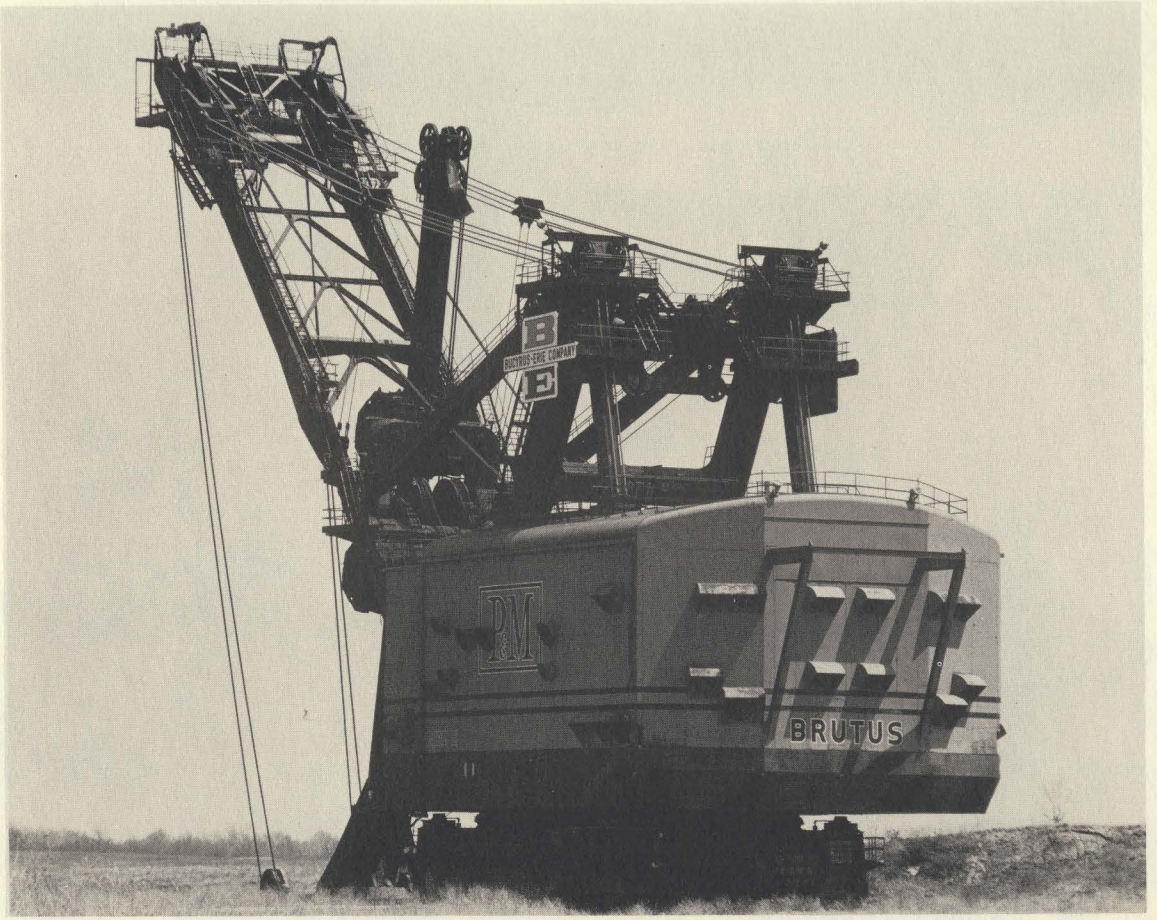


FIGURE 31. BIG BRUTUS IS 160 FEET TALL FROM THE GROUND TO THE TOP OF THE BOOM. This distance is about equal to the height of a 15-story building.

Companies must smooth out these ditches and plant trees and grass when they are finished mining. This is called land reclamation. After the land is leveled, it can be used for other things, such as farming and grazing.

Before 1969, companies didn't have to reclaim the land. Land that was not reclaimed can still be seen. Many of the abandoned ditches are now filled with water and have been stocked with fish.

FIGURE 32. THESE CUESTAS ARE NEAR POMONA. The arrow points to a steep slope called an escarpment.

Osage Cuestas

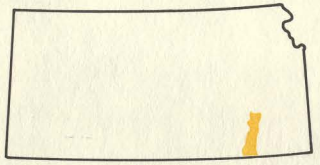
North of the Cherokee Lowlands is the Osage Cuesta (pronounced kwesta) region. This area was once covered with shallow seas. During the Pennsylvanian and Permian periods, about 230 to 310 million years ago, these seas would grow and shrink due to sea-level changes. The changes were caused in part by fluctuation in the amount of ice in the polar ice caps. When more of the Earth's water was frozen at the poles, world-wide sea levels in other areas would drop. Sometimes the Kansas seas completely disappeared. When some of the ice at the poles melted and water was released, water levels rose again.

Today the sea level is lower than during the Pennsylvanian and Permian periods and land in the area has been uplifted, or raised, by changes in the Earth. Lower sea levels and higher land caused the seas to retreat. The rocks formed from sediment deposited by the seas were then buried several thousand feet. Uplift and erosion have now exposed these rocks and formed hills, called cuestas.

Cuestas have a steep slope on one side (an escarpment) and gentler

slopes on the other sides. Cuesta is the Spanish word for cliff.

The Osage Cuestas are composed of several alternating layers of sandstone, limestone, and shale. Not all of the hills in the Osage Cuesta region are cuestas with escarpments. Rolling hills and flat areas also can be found. Like all regions in the state, the cuesta region has variety.



Chautauqua Hills

West of the Osage Cuestas are the Chautauqua Hills, known for their thick layers of sandstone and dense vegetation of oak and other timber. During the Pennsylvanian and Permian periods, rivers and streams flowed into the sea in this area. Sand and other sediment collected at the mouths of the rivers, forming deltas. When the seas dried up, the sediments were buried and formed rocks. The sands became sandstone and the muds became shale. Uplift and erosion eventually exposed sandstone and shale outcrops at the Earth's surface.

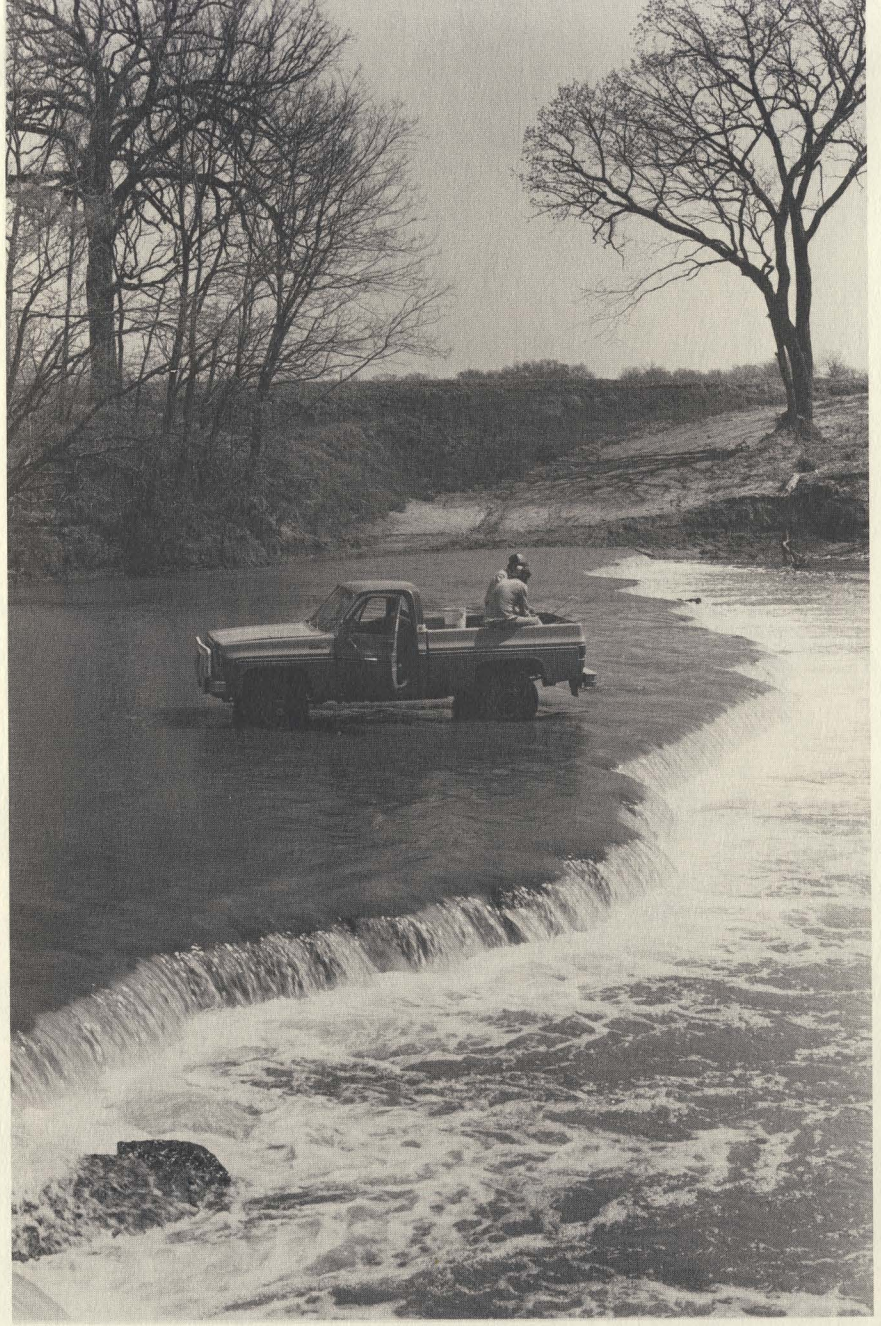
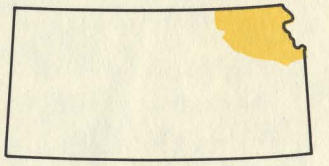


FIGURE 33. OSRO FALLS IN CHAUTAUQUA COUNTY is created where the Caney River runs over a limestone ledge.

FIGURE 34. BOULDERS, CARRIED INTO NORTHEAST KANSAS BY GLACIERS, were deposited on a hill near Wamego.

FIGURE 35. A ROAD WAS CUT THROUGH THICK LAYERS OF FINELY GROUND SILT CALLED LOESS, left behind by the glaciers in Doniphan County.

Glaciated Region



Several glaciers, which are huge masses of ice, covered much of the northern United States hundreds of thousands of years ago. The glaciers grew and melted as the climate changed. Most of the glaciers did not reach Kansas, but at least two dipped down into the northeast corner. When the glaciers retreated, rocks and soil that had been carried into the area from the north were left behind. The force of the moving ice was so strong, it broke large quartzite boulders off outcrops in South Dakota, Iowa, and Minnesota and carried them over 200 miles into Kansas. The boulders can still be seen scattered throughout the area today.

The glaciers also left behind a layer of sediment. Finely ground silt, called loess, was sorted and carried by the wind. Thick layers of loess were deposited throughout the area. Fertile soils formed from loess are good for farming because they contain few rocks.

Flint Hills

When settlers first moved to Kansas, many of them passed the Flint Hills by. They wanted good farmland, and the rocky soil was too hard to plow. Although the area is now used for grazing cattle, not much of the land has been plowed to grow crops, and the Flint Hills remain, for the most part, a natural prairie grassland.

The Flint Hills region, which runs north and south through east-central Kansas, is one of the few large areas of native prairie grassland left in the United States. The grassland that covers the Flint Hills once covered most of central and western Kansas and the surrounding states. When people moved in, the prairie in other areas became covered with farms and cities. Away from the roads and buildings, the Flint Hills region looks much as it did 10,000 years ago.

Although the Flint Hills region is known for its rolling grasslands, it is named for flint, a type of rock that is found embedded in the limestone that forms the hills. Flint, also called chert, doesn't erode as easily as the softer limestone. When the limestone at the surface is eroded by wind and water, it eventually breaks down into soil. The exposed flint is broken down into gravel, which mixes with the soil and makes the ground rocky.

FIGURE 36. IN 1868, THE STATE BEGAN PAYING RANCHERS TO BUILD FENCES TO KEEP CATTLE FROM ROAMING FREELY. Thousands of miles of limestone fences were built in the Flint Hills, including this stretch south of Alma.

FIGURE 37. A VIEW OUT OF PALMER'S CAVE IN ELLSWORTH COUNTY reveals sandstone outcrops in the Smoky Hills (photo courtesy of the Kansas Historical Society).

Smoky Hills

West of the Flint Hills is another hilly region called the Smoky Hills. The rocks in the Smoky Hills, like those in the Osage Cuestas, were formed from sediment deposited on or near a sea floor. While the Osage Cuestas were formed earlier during the Pennsylvanian and Permian periods, the Smoky Hills were formed from later deposits in the Cretaceous Period.

The Smoky Hills change from east to west. The eastern hills are capped with sandstone. This means the top layer of rock is sandstone with other layers, or beds, of rock underneath. The sandstone was formed from sediment carried by rivers into the shallow seas from the east.

The hills in the middle are capped with limestone. This area of the Smoky Hills is known as post-rock country. Because wood was scarce, early farmers quarried limestone to use as fence posts. Although most of the newer posts are made of steel or wood, limestone fence posts can still be seen along many roads in the area. Limestone and sandstone in the Smoky Hills also are used for building.

Limestone in the Smoky Hills was formed from deposits in fairly shallow areas of the Cretaceous sea. Fossils of seashells and even sharks' teeth are frequently found in this area.

When the seas dried up in the western part of the Smoky Hills region, thick layers of sediment were left behind. The sediment was later buried between 1,000 and 2,000 feet underground and formed into chalk. Some areas of the chalk bed were later exposed by erosion. Today, much of the chalk at the surface has been eroded away by water. In some areas, tall, steep-sided chalk formations were left standing after the surrounding chalk eroded away. In Gove County, the Smoky Hill River carved out a large formation called Castle Rock and a series of formations called Monument Rocks. Chalk bluffs also can be found along the Smoky Hill River in Logan, Trego, and Gove counties.

Chalk, like the post-rock limestone, contains marine fossils. Clams, small plants, sharks' teeth, and seashell fossils are fairly common. Fossils of large fish, giant swimming and flying reptiles, and swimming birds also have been found, but they are much rarer.

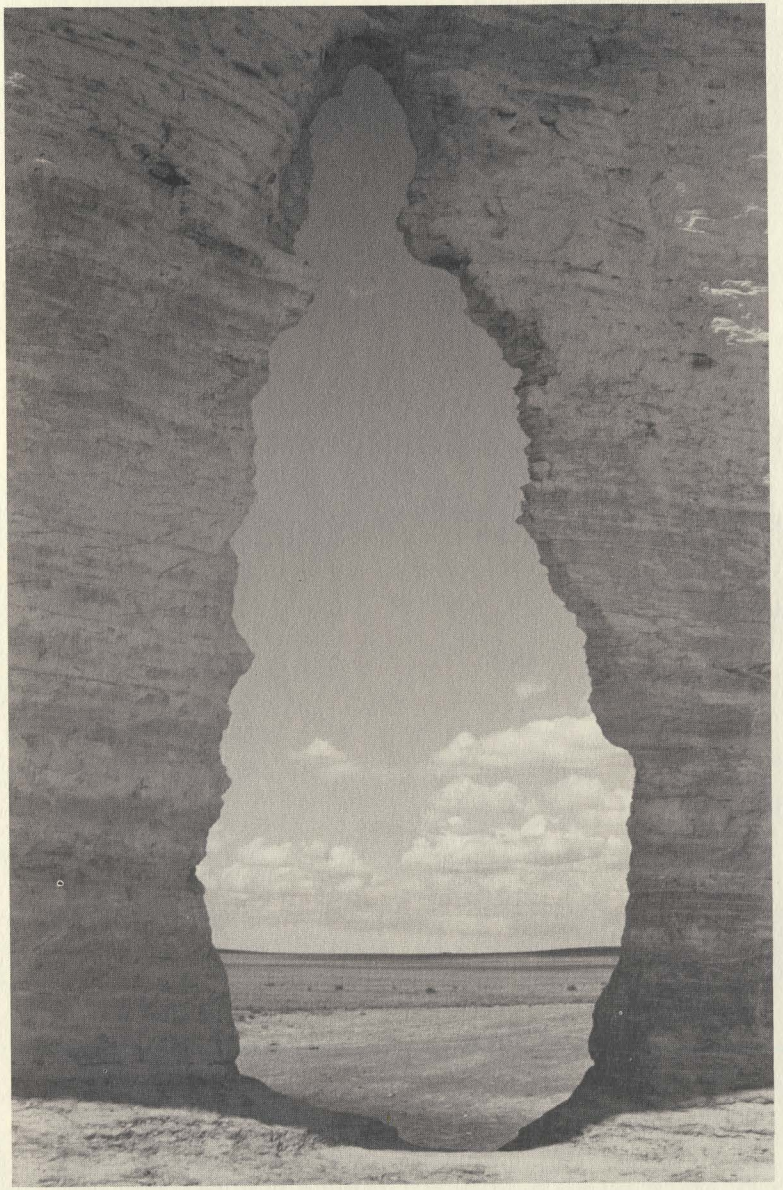


FIGURE 38. THIS OPENING IN MONUMENT ROCKS WAS FORMED OVER MILLIONS OF YEARS BY EROSION.

FIGURE 39. MUCH OF THE LAND IN THE WELLINGTON–MCPHERSON LOWLANDS IS FLAT, making it good farmland. This pasture is near Goessel.

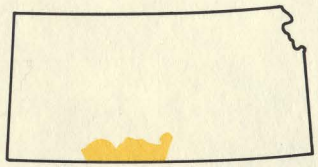
Wellington–McPherson Lowlands

Early Permian seas helped shape the the Flint Hills, the Osage Cuestas, and the Chautauqua Hills in eastern Kansas. Later Permian seas in central and western Kansas left behind thick layers of salt, which was buried by other sediment and remained hidden for millions of years until it was accidently discovered in 1887 by drillers looking for oil and gas near Hutchinson. This salt turned out to be part of a large bed that underlies much of central and western Kansas. Today, salt mining is a major industry in Reno, Rice, and Ellsworth counties.

Much of the salt is brought to the surface by miners who spend their workdays chipping, drilling, and dynamiting salt in caverns more than 600 feet underground. Most salt from underground mining is used in industry or to melt ice from roads in winter. Table salt, also mined in the area, is brought to the surface by drilling a hole deep in the ground and forcing water down it, dissolving the salt. The salt solution is then forced up to the surface where the water is evaporated, leaving the salt behind.

Because the salt contains no moisture, some of the caverns that are no longer mined are now used for storing things such as government papers and old Hollywood films. Underground salt is also dissolved to form caverns for storage of natural gas and similar products. Limestone and shale beds above and below the salt keep water out of the cavern.

FIGURE 40. MANY OF THE HILLS IN THE RED HILLS REGION HAVE UNUSUAL SHAPES.



Red Hills

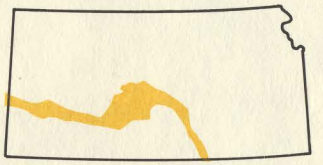
The Red Hills, like the Ozark Plateau in southeastern Kansas, are probably not the image a tourist or even many Kansans would conjure up when thinking of Kansas. Though both regions are in the southern part of the state, they don't look alike. The Ozark Plateau in the southeast corner has tree-covered rolling hills. In contrast, the Red Hills in south-central Kansas don't receive as much rainfall, so, except for cedars that dot the landscape, trees are sparse and the air is dry.

Thick shales and soil in this region are red because they contain iron oxide, also known as rust. The hills, of course, got their name from their color but they just as easily could have been named Flat-top Hills because of their shape. Many of the hills in the region are flat-topped, a shape not commonly found in Kansas. Flat-topped hills known as mesas and buttes are more commonly found in the desert southwest in Arizona or New Mexico.

Sometimes hills and valleys are formed when underground rocks, rather than surface rocks, are eroded away. Big Basin and Little Basin in the Red Hills region in Clark County were formed when underground salt and gypsum deposits were dissolved by water, creating empty spaces between rock layers. The land above collapsed into the empty space, leaving a dip in the ground. Holes formed in this way are called sinkholes.

FIGURE 41. IN 1872, A WAGON CROSSES THE ARKANSAS RIVER NEAR GREAT BEND. Although the river was shallow, it was 200 to 300 yards, or about one to two city blocks, wide. Now at this spot, it is only about 20 feet wide. The photograph on page 47 was taken in 1986 within a few miles of the same location (photo courtesy of the Kansas Historical Society).

Sinkholes come in all sizes, some only a few feet across. Others are very large. Big Basin is a mile across, about 100 feet deep, and has a highway running through it. Many of Kansas' natural lakes and ponds are water-filled sinkholes. St. Jacob's Well, a pool in the bottom of Little Basin, was formed by a spring.



Arkansas River Lowlands

Cutting through western and central Kansas is a region carved out—or in most areas, flattened out by the Arkansas River. The river has been pretty well tamed by the people who live along it. It doesn't flood much anymore and in some places it is dry most of the year because the water has been used faster than the rains can replace it. Some stretches in western Kansas were completely dry between 1965 and 1985. But in the past, before people settled along

the Arkansas, the river frequently flooded and meandered, forming a flat area, called a floodplain, for several miles on either side of the river.

The Arkansas and the Missouri (which forms the northeast border of Kansas) are the only rivers in Kansas that begin in the Rocky Mountains. So while the river has flattened out the land, it also has deposited sand and other sediment carried in from the Rockies and other points along its path. Sand dunes, created by wind and water, can be found in many places along the river.

Most of the sand hills don't change much anymore because they are covered with grass and other vegetation. However, some dunes in southwest Kansas are still active. Active dunes have little grass growing on them so they are always changing. Wind and water create new patterns in the sand and alter the shape of the hills and dunes. Although these changes usually don't happen overnight, the sand hills are more affected by the environment than hills made of solid limestone or sandstone.

FIGURE 42. THE ARKANSAS RIVER SOUTHWEST OF GREAT BEND IS NEARLY DRY MUCH OF THE YEAR. Less than 100 years ago this river bed was full of water year round.

FIGURE 43. ELEPHANT ROCK IN DECATUR COUNTY was formed from an outcrop of porous rock from the Ogallala Formation.

High Plains

As you drive across Kansas from east to west you are gradually going up in elevation. Although the rise is so gradual that you don't notice it, you go up more than 3,000 feet if you start at the lowest point of 700 feet in Montgomery County and end up at the highest point of 4,039 feet in Wallace County. The highest point in Kansas is named Mount Sunflower, although it's just a small hill, not a mountain. Mount Sunflower is in a region known as the High Plains. The High Plains, an area of open expanses of flatlands and gently rolling hills, were once covered by a short-grass prairie. Now, much of the land has been farmed and only small areas of prairie remain.

This region was once crossed by many rivers. When the Rocky Mountains were forming millions of years ago, sediment such as sand and gravel was carried in by the rivers from the mountains. Some of the loose sand

and gravel was naturally cemented to form a porous and permeable rock called mortarbed. Porous means it contains holes and permeable means the holes are interconnecting so that water can seep through. However, not all of the sand and gravel was compacted or cemented. Layers of tightly packed, but uncemented, sand and gravel are found in the subsurface in western Kansas. This layer of sand, gravel, and porous rock is known as the Ogallala Formation.

Most of the Ogallala Formation is underground, but in some places the porous rock crops out. Elephant Rock in Decatur County is an outcrop of the Ogallala Formation. Other good examples of Ogallala outcrops can be found in the bluff area around Scott County State Lake.

When it rains in the High Plains, water seeps into the ground and is stored in the Ogallala Formation. Since the region doesn't receive much rainfall, people in the area have to rely on this ground water for their water supply. Much of the water in eastern Kansas is taken directly from rivers, but in western Kansas it is often necessary to dig water wells. The ground water also is used by farmers to irrigate their crops.

People originally thought the water from the Ogallala Formation would last forever and pumped water out to be used by cities, industries, and crop irrigation. Geologists began monitoring wells in the area and have recorded fairly steady water-level declines in the Ogallala over the past 20 to 30 years. The sparse rain in the area hasn't replaced the water as fast as people have pumped it. Now we know that if it isn't used carefully, much of the water supply could be exhausted.

Next time you take a trip through Kansas, look around. At first glance, the landscape of Kansas seems simple and straightforward. There are no Rocky Mountains. The highest point in Kansas is just a small hill. There is no 5,000-foot-deep Grand Canyon. Kansas has its share of small ravines, but most are less than 100 feet deep, and none is much deeper than 300 feet.

Kansas has no geological features to attract hordes of tourists. But the changes that have taken place in Kansas over time, and the results of those changes, are still amazing.

Geologists, paleontologists, and other scientists have studied the rocks, minerals, fossils, landforms, water, and other natural resources for many years and have made many exciting discoveries. They have found evidence of ancient seas, glaciers, giant dust storms, buried hills and valleys, giant flying and swimming reptiles, dinosaurs, camels, woolly mammoths, and much more.

New discoveries continually add to our knowledge of the Earth around and beneath us. Scientists have found that the Earth is a very complex place. After years of exploration, there is still a lot to learn. Even Kansas, with its seemingly simple flat lands and gentle rolling hills, has a wealth of hidden information.

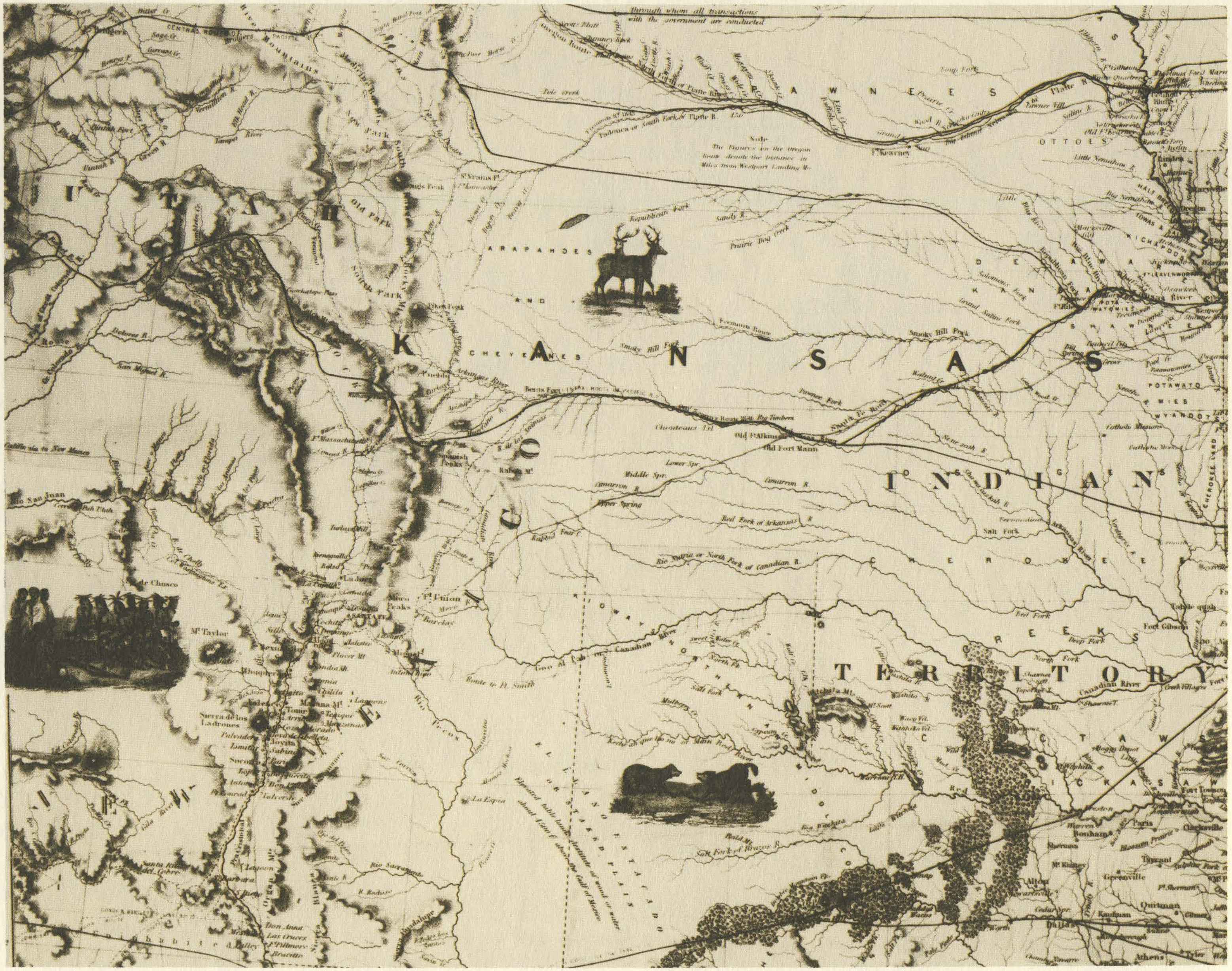
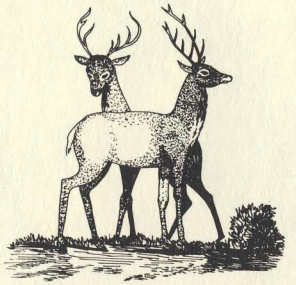


Figure 44. WHEN KANSAS WAS STILL A TERRITORY, it included land all the way to the Rocky Mountains. This map was drawn in 1855 (photo courtesy of the Kansas Historical Society).

MAPS



Suppose you wanted to see the sights of Kansas or look for a fossil or two. Where would you begin? When Coronado and his men began their search for gold in 1541, they had to depend on Indian guides and natural landmarks such as rivers and hills to keep them on course. If good maps of the territory had been available, Coronado could have checked them out, discovered that Quivira had no gold, stayed home, and avoided aching feet and saddle sores.

In 1803, the United States purchased the Louisiana Territory, which included most of Kansas, from France. Wanting to find out more about the newly acquired land, the U.S. government sent explorers out to investigate. Lewis and Clark headed out in 1804, and Zebulon Pike made the trip in 1806. Pike was unimpressed with the nearly treeless prairie of the Great Plains and called it the "Great American Desert."

Stephen Long, who visited the area in 1819-1820, produced an early map of Kansas. Using Pike's description, he included the label "Great American Desert" on his map. Even though the area was covered by prairie grasslands and not a desert, the name remained on many maps until the 1860's.

Long's and other early mapmakers' interpretations of the area were simple and not very accurate. They lacked the time and equipment to make better ones. As more people came to Kansas and the surrounding territory, they became familiar with the area and maps became more reliable.

Early maps were made primarily to help people find their way through unfamiliar territory. Many modern maps serve the same purpose. One of the most common maps, the road map, shows major roads, rivers, lakes, landmarks, other places of interest, and distances between cities.

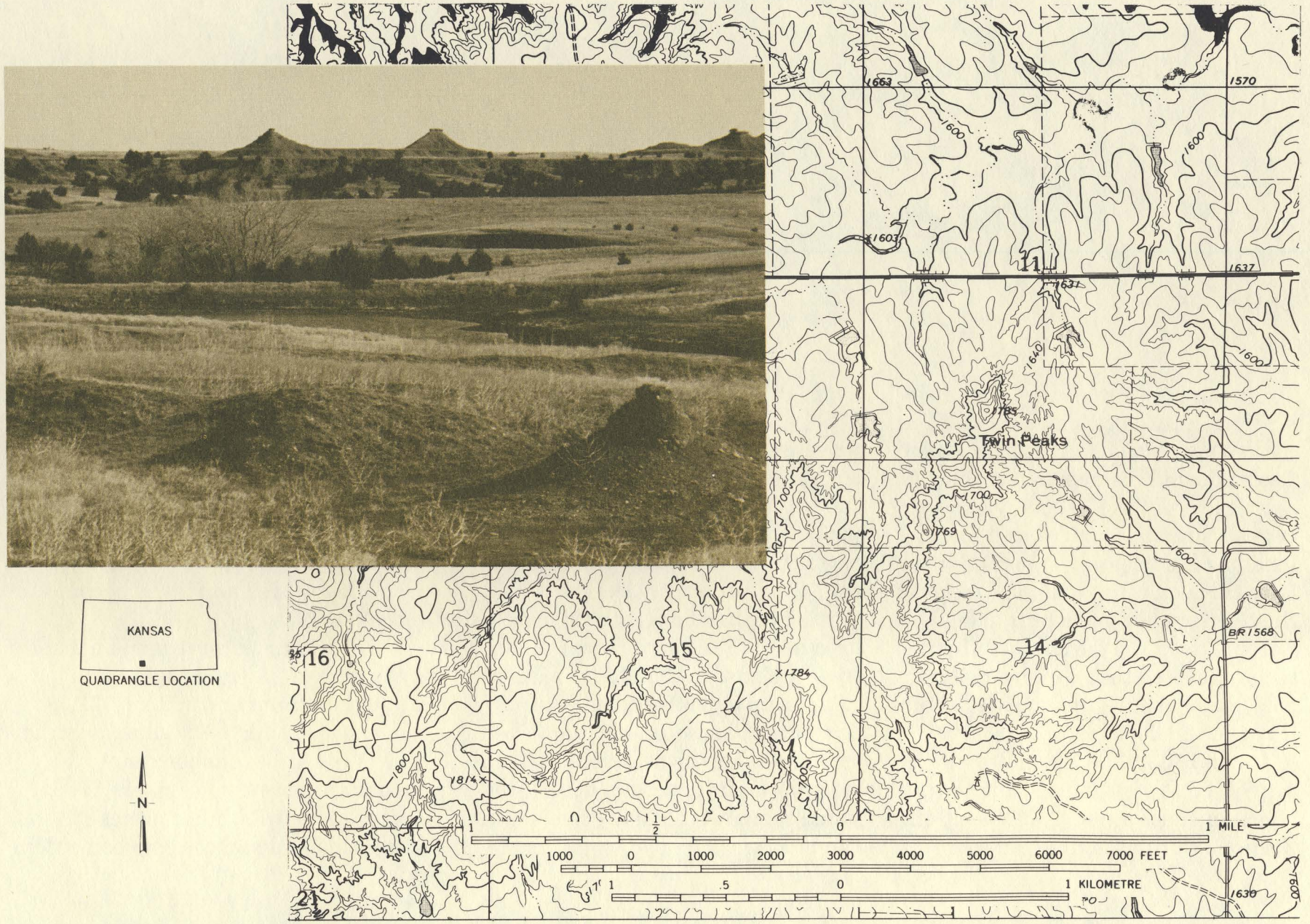


FIGURE 45. THE PHOTOGRAPH AND TOPOGRAPHIC MAP BOTH SHOW TWIN PEAKS in the Red Hills of south-central Kansas. On the map, the hills are represented by contour lines. The closer together the lines are, the steeper the slope. Flat areas have few contour lines. The photograph was taken from the northwest. The northern peak on the map is to the left in the photograph and the southern peak is to the right (map courtesy of the United States Geological Survey, Medicine Lodge SW 7 ½-minute quadrangle, scale 1:24,000).

Road maps are good for travelers, but other types of maps also are needed. Geologists, paleontologists, road builders, architects, city planners, and others need to know more details about the land. They use topographic maps, which, like road maps, show county boundaries, cities, roads, rivers, and lakes. But topographic maps also show hills, mountains, valleys, plains, plateaus, and other landforms. Together, all of these ups and downs form the lay of the land, which is known as the topography.

Hills and valleys and other landforms are represented on a topographic map with curved lines called contour lines. Each line represents a certain height above sea level. Sea level is the average level of all the oceans in the world. It is used as a base to measure the height of the land, which varies from place to place.

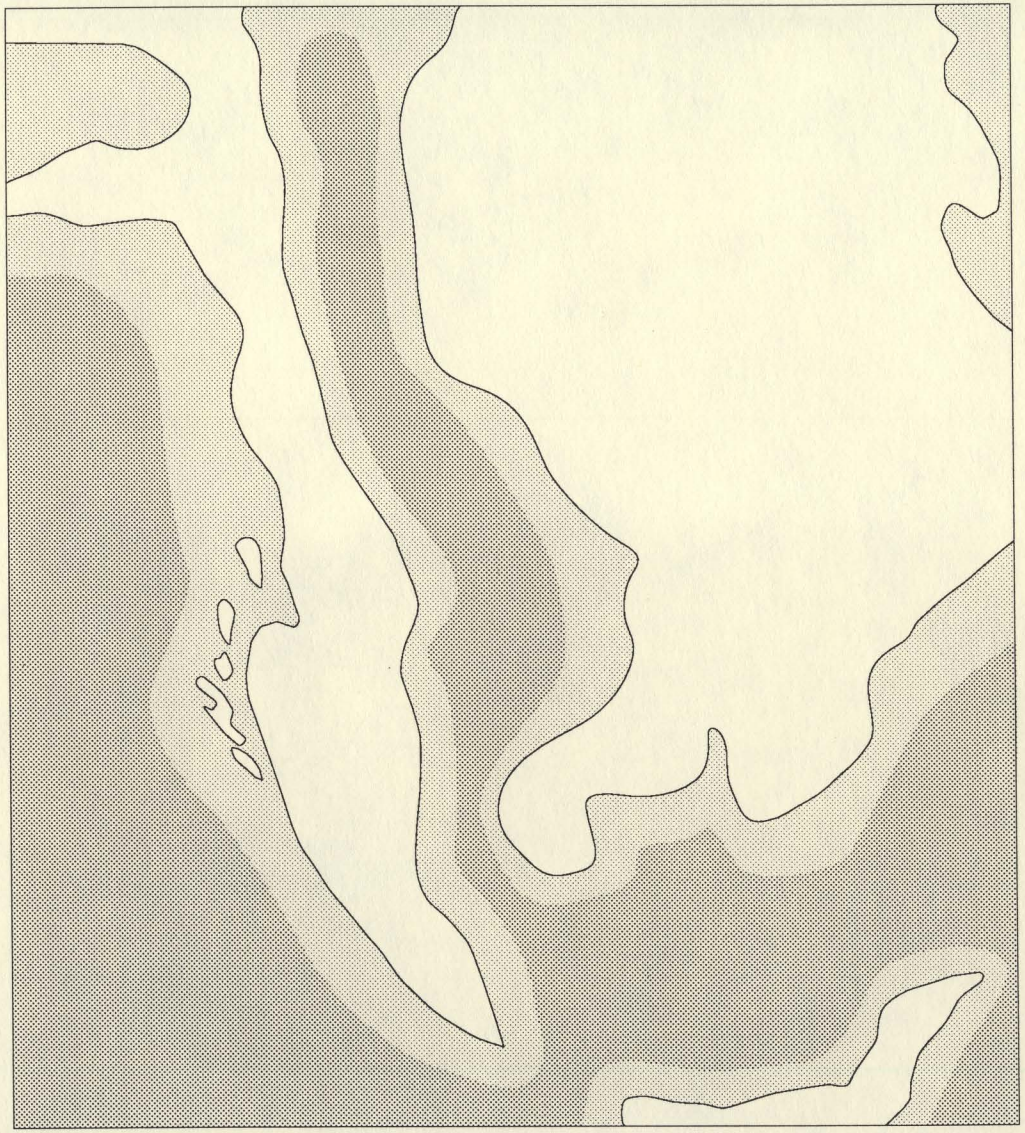


FIGURE 46. THIS IS WHAT NORTH AMERICA LOOKED LIKE AT ONE POINT DURING THE CRETACEOUS PERIOD about 100 million years ago when a sea covered part of Kansas. Can you find Kansas? If not, turn to the next page.

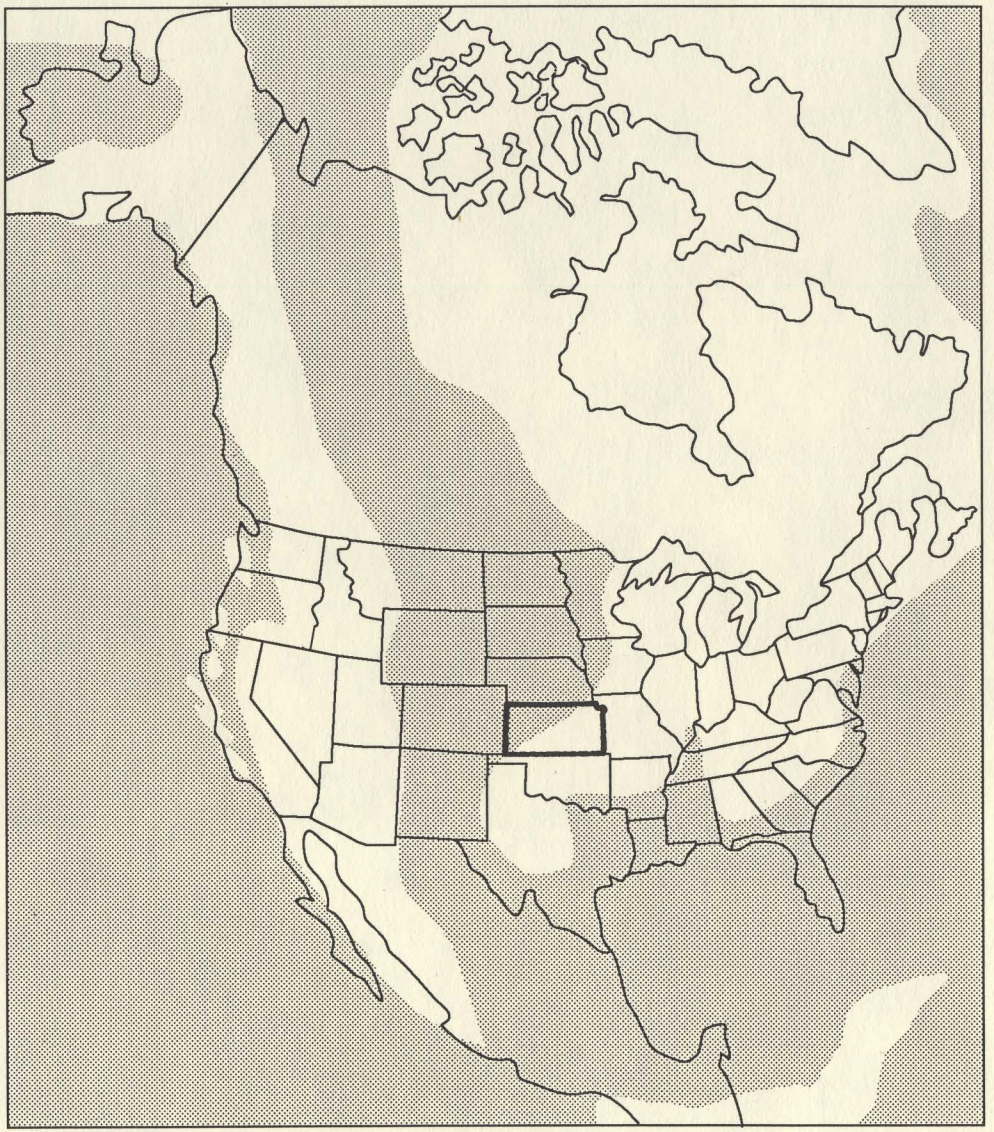


FIGURE 47. THE WHITE AREA SHOWS LAND THAT WAS ABOVE WATER DURING THE CRETACEOUS PERIOD AND THE DARK AREA IS THE SEA (modified from paleographic map of North America as it was in mid–Cretaceous time in Historical Geology by Carol O. Dunbar, 1964, John Wiley & Sons).

The distance above sea level at a particular point is called the elevation. If you were standing on a sea shore, you would be approximately at sea level. The elevation of the top of a hill rising 10 feet from the flat beach would be 10 feet above sea level. Even though some areas of land can be below sea level, all land in Kansas is above sea level ranging from about 700 feet in the southeast to over 4,000 feet in the west.

Many other types of maps besides road maps and topographic maps have been made. Maps can be flat or round, like a globe. Some are sketchy and not very accurate. Others are much more detailed and extremely precise. You can fit small ones into your pocket and barely fit some big ones on your wall.

Maps can guide you around the world or into outer space. But even if you stay in just one state, such as Kansas, maps can lead you to an endless number of places. Next time you ramble through the hills and plains of Kansas in search of mosasaurs, camels, or large woolly mammoths, take a map. You may not know exactly where you're going or what you're going to see along the way, but you'll know where you are once you get there.

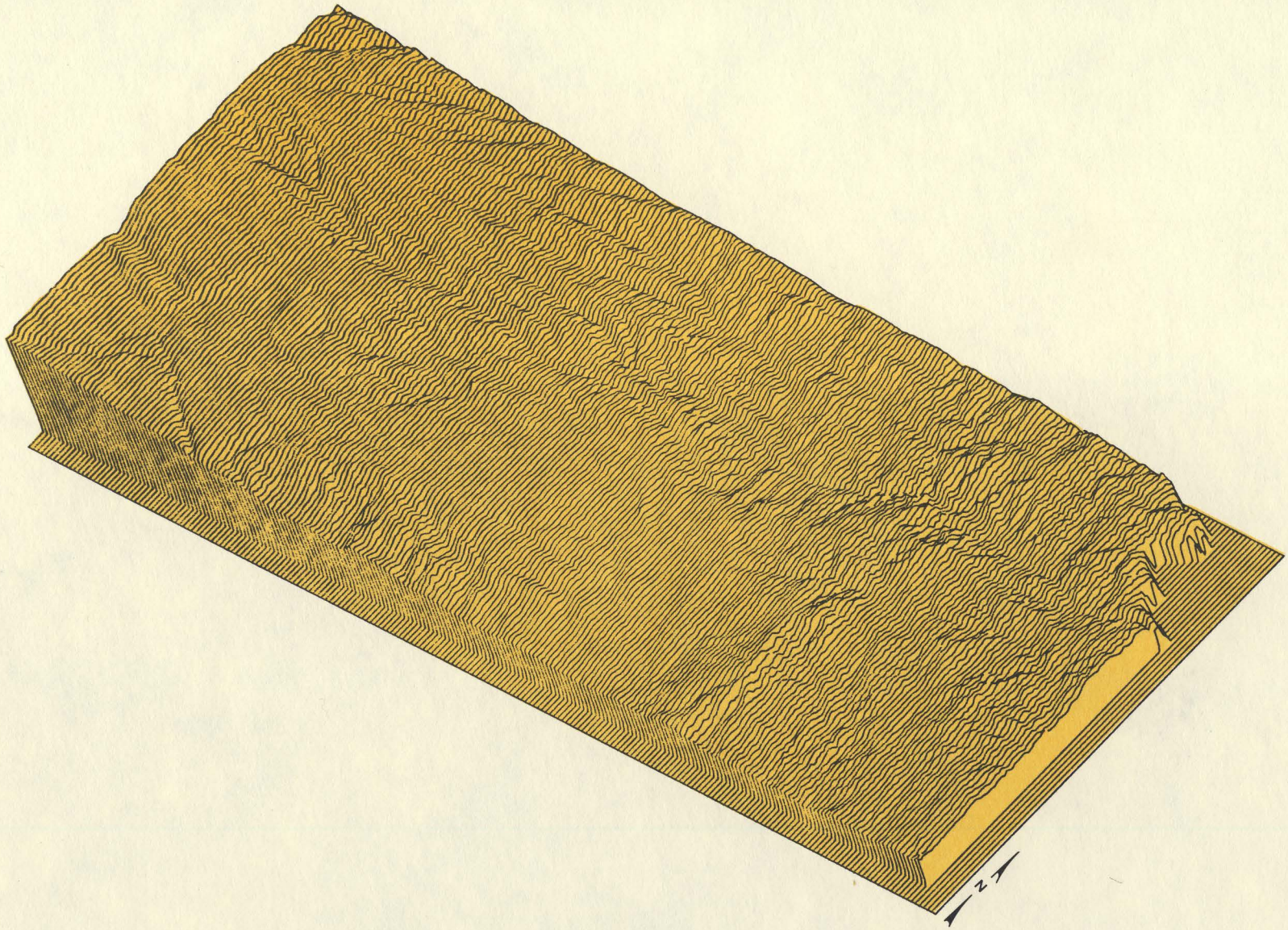


FIGURE 48. ELEVATIONS ACROSS KANSAS WERE PLOTTED ON THIS MAP USING A COMPUTER. The map shows that the eastern border is lower in elevation than the western border. Hills and flat areas throughout the state also are shown.

GLOSSARY

BED–A layer of rock in the Earth. Also the bottom of a body of water such as a river, lake, or sea.

BLUFF–A high and steep bank or cliff.

BUTTE–A steep-sided hill with steep sides that usually stands away from other hills.

CHAT–Small pieces of crushed rock and gravel. May be used for paving roads and roofs.

CUESTA–A hill with a steep slope on one side and a gentle slope on the other. Cuesta is the Spanish word for cliff.

DELTA–A deposit of sand and other sediment, usually triangular in shape. Deltas form at the mouths of rivers where the water flows into the sea.

DEPOSITION–The laying down of sediment such as sand, soil, clay, or gravel by wind or water. It may later be compacted into hard rock and buried by other sediment.

ERA–A unit of geologic time usually lasting hundreds of millions of years. Eras are divided into smaller units of geologic time called periods.

EROSION–The wearing away, breaking down, or dissolving of rock and other material by wind or water. The eroded material is often carried off and deposited in other areas.

ESCARPMENT–A steep slope or cliff.

EVAPORITE–Sediment deposited when sea water evaporates. Gypsum, salt, and anhydrite are evaporites left behind when ancient Kansas seas dried up.

EXTINCT–No longer existing. Many types or species of animals, such as dinosaurs, lived in the past but are found no where in the world today. They are extinct.

FAULT–A fracture or break in underground rock along which one or both sides move. Movement along faults may produce earthquakes.

FOSSIL–The outline, traces, or body part of a plant or animal that has been preserved in rock. Animal tracks preserved in rocks are also fossils.

GEOLOGY–The study of the Earth, what it's made of, and how it changes over time.

GLACIER–A moving mass of ice.

IGNEOUS ROCK–Rock that forms when a hot liquid (magma) cools and hardens.

INORGANIC–Not made of or derived from living matter. Minerals are inorganic.

INTRUSION–An igneous rock formed from magma that pushed its way through other rock layers. Magma often moves through rock fractures, where it cools and hardens.

LAVA–Hot molten rock (magma) that has reached the Earth's surface after flowing out of volcanoes or cracks in the earth.

MAGMA–Hot, liquid rock. Igneous rocks are formed when magma cools.

MARINE–Relating to the sea. Native to or formed by the sea.

MESA–A flat-topped hill with steep sides.

METAMORPHIC ROCK–Rock that has changed from one form to another by heat or pressure.

METEOR–Small bodies of matter, such as rocks, traveling in space. They are heated and often disintegrate after entering the Earth's atmosphere.

METEORITE–Stony or metallic material of a meteor that has survived passage through the Earth's atmosphere and reached the Earth's surface.

ORGANIC–Made from or derived from living matter. Coal is made from plants, which are organic.

OUTCROP–A natural exposure of a rock bed at the Earth's surface.

PALEONTOLOGY–The study of ancient life based on the examination of plant and animal fossils.

PERIOD–A unit of geologic time. Several periods make up an era.

PERMEABLE–Capable of being penetrated by fluid. Permeable rocks have interconnecting pores, or holes, that water can pass through.

PETROGLYPH–An ancient drawing carved on a rock.

POROUS–Having holes or pores that allow passage of gas or liquid. Porous rocks may contain gas, oil, or water.

ROAD CUT–A location where rock or dirt, usually on a hill, is cut away to make room for a road.

SEDIMENT–Rock or other material that has been worn or broken into small pieces. Sediment is often carried from its original location by wind or water and deposited in other areas.

SEDIMENTARY ROCK–Rocks formed from sediment, broken rocks, or organic matter. Many sedimentary rocks are formed when wind or water deposits sediment into the layers, which are pressed together by more layers of sediment, forming underground beds of rocks.

SINKHOLE–A natural dip or hole in the ground formed when underground salt or other rocks are dissolved by water and the ground above collapses into the empty space.

SUBSURFACE–Underground. Below the Earth's surface.

TOPOGRAPHY–Physical features, such as hills, valleys, and plains that shape the surface of the Earth.

UPLIFT–An upheaval. Elevation or raising of part of the Earth's surface through forces within the Earth.

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