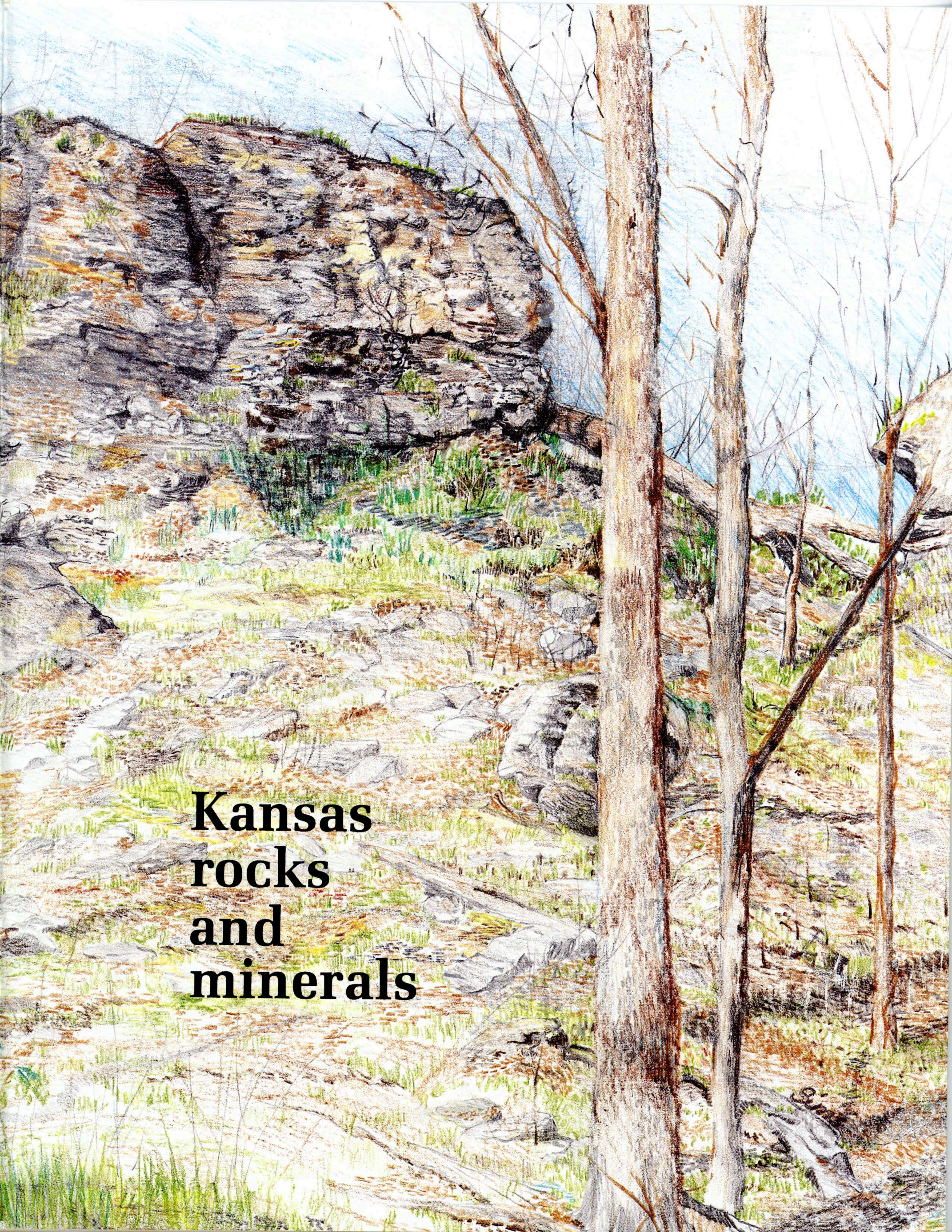

Kansas rocks and minerals

Kansas Geological Survey

Educational Series 2

Kansas rocks and minerals

revised by Rex Buchanan

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Introduction

The rocks of Kansas are the basis of our extensive mineral industries; they supply the parent materials for our soils and they contain our important groundwater supplies. In a very real sense, the economic well-being of the state is linked to the materials that are found below the surface. Not only are we economically dependent on our geology, but many Kansans have an intrinsic interest in the state's rocks and minerals.

The purpose of this booklet is to summarize, as far as possible in nontechnical terms, the various kinds of rocks and minerals found in Kansas and to describe them so that students, amateur collectors, and other interested persons can identify them. Describing in detail the infinite varieties of each of the rocks and minerals is impossible in a booklet of this size. For specific information, Kansas Geological Survey technical reports (of which there are more than 500) should be consulted.

Geologic history of Kansas

Geologists estimate the age of the earth to be at least 4.5 billion years, and in those years many things have happened. Mountains have been raised and eroded down, then raised again. Seas have advanced over the land; layers of sand, mud, and lime carbonate have been deposited on the sea floors, and the waters have retreated, leaving strata of rock thousands of feet thick. Volcanoes have erupted, just as they are doing in many places today, and lava fields have formed. Volcanic dust or ''ash'' has settled on the earth, sometimes in lakes or ponds, burying whatever lay beneath. Great glaciers, formed during long cold periods, have at times covered a large part of North America, but then melted back with the coming of warmer climates.

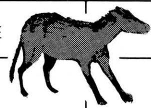
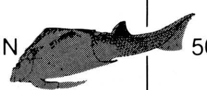
All these events have taken place during the geologic history of the earth. Just as human history is divided into major segments, like the Stone Age and the Bronze Age, the four billion years of earth history have been divided into large units of time called eras, and these in turn have been divided into smaller units called periods. The rocks that were formed in any one period are named after that time and are subdivided into smaller units called formations.

Dividing and subdividing are not enough. Each of the eras and periods—and the rock formations deposited during these parts of geologic time—must be given a name so that one person can recognize any unit referred to by another person. The names of the eras seem long and complicated, but several of them describe the life that existed during the era's time-span. The oldest or first era is the Precambrian, which includes the time from the formation of the earth up to about 600 million years ago. After the Precambrian was the Paleozoic Era (paleozoic means ''early life''), and it lasted from 600 million to about 240 million years ago. The succeeding eras are the Mesozoic (middle life) and Cenozoic (recent life).

Eras have been divided into smaller units of time called periods, which have been named in a different way. Some were named from large geographic features. For example, the name Pennsylvanian was chosen for one period because many rocks of that age are found in Pennsylvania. The word Cretaceous, on the other hand, means chalk-bearing, and rocks of Cretaceous age in many places are made of chalk.

Rock formations are named from some geographical feature—such as a town, a river, a mountain—at

(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

Eons not shown.

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

GEOLOGIC TIMETABLE AND KANSAS ROCK CHART.

or near where the particular rock units are well exposed. Thus, the Wellington Formation, deposited during the Permian Period of the Paleozoic Era, was so named because it is well exposed in the region around Wellington, Kansas.

Some of the eras were much longer than others and, likewise, the periods were not of equal length. The shortest period, the Quaternary, began one to two million years ago, and the two longest lasted about 80 million years each. The geologic timetable lists the eras, periods, and typical rocks of each as found in Kansas and includes the estimated length of each period.

In general, the oldest rocks were deposited first and lie below the younger rocks that were laid down later. Consequently, in geologic timetables it is cus-

Outcrop of Mississippian limestone in Cherokee County.

tomary to put the oldest rocks at the bottom and the youngest rocks at the top.

As is evident from this timetable, Kansas has had a long and varied history. Most of the early history is known only from subsurface data gathered by studying samples collected during well drilling and by the indirect methods of geophysics. For example, Precambrian rocks underlie the entire state but do not appear at the surface. Most Precambrian rocks are igneous (such as granite) and metamorphic in nature and have been covered by younger sedimentary rocks. Geologists often refer to the Precambrian as "basement rock" because it underlies the sedimentary rock of Kansas the way a basement lies beneath a house.

Beginning with rocks from the Mississippian Period of geologic history, however, geologists can study formations that crop out at the surface in the southeasternmost corner of Kansas. Those rocks show that during the early Paleozoic, Kansas was undergoing alternate lowering and raising of the land. When the land was lowered, the sea advanced, but when the land was raised, the sea retreated and erosion set in. These conditions lasted through the Mississippian Period, during which time limestone and occasionally shales were deposited.

During the Pennsylvanian Period, the land was flat and near sea level. Deposits of this period are unusual in that they show a regular alternation of sandstone, shale, limestone, shale, and sandstone. Geologists call this regular sequence of rocks "cyclic sedimentation," and it is evidence that the sea level was slowly fluctuating. Generally, where the water was deepest, limestone was deposited. But as the seas became shallower, shale and then sandstone were laid down, with the sequence beginning again when the oceans deepened.

Fossils are common in these Pennsylvanian deposits and some of the limestones consist almost entirely of the shells of sea animals. Pennsylvanian coal deposits are common. The coal was formed from the remains of plants that lived in brackish swamps. These plant remains were buried by later deposits as the sea came over the region and were converted into coal during compaction. Good exposures of Pennsylvanian rocks showing alternations of shale and limestone exist in many places in eastern Kansas.

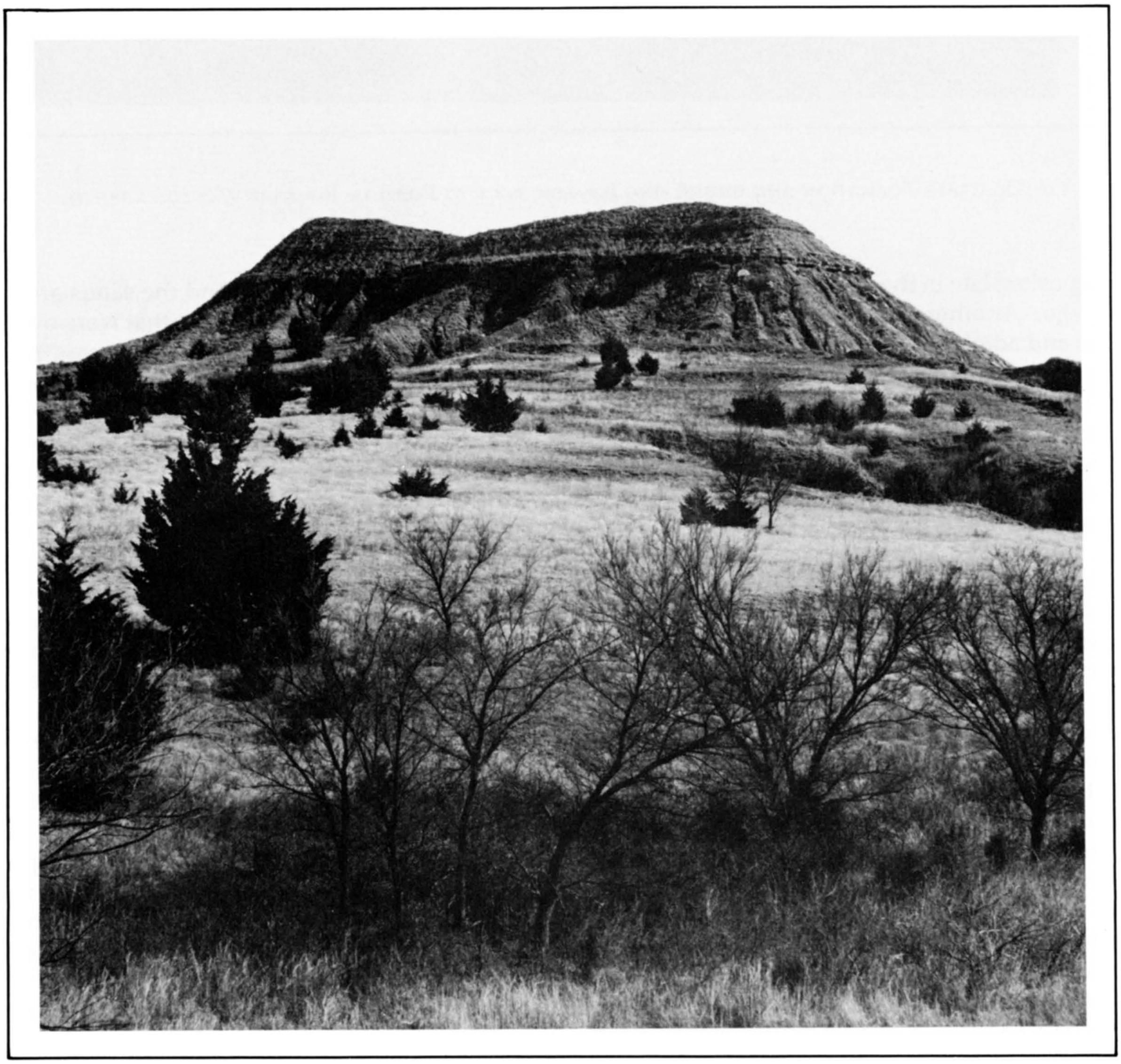
The early part of the next period, the Permian, was much like the Pennsylvanian, although during most of the time the sea covered the region and little coal was formed. During the early Permian, limestone and shale were deposited, including many of the

A COAL MINE IN CRAWFORD COUNTY.

rocks that form the Flint Hills. Sometime during the Permian, however, the seawater began to change in composition. Because seawater contains large quantities of dissolved salts such as calcium carbonate, calcium sulfate, and sodium chloride, a salt residue is left behind when seawater evaporates. Seemingly, the Permian sea in Kansas became partly separated from the main body of the ocean, and the water in this sea left layers of sodium chloride (which we call simply salt) and calcium sulfate (gypsum and anhydrite) many feet thick. A supply of water must have been coming into this inland sea from the ocean in order to provide enough salt to form deposits so thick. At times the sea was drained and sand and silt were deposited over the salt, gypsum, and shale. These Permian deposits include the red beds of south-central Kansas. The sand and silt were washed down from the distant mountains and deposited along the shores of the retreating Permian sea. The red beds have gypsum, salt, and dolomite interbedded with them.

The Permian Period ended about 240 million years ago and was followed by a long interval of non-deposition and erosion in Kansas. Rocks of Jurassic age, about 175 million years old, underlie much of western Kansas and crop out in two locations in Morton County in southwestern Kansas. Rocks of Jurassic age crop out at Point of Rocks in Morton County, a landmark along the Santa Fe Trail.

The next rocks laid down in Kansas were those of Cretaceous age. The sea again came over the region, this time leaving a succession of sands, muds, and chalks, alternating with near-marine stream, swamp, and beach deposits. The well-known chalk of Kansas



Permian shale and gypsum in Barber County.

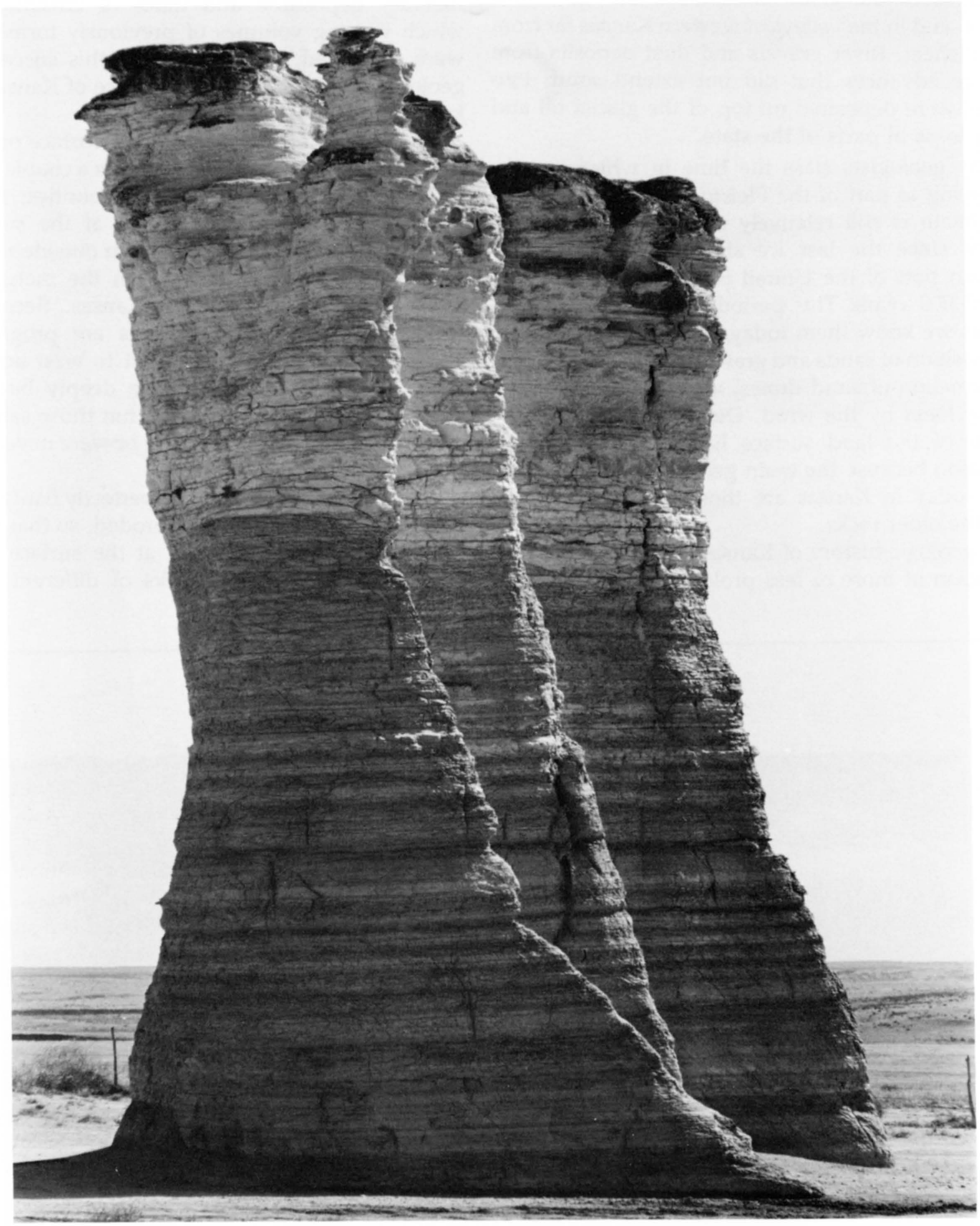
Ogallala Formation and underlying Jurassic rock at Point of Rocks in Morton County.

was deposited late in the Cretaceous, about 60 million years ago. Another famous Cretaceous deposit of Kansas and adjoining states is the Dakota Formation, frequently called a sandstone because the most prominent beds—those that cap the hills and stand out as cliff formers—are sandstones. These sandstone layers are the source of water in many wells in the central and western parts of the state. Approximately 80% of the Dakota Formation, however, consists of clays of many colors. The formation also contains beds of lignite, used by the early pioneers for heating their homes.

Exceptionally good fossil specimens found in the Upper Cretaceous beds have made Kansas rocks world-famous among fossil experts. These fossils include fishes, batlike flying reptiles, swimming lizardlike animals called mosasaurs, and toothed swimming birds. Giant clams and sharks' teeth also are common fossils.

After the close of the Cretaceous, the surface of Kansas was subjected to prolonged erosion. The Rocky Mountains were created by deformation of the earth's crust that occurred at intervals from late in the Cretaceous until well into Tertiary time. After the Cretaceous the next deposits found in Kansas are the late Tertiary sands and gravels of the Ogallala Formation, deposited less than 60 million years ago. The Rocky Mountains then were being worn down by the action of rivers and wind, and the sands and gravels were carried eastward by rivers that were overloaded with sediment and that dropped excess sand and gravel along the river valleys. Gradually the valleys were filled with these sediments and finally the hills themselves were covered, creating a huge, gently sloping flood plain. The remnants of that plain extend from Colorado east through the western one-third of Kansas, and from South Dakota southward into Texas. Today this entire area is known as the High Plains, and the Ogallala Formation is one of the chief sources of ground water in western Kansas. In fact, it has been so heavily used for irrigation that the formation is showing dramatic water-level declines in some areas.

When deposition of sand and gravel in the High Plains stopped, a long period of stability followed. Another interval of erosion followed before the glaciers of the Ice Age or Pleistocene Epoch invaded Kansas in Quaternary time, all within the past two million years. Only the northeastern part of the state was covered by glaciers. Consequently the rocks carried by the glaciers and dropped as the ice melted are found only in that part of the state. On the outskirts of this glaciated area are many river gravels containing pebbles and boulders washed out of the glacier by streams of water from the melting ice. A wind-blown dust called *loess* was deposited around



Cretaceous chalk formation at Monument Rocks in Gove County.

the edges of the glacial area, on the High Plains surface, and in the valleys of western Kansas far from the ice sheet. River gravels and dust deposits from later ice advances that did not extend south into Kansas were deposited on top of the glacial till and earlier loess in parts of the state.

Many geologists class the time in which we are now living as part of the Pleistocene Epoch because the climate is still relatively cold. The time to the present since the last ice sheet melted from the northern part of the United States is probably less than 25,000 years. This period is marked by conditions as we know them today, including the erosion or deposition of sands and gravels along river valleys, the formation of sand dunes, and the deposition of dust or loess by the wind. During this time, more erosion of the land surface has taken place than deposition because the main geologic forces that are active today in Kansas are those that are wearing away the older rocks.

The geologic history of Kansas, then, is largely an alternation of more or less prolonged times of sedimentary deposition and times of erosion, during which varying volumes of previously formed rocks were destroyed. What effect did this succession of geologic events have on the surface of Kansas as we know it today?

First, nearly all the rocks at the surface of Kansas are sedimentary in origin. Except for a couple of small localities in Riley and Woodson counties, the only igneous and metamorphic rocks at the surface of Kansas have been brought in from outside the state. Glaciers, for example, hauled in the metamorphic rocks found in northeastern Kansas. Second, the rocks at the surface of Kansas are progressively younger as you move from east to west across the state. Younger sediments have deeply buried the older rocks in western Kansas, but those same sediments were either eroded away or were never deposited in eastern Kansas.

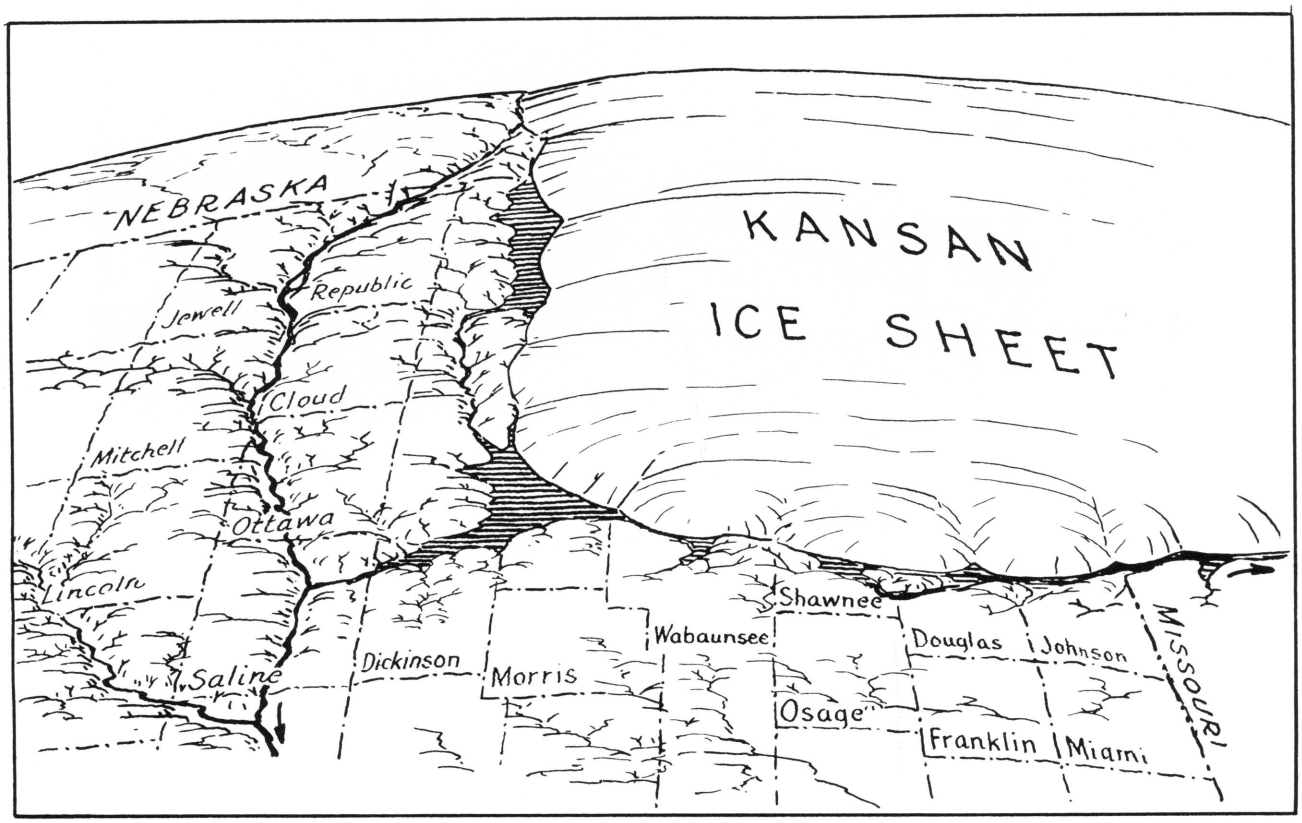
Also, the rock layers are not perfectly flat-lying, but have been tilted slightly and eroded, so that some of the older rocks can be seen at the surface. Gentle deformation has caused rocks of different ages to

Dune sand near the Arkansas River in Hamilton County.

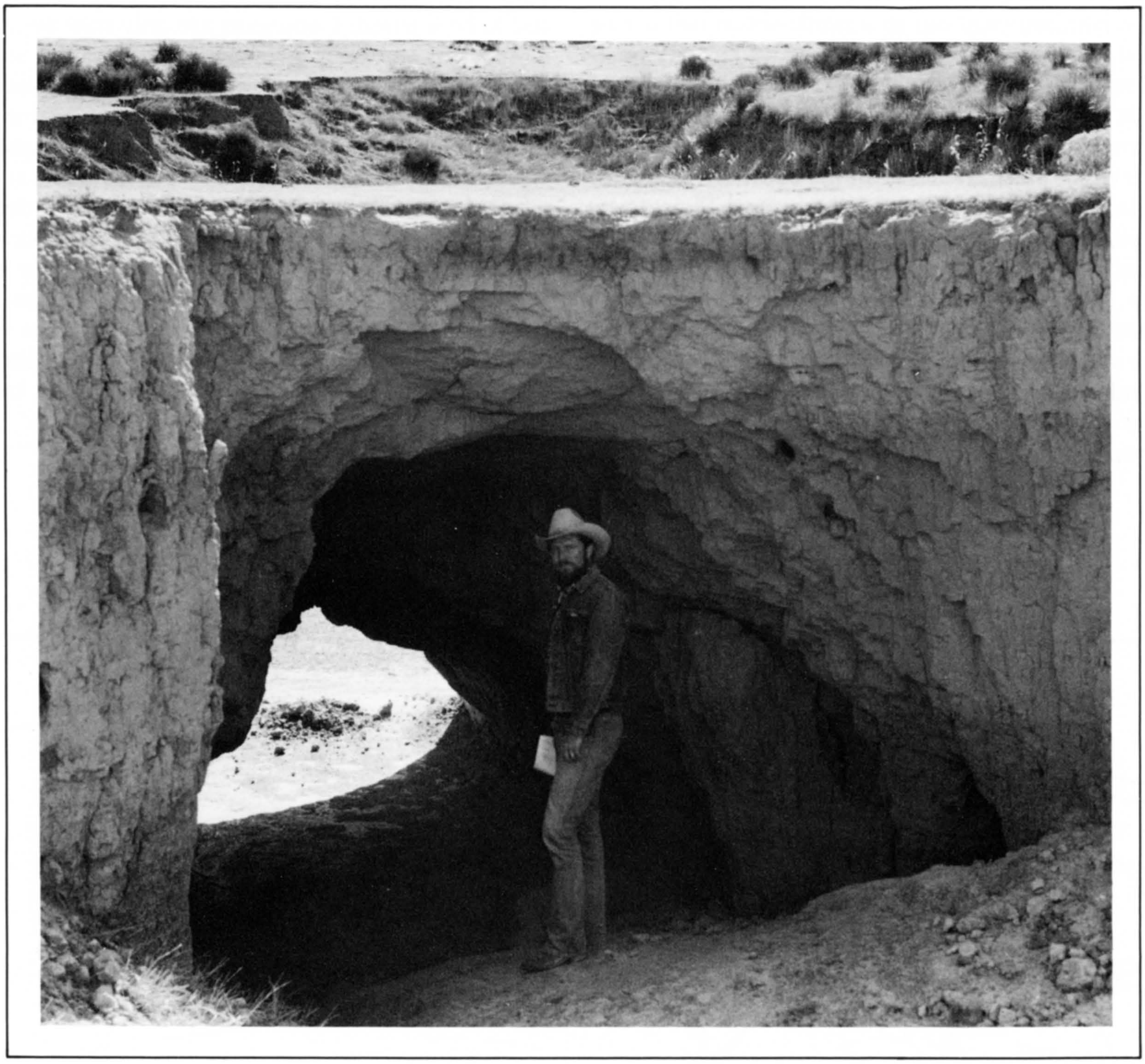
crop out in the various parts of the state. The older rocks, those of Cretaceous age and earlier, have been tilted and the younger rocks have been eroded or worn from above them. Thus the Mississippian and Pennsylvanian rocks occupy the eastern quarter of Kansas. The rocks of Permian age (next younger than Pennsylvanian) crop out in a north-south belt across central Kansas, and the Cretaceous and Tertiary rocks are found farther west. The indentations made by valleys that have been cut into the rocks make the pattern of the outcrops irregular. In the northeastern corner of the state, evidence of the southern border of the glaciers may be seen, although most Pleistocene deposits are not shown on the map because they are so thin and widespread.

The map indicates the age of the rocks at the surface of each county. If you live in the western part of the state, you will be most interested in rocks and minerals described as occurring in the Tertiary and Upper Cretaceous deposits. If you live in eastern Kansas, the rocks of Pennsylvanian age will interest you. If the central part of the state is your home, you can expect to find rocks and minerals of Permian and Cretaceous age.

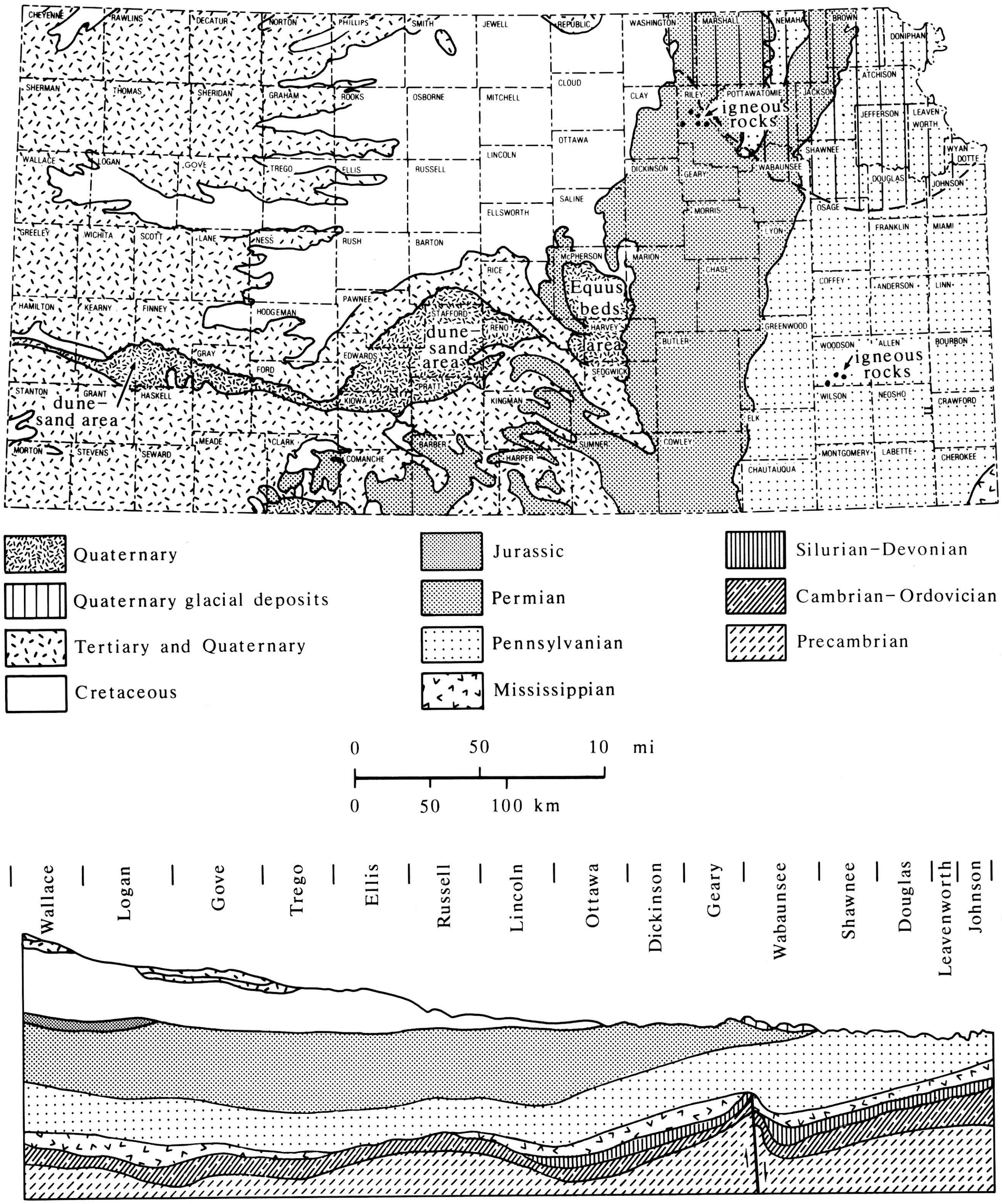
The earth is 4.5 billion years old, but people have lived in Kansas only a few thousand years and have studied its geology for less than 150 years. Much is still to be learned. Geologists are only now beginning to sort out the early geologic history of the state, a time more than a billion years ago when the state was being pulled apart by continental plates and molten rock flowed onto the earth's surface. Geologists are still learning the extent of economic minerals such as oil and gas. They are only now making detailed studies of Kansas earthquakes, and they are occasionally surprised by the discovery of previously unexpected minerals. Yet in spite of the limits of knowledge, geologists know much about the origin of rocks in the state and their economic potential. The following sections provide an introduction to that knowledge of the state's rocks and minerals.



The Kansan Ice Sheet was a glacier that extended into Kansas approximately a million years ago. This map, by former Survey director R. C. Moore, shows the approximate southern limit of the glacier, which carried quartzite boulders and glacial till into northeastern Kansas.



Loess forms a natural bridge in Cheyenne County.



Generalized geologic map and cross section of Kansas.

Kansas rocks

In 1541 the Spanish explorer Coronado made the first European observation about Kansas geology—there was no gold. Since that time rocks and minerals have played an integral part in the state's history. The earliest residents of Kansas, American Indians, used native flint to fashion their arrowheads and spearpoints; they used chunks of native sandstone to grind their grain; they even mined native clay to make their pottery. The first white residents, moving into Kansas 300 years after Coronado, quarried limestones to build their houses and dug coal for heating and cooking. By the turn of the century, Kansans were mining everything from salt to gypsum, lead and zinc, oil and natural gas, and even ground water for irrigation.

In short, Kansas residents have long been interested in their state's geology. That is partly due to geology's economic importance. Rocks are the source for the multibillion dollar mineral industry in Kansas. Other Kansans are interested in rocks and minerals because of their intrinsic beauty, their appearance. The following chapter describes Kansas rocks: where they are found, how they were formed, what they are composed of, and how we use them today. To begin, we must answer a simple question: what is a rock?

A rock is any naturally occurring mass that forms a part of the earth's crust. Such a mass may consist of sediments and particles (sand, gravel, clay, or volcanic ash, for example) as well as solid material (limestone, sandstone, granite, etc.). A rock generally is composed of one or more minerals. Rocks occur in three main types, each of which was formed in a different way. These types are igneous, sedimentary, and metamorphic rocks.

Igneous rocks have been formed by the cooling and hardening of molten rock material. Igneous rocks therefore are those that have been heated to melting temperatures, forming magma, and then have cooled and hardened or solidified, as black cindery rock is formed by the cooling of lava. Some rocks have been formed by slow cooling of molten materials beneath the surface of the earth. This slow cooling allows time for relatively large mineral crystals to form, and the resulting rocks are called "coarsely crystalline." Rocks that have cooled rapidly on or near the surface of the earth do not have large crystals and are said to be "finely crystalline" or "glassy."

Sedimentary rocks are formed by wearing down and dissolving other rocks into small bits or particles of various sizes and by later deposition or laying down of these particles. Such deposits, made of the broken-down substance of preexisting rocks, are called clastic rocks. Two other important varieties of sedimentary rocks exist—chemical sediments (which are nonclastic) and deposits of organic origin. The chemical deposits include gypsum, salt beds, some limestone, some quartz-containing rocks such as cherts, some iron ores, and some carbonate spring deposits such as travertine. The organically formed deposits include many limestones, diatomaceous earth, many iron ores, and coal.

These deposits may be laid down on the sea floor, along stream and river valleys, in lakes or ponds, on the land surface by the action of wind or gravity, and around the edges of and under glaciers. When first deposited, these sediments commonly are loose or unconsolidated, but many of them are hardened into solid rocks by the weight of materials above them or by the cementing action of mineral substances deposited between the grains.

Clastic sedimentary rocks are named according to the size of the particles they contain. Loose sediments in which the grains are very fine may be silt, mud, or clay. Particles slightly larger than clay size are called silt; those larger than silt are called sand; and so it goes from pebbles, to cobbles, to boulders. Of course, the sizes may be mixed, and clays and sands may be found in the same deposit with boulders, but the rock is named for the particle size that is predominant.

Metamorphic rocks are those formed by change in igneous or sedimentary rocks. This change, or metamorphism, is the result of great heat, pressure, or action of some usually hot mineral solution. Through metamorphism, limestones become marble, shales become slate, and sandstones become quartzites.

Of the three main types of rocks, sedimentary rocks are by far the most common in Kansas. In fact, nearly all the surface exposures of the state consist of this type. The exceptions are several small areas of igneous rocks in Riley County and two areas of igneous and metamorphic rocks in Woodson County. Many pebbles and boulders of igneous or metamorphic rocks are found in Kansas, but they are not native to the state. They were formed elsewhere and brought to Kansas by ice or water and now are considered parts of sedimentary deposits.

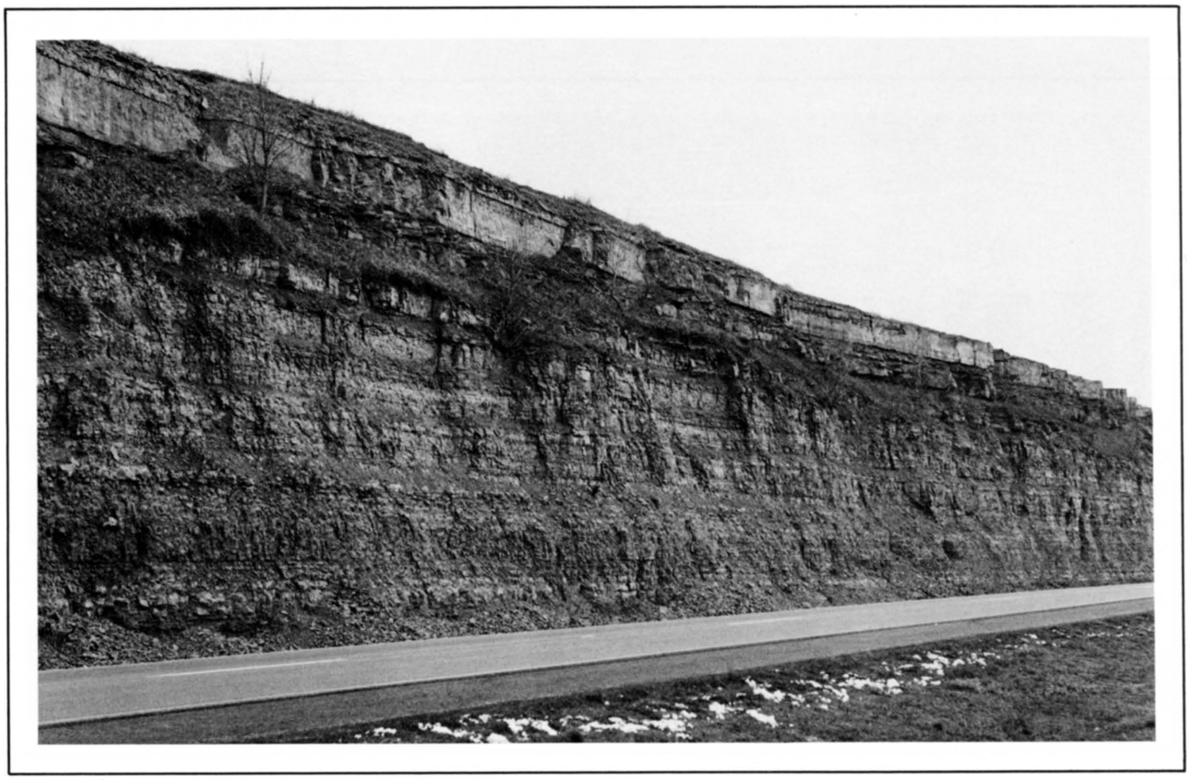
All rocks on or near the surface of the earth are undergoing weathering. This weathering causes changes in the rock and a breakdown into smaller fragments. It may be caused by changes in temperature; by chemical action between the rock minerals and the air, ground water, or plants; or by other factors. The effects of weathering can be seen on the surfaces of rocks that have been exposed to the atmosphere. The weathered surfaces commonly have a color different from that of unweathered or fresh surfaces, and one must be very careful to find the true color of the unaltered rock beneath the weathered outer surface.

Sedimentary rocks

Limestone and dolomite

Limestone and dolomite are two very closely related rocks. The former, in a pure state, consists of grains and crystals of the mineral calcite, and the latter of the mineral dolomite (which is calcite with some magnesium added). Thus the term dolomite is used for both the mineral and the rock.

Calcite consists of calcium carbonate and is one of the most common minerals known. The mineral dolomite is made of calcium magnesium carbonate and also is fairly common. These two minerals are commonly found together in the same deposits, and whether the rock is classed as a limestone, a dolomitic limestone, or a dolomite depends on the proportion of each mineral. The two minerals can be told apart by the way dilute hydrochloric (muriatic) acid reacts on each. Cold dilute hydrochloric acid will bubble and fizz when it is put on limestone. In order to react in the same manner with dolomite, the hydrochloric acid must be heated or the dolomite must be powdered.



Fort Riley Limestone Member and underlying limestone formations in Geary County.

In surface exposures, dolomite is found in southeastern Kansas and in certain rocks of Permian age, which occur in the central part of the state. Limestone, on the other hand, is very widespread. Many of the rocks of eastern Kansas consist of nearly pure limestones. In the central and western parts of the state, limestone is not quite so common, although extensive deposits of chalk, a type of limestone, are found.

Limestone

Pure limestones are white or almost white. Because of impurities such as clay, sand, organic remains, iron oxide, and other materials, many limestones exhibit different colors, especially on weathered surfaces. Limestone may be crystalline, clastic, granular, or dense, depending on the method of formation, and crystals of calcite, quartz, or dolomite may line small cavities or geodes in the rock. Chert balls or nodules and stringers are common in limestone layers, especially in the Florence limestone of Permian age, which crops out in the Flint Hills area from Marshall County southward to Cowley and Chautauqua counties.

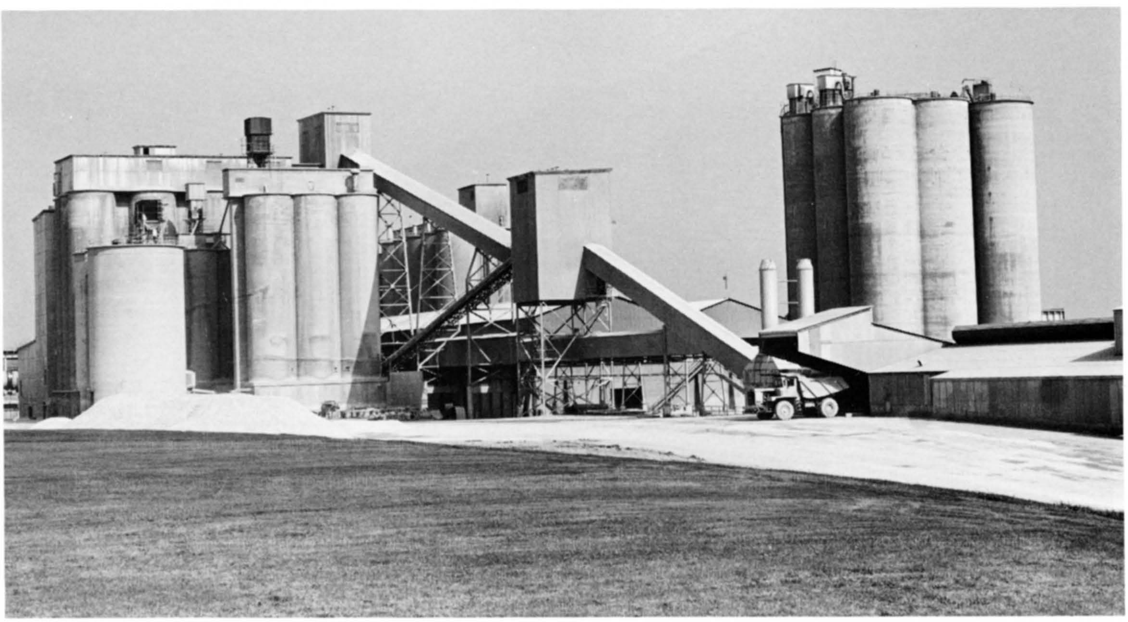
Most limestones are marine deposits, but some are formed in lakes, in rivers, and on land. Kansas has many different varieties of limestones as spring deposits or as caliche beds. These are described separately as to occurrence and origin.

Limestone is used in making Portland cement, and the alternating limestone and shale beds of eastern Kansas are a good source of the two chief ingredients of the cement. Portland cement is manufactured in Allen, Montgomery, Neosho, Wilson, and Wyandotte counties. Limestone also is used in the construction of roads and railroads, as a building stone, as a soil fertilizer, as a source of lime in chemicals, and in many other ways. Chalk, one type of limestone, is an ingredient in paints and polishes.

Limestones consisting mainly of animal shells

The shells of many animals, those that live either in the sea or in freshwater, consist of calcite and the mineral aragonite, which also is composed of calcium carbonate. When the animals die, their shells are left on the ocean floor, lake bottom, or river bed where they may accumulate into thick deposits.

CRINOIDAL LIMESTONES—Crinoids are sea animals having long stems and cuplike bodies that look so much like flowers that they are called sea lilies. The stems break into small, disc-shaped fragments. Some limestones of the Pennsylvanian and Permian rocks of Kansas contain so many of these stem fragments that the term crinoidal limestone describes them well. These are found extensively in eastern Kansas. The Cretaceous Niobrara Chalk in a few localities in



CEMENT PLANT NEAR HUMBOLDT IN ALLEN COUNTY.

western Kansas contains beautiful specimens of stemless crinoids, in which both the bodies and the long arms are excellently preserved.

FUSULINID LIMESTONES—One group of the single-celled animals called Foraminifera is known as the fusulinids. These small animals, whose shells look like grains of wheat, were abundant during the Pennsylvanian and Permian periods, and many of the rocks of those ages are almost solid masses of fusulinid shells. Both limestones and shales contain multitudes of these animal shells.

REEFLIKE LIMESTONES AND SHELL LIMESTONES—Many limestones contain the shells not only of crinoids and fusulinids, but also of corals, brachiopods, clams, oysters, bryozoans, and other forms. Some of the animals lived in colonies, and the remains formed lens-shaped or elongate deposits, which sometimes grew to several hundred feet in thickness and hundreds of miles in length. However, those in Kansas were much smaller. Reeflike bodies in eastern and southeastern Kansas were formed by limy mud trapped by leaflike blades of marine algae. (One limestone formation in Labette County has a reeflike structure at least 12 miles long and 13 feet thick.) Small colonies or groups of fossil shells in some formations measure only a foot in diameter.

Limestones formed partly by chemical processes

Calcium carbonate is more soluble in water that contains carbon dioxide than in pure water, and when the carbon dioxide is removed for any reason, the calcium carbonate falls out of solution and settles to the bottom. Plants remove carbon dioxide from the water by using it in their food. When the water is heated, evaporated, or merely stirred, the carbon-dioxide content is decreased and limestone is deposited.

ALGAL LIMESTONE—Algae are primitive plants; most seaweeds and pond scums are algae. They may live in seawater or freshwater. Like all plants, they use carbon dioxide to manufacture food and when the carbon dioxide comes from water containing calcium carbonate, the calcium carbonate may be precipitated. The limestone that results commonly takes on the form of algae or groups of algae and may form irregularly shaped, banded structures. Approximately half the limestones of the Pennsylvanian and Permian rocks of eastern Kansas are at least partly formed by algae. Particularly good exposures can be seen in Johnson and Brown counties and in the Flint Hills.

OOLITIC LIMESTONES—Oolites are small rounded particles or grains, so named because they look like fish eggs. Oolites commonly are formed by layers of material, usually calcite, that have been deposited around some tiny particle such as a sand grain or fossil fragment and then formed by rolling back and forth in quiet waters. When the grains formed by this method are more than two millimeters in diameter (about the size of the head of a pin), they are called pisolites.

Many limestones in Kansas, particularly limestones of Pennsylvanian age, contain oolites. They are especially noticeable in Johnson, Miami, Linn, Bourbon, and Labette counties, and near the towns of Independence and Cherryvale in Montgomery County. Rocks of Permian and younger age in Kansas do not contain many oolites; hence, most outcrops of oolitic limestone are found in the eastern third of the state. Some of the oolites may be of algal origin.

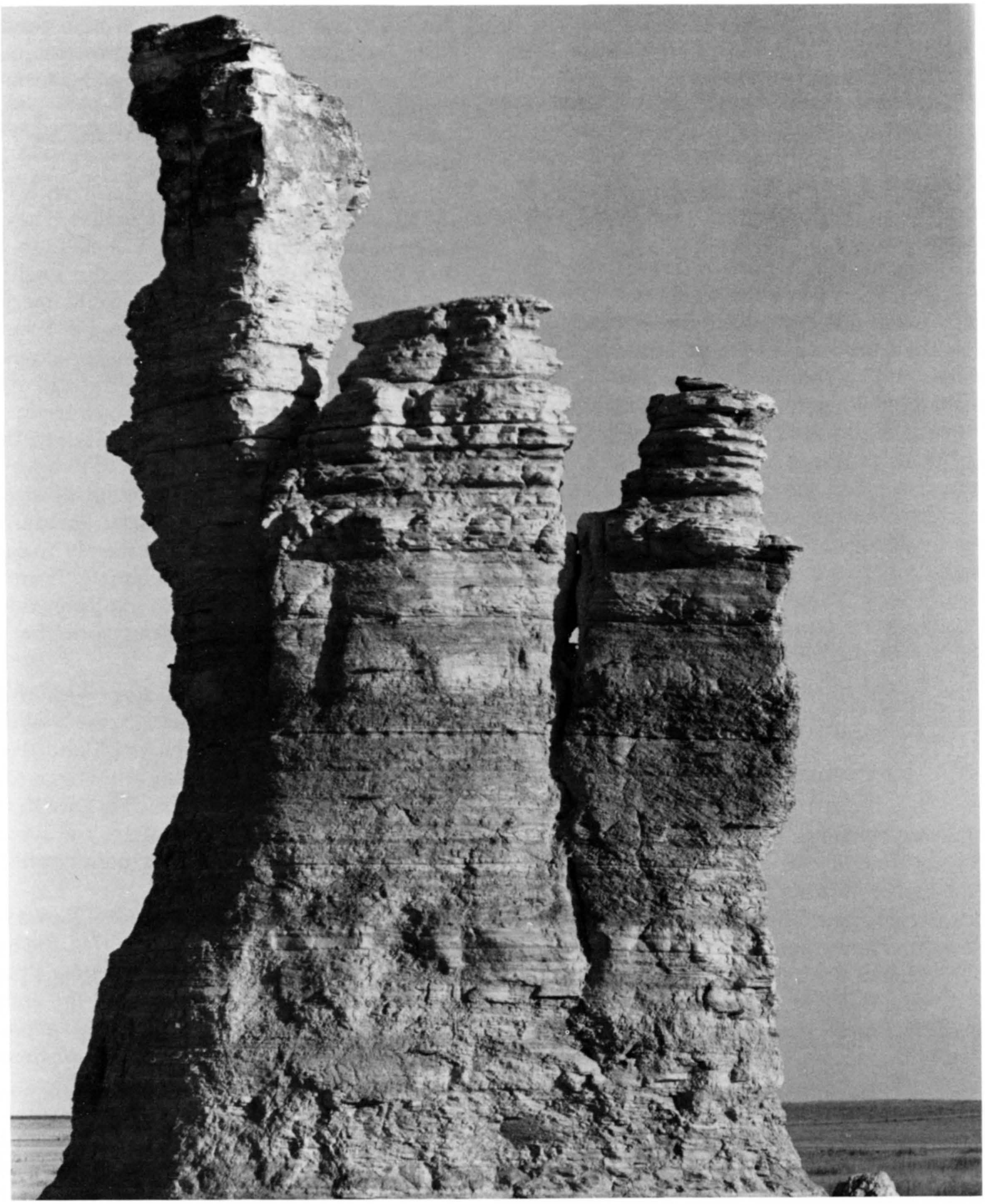
CHALK—Chalk is a variety of limestone that probably was formed in either or both of two ways. Part of the limestone is the accumulation of shells of the small, single-celled animals called Foraminifera. The rest of the limestone resulted mainly from chemical precipitation of calcium carbonate. Pure chalk is white, but it may be stained with iron oxide or other impurities. It is a soft, porous rock that crumbles easily.

In the Upper Cretaceous rocks of western Kansas, a chalk and chalky shale formation, the Niobrara, crops out in an irregular belt from Smith and Jewell counties on the northeast to Finney and Logan counties on the southwest. In color the rock is gray to cream but weathers white, yellow, or orange. The average thickness of the entire formation including pure chalk and chalky shale is about 600 feet.

Chalk is abundant in west-central Kansas and is as representative of Kansas geology as the sunflower and the cottonwood tree are of the state's plant life or the meadowlark and buffalo are of the animal kingdom. Furthermore, chalk has been a part of the Kansas region not for centuries but for thousands of centuries.

Kansas chalk beds are known the world over for the reptilian and other vertebrate fossils found in them, and they are equally famous for the pinnacles, spires, and odd-shaped masses formed by chalk remnants in many localities. Particularly notable are Monument Rocks and Castle Rock in Gove County and the chalk bluffs along the Smoky Hill River in Logan, Gove, and Trego counties.

DIATOMACEOUS MARL—This rock is important not because of the calcium carbonate it contains, but because of the diatoms: tiny, single-celled creatures that have characteristics of both plants and animals and have outer shells of silica. When diatoms die, their shells settle to the bottom of the lake or sea and accumulate. In the Ogallala Formation of Wallace and



CASTLE ROCK IN GOVE COUNTY.

Logan counties are deposits of white marl containing many shells of these small diatoms. The deposits can be seen plainly from a distance where they crop out along the south side of a valley for about four miles. Outcrops of diatomaceous marl also are found in Meade and Seward counties and elsewhere in western Kansas. The marl can be mined and used for filtering water or other solutions and as a filler in paints and other products.

TRAVERTINE—Travertine is formed along streams, particularly where there are waterfalls, and around hot or cold springs. Calcium carbonate is deposited

WACONDA SPRING, NOW COVERED BY WACONDA LAKE, IN MITCHELL COUNTY.

because evaporation of the water leaves a solution that is supersaturated with chemical constituents of calcite. Travertine is a banded and more or less compact variety of limestone. A good deposit of travertine in Kansas was once found around Waconda Spring in Mitchell County, where the minerals in the spring water gradually built a hill of travertine 42 feet high and 300 feet in diameter. The travertine of Waconda Spring, now covered by the waters of Glen Elder Reservoir, was formed chiefly of the mineral aragonite, an unusual form of calcium carbonate.

Tufa, a porous or cellular variety of travertine is found near waterfalls. Such deposits have been reported in Riley, Wabaunsee, Geary, Meade, and Butler counties, and they occur in many more places.

CALICHE—Caliche is a type of calcite-cemented sandstone that forms in the soils of dry regions. It is generally impure (clayey, silty, sandy) and fairly soft, although very old caliche may be extremely hard. Some caliche consists only of small nodules, such as the Loess Kindchen in wind-blown silt, but also occurs as a continuous bed that can be traced for many miles. The pisolitic limestone near the surface of the High Plains in western Kansas is such a bed. This dense limestone (formerly called "algal") has a distinctive structure and can be recognized by its pinkish color, banded appearance, and concentric areas. It was formed after the close of Tertiary time when the climate was drier than it is now.

Dolomite

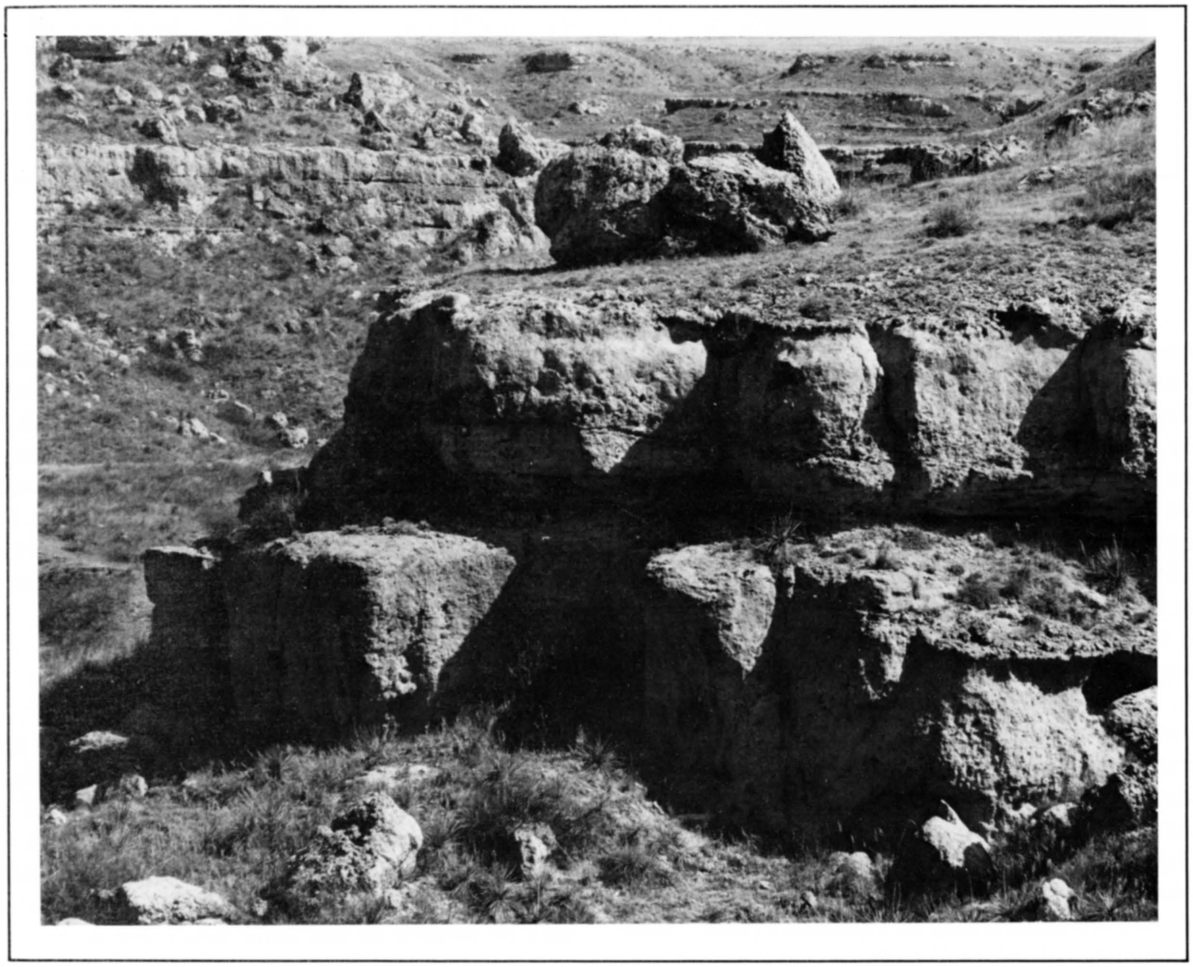
Dolomites are fine- to coarse-grained rocks that, in the unweathered state, are generally gray to light colored. On weathering they may become buff or tan because of impurities that commonly consist of iron within or between the dolomite crystals or of small amounts of pyrite, siderite, or marcasite. Dolomites may be formed by the same processes as limestones such as chemical precipitation, or occasionally by breakdown and redeposition of older dolomites. They also are converted from limestone by a process appropriately called dolomitization. This involves the replacement of calcium by magnesium. The change may take place before or after the rock has been solidified and is caused by the action of seawater, ground water, or hot mineral water.

Among the surface rocks of Kansas, dolomite is found chiefly in three formations in the central and southern part of the state. One formation (the Stone Corral dolomite) has a maximum thickness of about six feet in Rice County. Another formation (Day Creek Dolomite), found in Clark County, is about two and a half feet thick. These formations were deposited in the enclosed evaporating basin of the Permian sea, as evidenced by the presence of much anhydrite, an evaporite deposit in the subsurface rocks. A thick dolomite also is found in the southern Flint Hills. Dolomite is used in ways similar to that of limestone.

Clay

Clay is one of the most common earth substances in Kansas. It is a very fine grained material that can be molded into shapes and can be heated or baked into hard, resistant forms that have many uses.

The particles in a clay deposit are so small (less than 1/256 mm in diameter) that they cannot be seen without a microscope. Formed by weathering and breaking down of solid rocks, these particles may then be carried to some quiet body of water, such as a lake or pond or the sea, where they settle to the bottom. Clay particles are made of several types of minerals, most of which are small, platy flakes. The deposits formed may have almost any color—white, gray, black, red, yellow, buff, or green. Many clay deposits contain impurities such as sand, calcium carbonate (the chemical compound that forms limestones), and iron minerals.



Mortar beds in the Ogallala Formation at Scott County State Lake.

Clays and shales are used in making bricks, tiles, pottery, chemical ware, furnace linings, and lightweight concrete aggregates. In Kansas, the best deposits of refractory clays—those that can withstand firing at high temperatures—are in rocks of Cretaceous age in Washington, Clay, Cloud, Lincoln, Ottawa, Ellsworth, and other central Kansas counties. Thousands of tons of these Cretaceous clays are used each year in the manufacture of light-colored face bricks, and smaller amounts are used in making pottery.

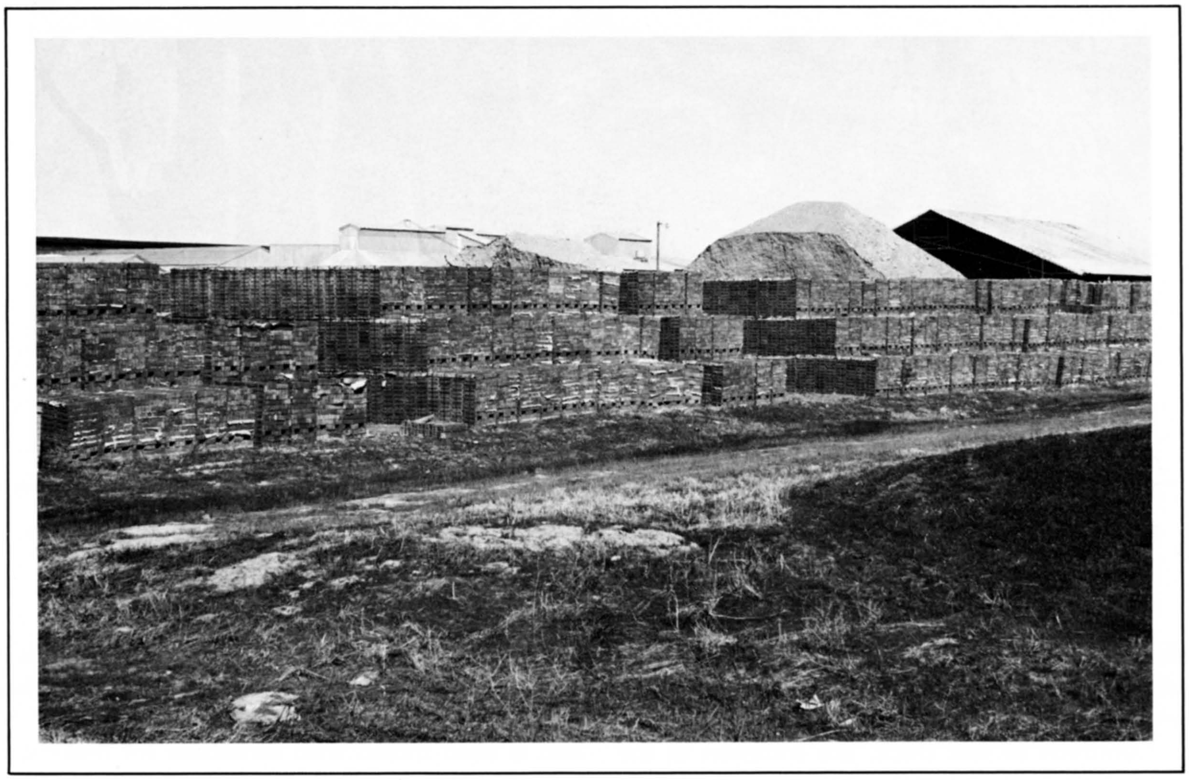
Bentonite is a clay formed by chemical alteration of volcanic ash. When water is added to it, bentonite may swell to as much as 15 times its original bulk and form a milky cloud in the water. Most Kansas bentonites swell, when wet, to less than three times their original volume. Some bentonites can be identified by their waxy or soapy appearance. Many deposits are known in western Kansas, the thickest in Phillips County. Very thin layers can be seen at McAllaster Buttes in Logan County, and a thin layer occurs in places above the volcanic ash in the Calvert ash mine in Norton County. Other thin deposits are interbedded with the chalks and chalky shales in western Kansas, and a particularly pure bed is located in Clark County.

Underclay is a clay that occurs under a coal bed or under a coal horizon. This clay, generally characterized by lack of bedding, commonly contains fossilized roots of plants and other carbonaceous material. Underclay is present under many of the coal beds in southeastern Kansas; in Cherokee County it is utilized in the manufacture of buff brick. Some of the underclays are suitable for firing at high temperatures.

Shale

A hardened, compacted clay or silty clay that commonly (but not in every case) breaks along bedding planes is called shale. The particles that make up a shale are too small to be seen without a microscope. Many shales have a leaflike bedding and weather into thin slabs or plates, some of which are no thicker than paper. When shales weather, they form clays or muds.

Shales and clays are easily eroded, or worn away. Consequently the best exposures are found beneath ledges of harder, more resistant rocks, such as limestones and sandstones. Most shales are soft enough to be cut with a knife and are either brittle or crumbly. They are usually gray, but black, green, red, or buff shales are common. Many contain nodules of pyrite, selenite (gypsum) crystals, or concretions of various forms, which are described in other sections of this booklet.



Brick plant near Kanopolis in Ellsworth County.

DARK-BLACK SHALE IN THE FORT SCOTT FORMATION IN CRAWFORD COUNTY; ROUND FEATURES ARE MARBLE-SIZED NODULES OF PHOSPHATE.

Shale and clay together make up about 80% of the sedimentary rocks of the earth's crust. In Kansas they are very common. Dark-gray to black Cretaceous shales, hundreds of feet thick, are common in the west-central part of the state. Much of the shale found in Pennsylvanian rocks is interbedded with layers of limestone. Shale in eastern Kansas has been used for many years in making bricks. When heated its color changes to well-known "brick-red." Shale also is used mixed with limestone for making Portland cement.

Loess canyon in Cheyenne County.

In certain eastern counties, particularly Labette and Neosho, are several black, platy shales that contain large amounts of organic matter. Some are so rich in this material that thin slivers may be set on fire with a match; they are a form of oil shale.

Some black, very thin bedded shales often are called slate because they have the same color as many slates and because they break into thin, hard, platy sheets. Slate, however, is a metamorphic rock, formed when shale is put under great heat and pressure, and no true slate occurs naturally in Kansas.

Silt and siltstone

Silt is a common sedimentary rock composed of tiny particles smaller than sand size yet larger than clay size (1/16–1/256 mm). It is found in stream deposits and lake beds, but it occurs chiefly as a wind-blown deposit, called loess, which mantles the High Plains of western Kansas and in thick deposits along the bluffs of the Missouri River in northeast Kansas. It occurs to some extent in many other counties in the state. The loess is typically a yellowish-buff porous silt that crops out with steep faces along hillsides and valley walls. Much loess contains white or cream-colored concretions an inch or two in diameter, which are composed of calcium carbonate and have been called *Loess Kindchen* (little children of the loess). Small, white shells of snails also may be found in the loess.

Some of the finest and thickest soils in the world are formed in the upper part of thick deposits of loess. As wind moves small particles only, a soil developed in a deposit of this kind is free from boulders and pebbles. Loess deposits have been built up by successive dust storms. More than 90% of the soil in Thomas, Sherman, Cheyenne, Greeley, Hamilton, Wichita, Scott, Lane, and other western counties consists of the upper part of these loess deposits. In Ford, Grant, Gray, Haskell, Kiowa, Meade, and Stevens counties in southwestern Kansas, loess deposits also are widespread. In short, those dust storms past and present, which we consider as damaging to the state, have helped to give us one of our most valuable resources—a rich, fertile soil.

In northeastern Kansas a very rich soil has developed on the loess, especially in Brown and Doniphan counties and along the bluffs of the Missouri River as far south as Kansas City. This loess is present on the hilltops and slopes and in the valleys. It is thickest in a strip about two miles wide bordering the Missouri River and in Doniphan County in the area of the big bend of the Missouri River. On the river bluffs the loess is 60–100 feet thick. Farther from the river it may be no more than five feet thick. This loess of northeastern Kansas is the fine material ground by the advancing ice sheet and deposited on the flood plains by streams coming from the melting glaciers. The material was later worked over by winds. It is thought that most of the loess in northeastern Kansas was laid down more than 50,000 years ago.

Consolidated or compacted silt is known as siltstone. This rock may be found as thin, slabby beds in many of the Pennsylvanian formations of eastern Kansas. Many siltstones and fine sandstones contain layers rich in tiny flakes of mica which glitter in the sun. The mica is concentrated along the bedding planes where the rocks break easily.

Sands and sandstone

Sands are loose, unconsolidated rocks having particle sizes between those of silt and pebbles (1/16–2 mm). When held together by chemical cement or by clay, they are called sandstones. These rocks result from the breaking down or weathering of older rocks and from the transportation and sorting of rock fragments by moving water or by wind.

Sand is found abundantly in Kansas. Most of it consists of grains of quartz, but some of it contains a large amount of feldspar. Sand also contains traces of rare igneous and metamorphic minerals formed outside the state and carried in, along with the other grains, by running water. Sand occurs almost every-

Outcrop of sandstone in the Dakota Formation, Ellsworth County.

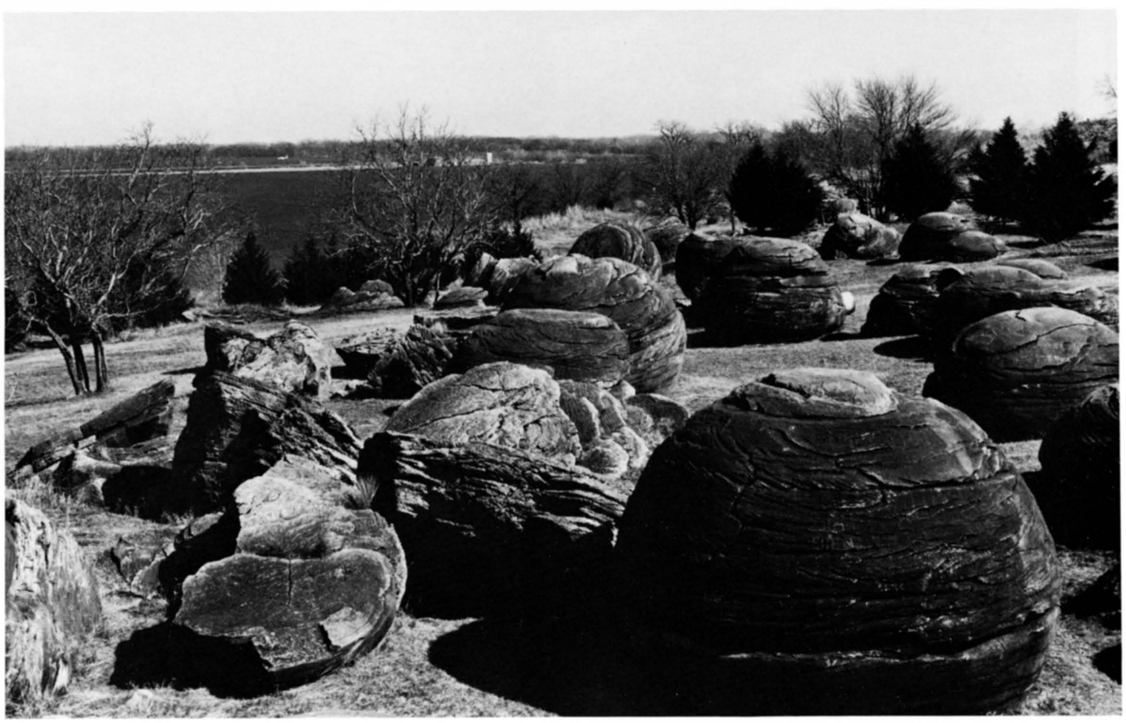
where along the large stream valleys in the state; in regions of old glacial drainage or outwash, particularly near Atchison in Atchison County; or in great deposits of wind-blown sand in dunes along the Arkansas River in Hamilton, Kearny, Finney, Gray, Ford, Kiowa, Edwards, Pratt, Pawnee, Stafford, Barton, Clark, and Reno counties. Also loose sand is found in parts of the Tertiary Ogallala Formation along old river deposits in western Kansas.

Sandstones, like sand, consist largely of quartz grains, but sandstones are held together by some natural cement or matrix such as calcium carbonate, iron oxide, silica cement, or clay, and the rocks can be classified according to the type of cement.

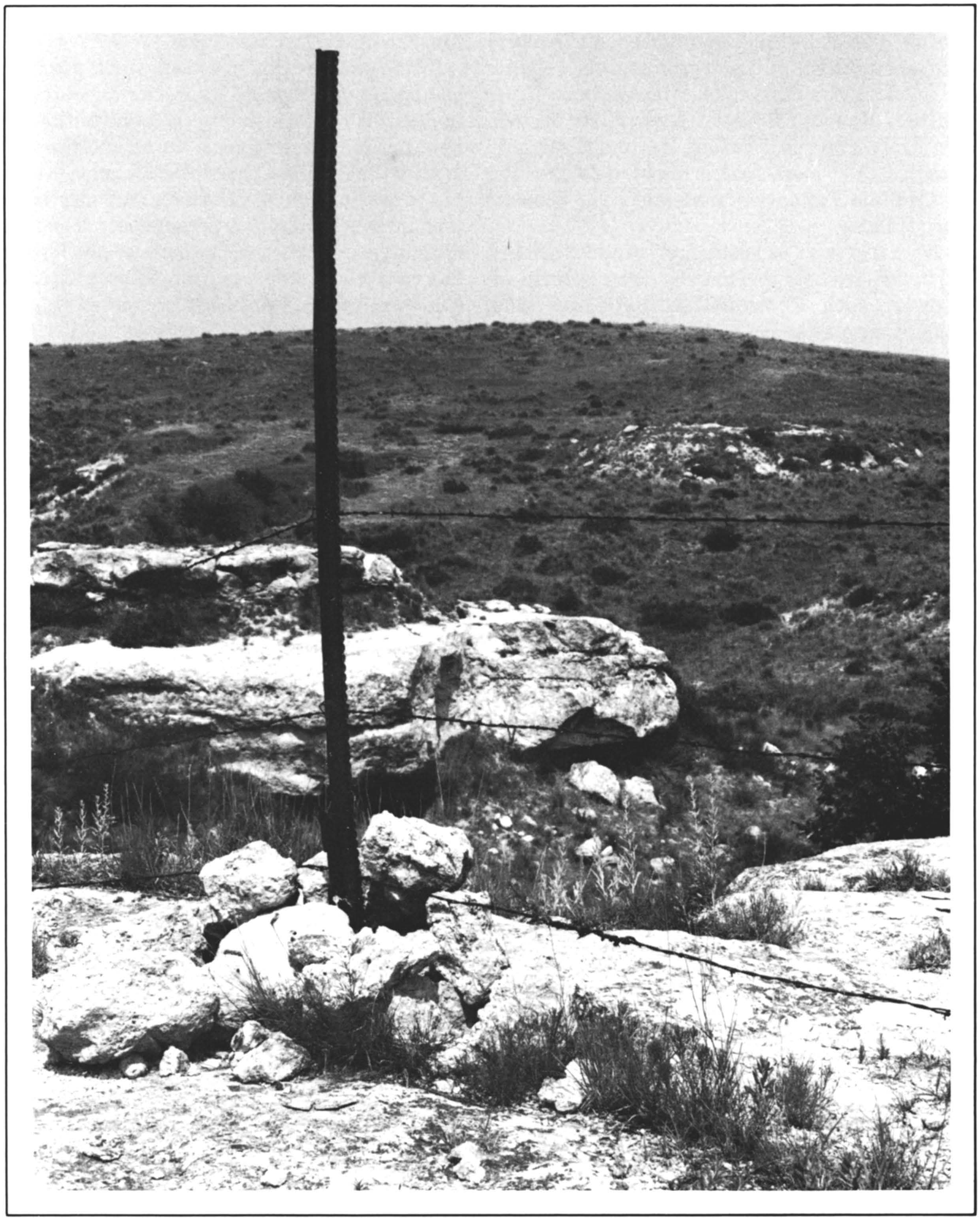
Sandstone occurs interbedded with shale and limestone in the eastern part of the state. In Pottawatomie, Wabaunsee, Nemaha, Brown, Jackson, Riley, Shawnee, Lyon, Greenwood, Cowley, and Chautauqua counties, it occurs as channel deposits cutting through shale and limestone. Most of this sandstone is buff or brownish in color, and some is cemented by iron oxide. Sandstone of the Dakota Formation is present in the Smoky Hill region in north-central Kansas in a wide belt extending from Rice and McPherson counties to Washington County. Much of it is cemented by dark-brown iron oxide and is so resistant to erosion that it caps steep hills. This Dakota sandstone also forms the giant concretions at Rock City near Minneapolis and at Mushroom Rocks State Park.

In the same region are some small areas where the sandstone is cemented by calcite (calcium carbonate) in crystals so large that wide areas of the rock reflect light in a manner known as "luster-mottling." This rock is sometimes called "quartzite" because it is very hard, but it is not a true quartzite. True quartzites are cemented by a form of quartz commonly called silica. Soft, crumbly sandstones of Cretaceous age form cliffs and box canyons in small areas in Kiowa, Comanche, and Clark counties. Iron-oxide cement in this sandstone (the Cheyenne) produces a wide range of colors, including yellow, various bright reds, purple, and brown. Bright-red, fine-grained sandstones of Permian age crop out in picturesque canyons in south-central Kansas.

At the surface, the most common rock in the Ogallala Formation of Tertiary age in western Kansas is sandstone cemented by very fine grained calcium carbonate. This rock is porous and the particles are poorly sorted. It looks much like concrete and is popularly known as mortar beds. Good outcrops of the mortar beds occur at Scott County State Lake and cap Point of Rocks in Morton County. Hard, dense, gray-green sandstone also is found in some parts of the Ogallala, especially in southern Phillips County, but also in Graham, Hodgeman, Ness, Norton, Rawlins, Rooks,



Sandstone concretions at Rock City, Ottawa County.



OGALLALA FORMATION IN RAWLINS COUNTY.

and Smith counties. This rock has an opal cement and therefore is called opaline sandstone or orthoquartzite. It is occasionally used as a building material, and good examples are present in a Hill City park.

Sands and sandstones are used in making glass, as building materials (mainly in concrete), as filters, and for making molds in foundries. The supply along the larger rivers is abundant, although some of the deposits are impure.

Glacial erratic near Vermillion in Marshall County.

Gravel and conglomerate

The term "gravel" in lay terms usually means a rock composed of particles ranging from sand to pebble size or larger (2–64 mm). *Gravel* deposits vary greatly in mineral composition, size, shape, and color. Glacial-outwash gravels occur in northeastern Kansas. Stream gravels underlie the High Plains in the western part of the state. In the Flint Hills section and in southeastern Kansas are gravels that consist mainly of just one mineral, chert or flint, which weathered from Paleozoic limestones. These brown, hard, resistant gravels commonly cap the uplands in Anderson, Cowley, Elk, Greenwood, Lyon, Morris, Wabaunsee, Geary, Riley, Pottawatomie, and Marshall counties.

The gravels from the continental glaciers, and those gravels in the western part of the state that came from the Rocky Mountains, are excellent sources of many rocks and minerals that are not found in place in the sedimentary rocks cropping out in Kansas. Among these are feldspar, agate, clear transparent quartz, native copper, granite, basalt (a dark, fine-grained igneous rock), and other igneous rocks.

Conglomerate is a hardened, generally cemented gravel and, like sand, silt, and clay, has been formed by the breaking down of older rocks and by later redeposition. Commonly it is found interbedded with layers of sandstone. It also occurs at the base of many Pennsylvanian formations, as for example near the town of Baldwin in Douglas County. Local small areas of hard conglomerate are found in many gravel pits in Tertiary and Pleistocene deposits. Conglomerate and gravel are used in making concrete, in surfacing roads, and as railroad ballast.

Boulder clay

Boulder clay is an extremely varied deposit consisting, as the name suggests, of particles of all sizes from large boulders to clay. It is a typical product of glacial action and is often called glacial till. Therefore, boulder clay is found only in the northeastern section of Kansas, the only part of the state that has been glaciated. Boulder clay forms low, rounded, rolling hills covered with loess, soil, and vegetation. Consequently very few good outcrops occur. The boulders and pebbles which have been carried by ice from both local and distant rocks are of many different types.

They include limestone, sandstone, quartzite, granite, basalt, and many others. The quartzite boulders are hard, red rocks and their nearest source is southeastern South Dakota, more than 400 miles away. Most of these rocks have been deeply weathered since they were left by the melting of the ice sheet. Often they have been weathered so much that a "hard" granite can be crumbled with bare hands. Some of the quartzite, however, is so hard and well preserved that it cannot be broken with a hammer. Upon close examination, some pebbles and boulders are seen to have been scratched and polished from rubbing against other rocks in the ice.

Glacial till conceals the bedrock over much of the glaciated region. This is one of the reasons that northeastern Kansas was overlooked so long in prospecting for oil and gas. However, the thick deposits of boulder clay have formed deep soils, especially good for fruit crops. Furthermore, the streams cutting their valleys into the unconsolidated glacial material have produced a type of scenery that is not found in other parts of the state.

Evaporites

Rocks formed by the evaporation of water are known as evaporites. This evaporation may take place either in shallow basins on the land or in the sea. However, the rocks that were laid down under the sea form the thicker and more widespread deposits. Kansas rocks formed in this way include deposits of gypsum, anhydrite, and common salt or halite.

Seawater contains many salts in solution. These are brought into the oceans by rivers, which are continually wearing down or eroding land surfaces and dissolving the salts. When seawater evaporates, the salts precipitate and settle to the bottom. The less-soluble compounds, those that dissolve less readily in water, are deposited first during the evaporation process. Calcium sulfate, the compound that forms gypsum and anhydrite, is among the least soluble and consequently is one of the first deposited after dolomite. Next in order of solubility and hence in deposition is sodium chloride, or common table salt.

The Permian sea, in which evaporites were deposited in Kansas, was a shallow arm of the ocean that was shut off from the main body of water by some barrier, perhaps land areas in Oklahoma and Texas. The rate of evaporation was greater than the combined inflow of water from the ocean and from rainfall and as evaporation continued, the salts of the ocean water became more and more concentrated. Occasionally more water from the ocean came into the Kansas sea, and this in turn was evaporated. Gradually thick deposits of gypsum, anhydrite, and salt were built up on the sea bottom. These were buried by later deposits of Permian age and then by younger rocks.

Evaporite deposits are described more fully under the separate mineral names gypsum, anhydrite, and halite. They are very common in Kansas, particularly in the central and western parts of the state, and they have many uses.

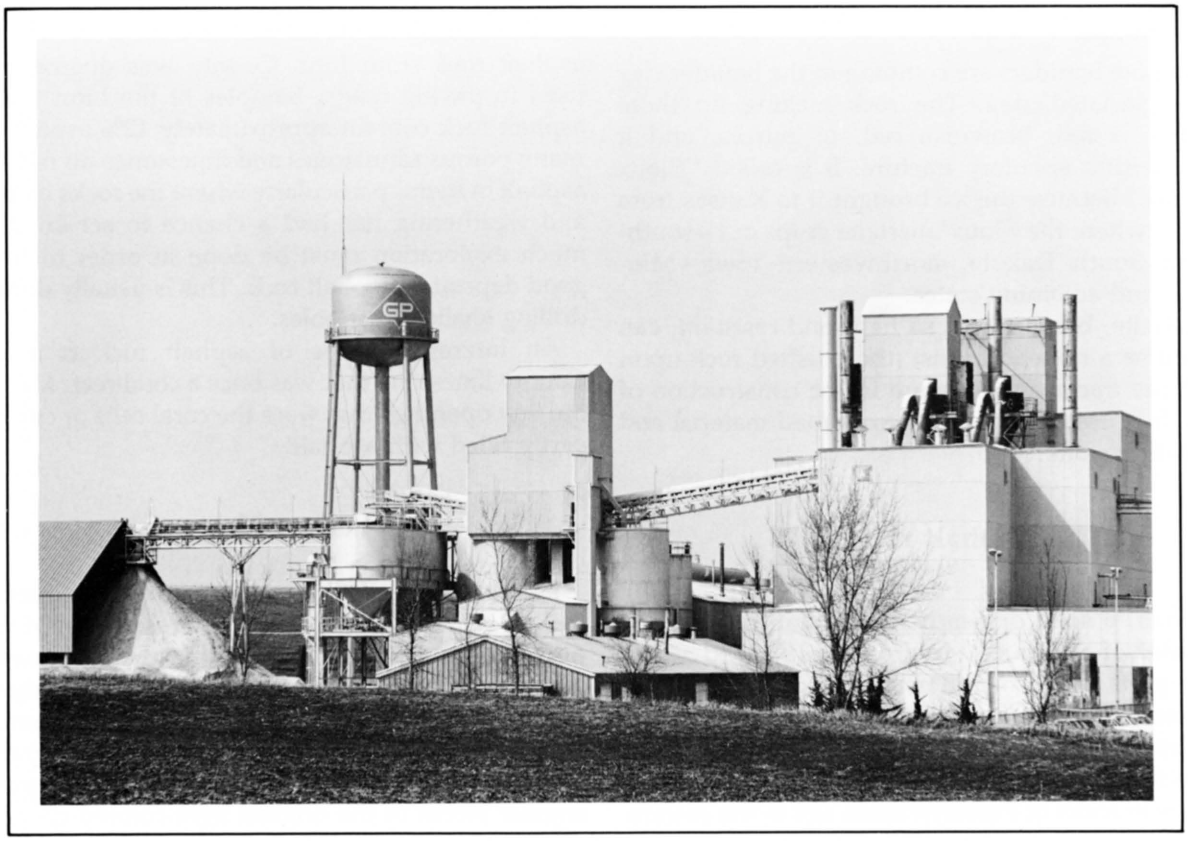
The evaporites formed on the land are neither so thick nor so common as those formed under the sea. However, at various places in Kansas, especially in northeastern Stafford County and near Jamestown in Cloud County, salt flats occasionally form. These result from the solution of gypsum or halite by ground water that later evaporated when it reached the surface and left the gypsum and salt deposited on or near the top of the ground. Gypsum deposited in this way looks like dark granular earth and is called gypsite or "gypsum dirt."

Quartzite

Quartzite is a rock consisting of quartz sandstone so thoroughly cemented with silica that the rock breaks through the grains as easily as around them. It is distinguished from sandstone not only because it breaks through the grains, but also because it cannot be scratched by a knife. Quartzites may be either metamorphic or sedimentary in origin, and the two types are so similar in appearance that in many cases they cannot be differentiated without a microscope. Kansas has small quantities of both types.

Metamorphic quartzites are caused by intense folding of the rock or by solutions from nearby igneous intrusions, or both. The only metamorphic quartzite known in Kansas is located in Woodson County, four miles west and 10 1/2 miles south of Yates Center and is probably associated with an intrusion of igneous rock in that area. The quartzite of Woodson County is a thin-bedded, slabby, hard rock of many different colors—green, gray, pink, and black. It crops out in a hillside for hundreds of feet. During the 1870's, this location was the site of an unsuccessful silver-mining rush, and many old prospecting pits can still be seen.

Sedimentary quartzite in Kansas is found locally in two Cretaceous formations, the Kiowa Shale and the Dakota sandstone, where quartzite caps hills and forms hard, resistant ledges in eastern McPherson County and in Kearny County near Hartland. The silica cement was deposited from solution in seawater during or shortly after deposition of the sand. The rock ranges in color from white to brown and light red. The green opal-cemented rock in the Ogallala Formation has been described in the section on sandstones, but it is almost as hard as a true quartzite. As opal is a form of silica, this rock may be considered a special type of quartzite. Typical



Gypsum plant near Blue Rapids in Marshall County.

Field of glacial boulders south of Wamego in Wabaunsee County.

quartzites, however, are cemented with quartz rather than with opal.

Quartzite boulders are common in the boulder clay of the glaciated area. The rock making up these boulders is red, brownish red, or purple, and it breaks with a splintery fracture. It is called "Sioux quartzite" because the ice brought it to Kansas from the area where the Sioux quartzite crops out—southeastern South Dakota, northwestern Iowa, Minnesota, and adjoining states.

Quartzite, because it is so hard and resistant, can be used as a railroad ballast (the crushed rock upon which the tracks are laid) and in the construction of dams. It is used in some places as road material and as building stone.

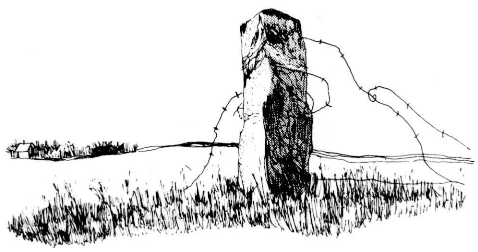
Asphalt rock

Asphalt, a solid or nearly solid organic substance composed of carbon and hydrogen, is formed as the lighter parts of petroleum evaporate and the heavy, tarry residue remains behind. Natural asphalt, that made by nature and not in an oil refinery, is found in Kansas in the pores of both limestone and sandstone. It occurs in rocks of Pennsylvanian age in the eastern part of the state and in small amounts in the Cretaceous sandstone of McPherson County. At one time asphalt rock from Linn County was quarried and used in paving roads. Samples of the Linn County asphalt rock contain approximately 12% asphalt. As many porous sandstones and limestones do not have asphalt in them, particularly where the rocks crop out and weathering has had a chance to act on them, much exploration must be done in order to find a good deposit of asphalt rock. This is usually done by drilling shallow test holes.

An interesting type of asphalt rock is a Linn County limestone that was once a coral reef. Many of the tiny openings that were the coral cells or cups are partly filled with asphalt.

Jasperoid

Jasperoid is slightly metamorphosed sedimentary rock in which the lead and zinc ores of the Tri-State mining area (a district comprising the southeastern corner of Cherokee County, Kansas, and adjacent parts of Missouri and Oklahoma) are commonly found. A gray to black mottled chert, coarser grained than ordinary chert, is the cementing material around angular pieces of the original light-colored chert.



Igneous rocks

Granite

Granite is a coarsely crystalline igneous rock formed by the slow cooling of hot molten rock deep within the earth. All granite contains quartz and feldspar and a small amount of at least one of several other minerals.

The only granite native to Kansas and exposed at the surface crops out on a low hill or ridge along U.S. Highway 75, eight miles south of Yates Center, Woodson County. The granite consists largely of cream-colored to white feldspar crystals and bluish quartz. It is badly weathered, but fresh specimens may be obtained by breaking into the rock. Most of the granite that is seen at this locality is in the form of residual boulders. Probably the granite exposed here does not represent an igneous body that extends to great depth at this locality. Drilling to demonstrate tonnage of the granite revealed peridotite and metamorphosed and unmetamorphosed Pennsylvanian sediments below the surface. The granite has been age-dated as Precambrian, whereas the peridotite is Cretaceous. It is apparently a large boulder that was ripped loose at depth and carried to the surface by the eruptive force of younger igneous rocks.

Tremendous quantities of granite and granitelike rock occur in the subsurface rocks of Kansas. This granite is the "basement" rock upon which the oldest Paleozoic sediments were deposited, and it is found at depths of from 600 to several thousand feet. It is closest to the surface in Nemaha County.

Specimens of many varieties of granite and other igneous rocks are found in the boulder clay or glacial till in northeastern Kansas. Cobbles and pebbles of granite are also found in western Kansas, brought there from the Rocky Mountains by prehistoric streams.

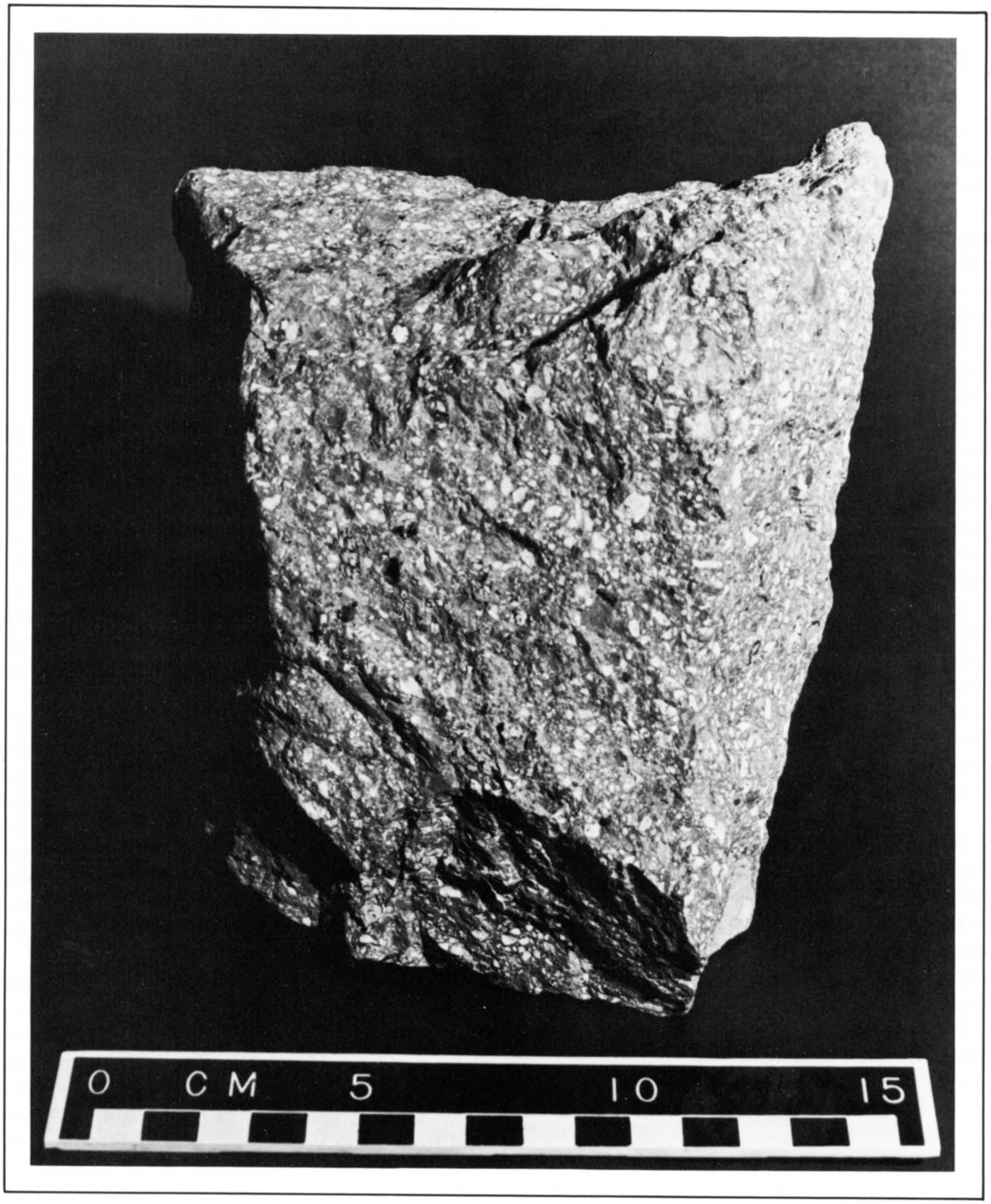
Peridotite

Peridotite crops out in a sill-like mass about one mile long and one-fourth mile wide in southern Woodson County. Peridotite is a medium- to coarse-grained basic igneous rock, containing phlogopite mica in this area. At the surface, the rock is altered to a yellowish-gray mass of clay studded with vermiculite. Kimberlite, a form of peridotite, is found in several locations in Riley County. Kimberlite is formed much like a volcano, as igneous rock wells up to the surface from deep underground. Therefore, these rocks, like the granite, are called intrusive igneous rocks because they were forced into other rocks below the surface of the earth. In appearance the kimberlite is a soft, dull gray-green rock and is cut by thin white veins of calcite and magnetite. Kansas peridotite also contains irregular spots of hardened or altered shale. When the hot, molten igneous rock came in contact with the Paleozoic shale, or country rock, pieces of shale broke off and fell into the liquid mass. Several kimberlites also contain such minerals as ilmenite and garnet. In some places, such as South Africa, diamonds are formed in kimberlites, although no diamonds have been found in the Kansas kimberlite.

Volcanic ash

Volcanic ash, or volcanic dust (in some places called "silica," although this name is not exactly accurate), consists of tiny glass or congealed lava fragments that have been blown into the atmosphere during the eruptions of volcanoes such as Mount St. Helens. It is a type of extrusive igneous rock; that is, it has been forced out, or extruded, onto the earth's surface. Volcanic ash in Kansas is found in sedimentary deposits of Tertiary and Quaternary age. In some places it is more than 20 feet thick. Under a microscope or a hand lens, ash is seen to contain small curved pieces of glass that are the broken walls of bubbles of the lava rock that burst from the volcano. Kansas volcanic ash has about the same chemical composition as granite, but in the case of the ash, the molten rock cooled so quickly that there was not time for crystals to form. Ash can easily be distinguished from other rocks by its white to bluish-gray color. Its glassy surfaces sparkle in the sun, and its particles do not dissolve in water as do particles of limestone and chalk.

No volcanoes existed in Kansas during Tertiary and Quaternary times so a source outside the state must have been responsible for the large quantities of ash deposited here. Most of the Kansas ash was probably carried in by wind from a volcano in north-central New Mexico, eruptions in Yellowstone, Wyoming, and from Long Valley caldera in California. Once in Kansas, some of it was carried for short distances by streams and was deposited in quiet ponds, burying pond grasses and snails in the clays beneath. Ash occurs abundantly in central and western Kansas and has been found as far east as Nemaha, Douglas, and Chautauqua counties. In the past it has had many uses: in toothpastes and powders; as abrasives, cleaning compounds, and glazes for pottery; in filters; and in the manufacture of cement and road asphalt.



Riley County kimberlite; dark specks in rock are garnets.

VOLCANIC-ASH MINE NEAR CALVERT IN NORTON COUNTY.

Basalt

When volcanoes erupt quietly instead of explosively, molten rock pours out in a liquid state of varying thickness depending on the silica content of the lava. The solidified material formed by cooling of the lava sometimes has a ropy appearance. It is a dark, fine-grained rock called basalt. No basalt native to Kansas occurs at the surface, but many persons have mistaken for such igneous rock some of the ropy-appearing, dark-brown sandstone of the Dakota Formation, as that on Coronado Heights in Saline County. This structure, which had nothing to do with molten rock, was caused by the chemical deposition of iron oxide in the sand.

Boulders and pebbles of basalt occur in stream deposits in the southwestern part of the state and in the boulder clay and related deposits of the glaciated region.

Meteorites

Almost everyone has seen ''shooting stars.'' These ''shooting stars,'' or meteors, are properly called meteorites if they reach the earth's surface. They consist of extra-terrestrial rock fragments that have come into the earth's atmosphere. The friction between the rock and the air causes the meteors and surrounding gases to glow from the heat, and it is these hot, glowing objects that we see. Most of them never reach the earth's surface because the intense heat consumes them very quickly by vaporization.

Two main types of meteorites can be identified, one easily, the other with difficulty. The first type, the iron meteorite, consists mostly of the heavy metals, iron and nickel. The other variety, the so-called stony meteorite, consists of heavy minerals and looks very much like volcanic rock. Ordinarily, however, these stony meteorites, unlike true volcanic rocks, contain metallic iron. Meteorite fragments vary from pea size to a mass of about 36 tons and most of them weigh less than 100 pounds. In general, meteorites may be distinguished from other rocks in the following ways: 1) as a rule they are denser than other rocks, 2) in all cases they are solid masses of either iron or stone or both, 3) they have a distinct ''burned'' appearance, 4) they are commonly pitted or pockmarked, and 5) most of them will attract a magnet because of the iron they contain.

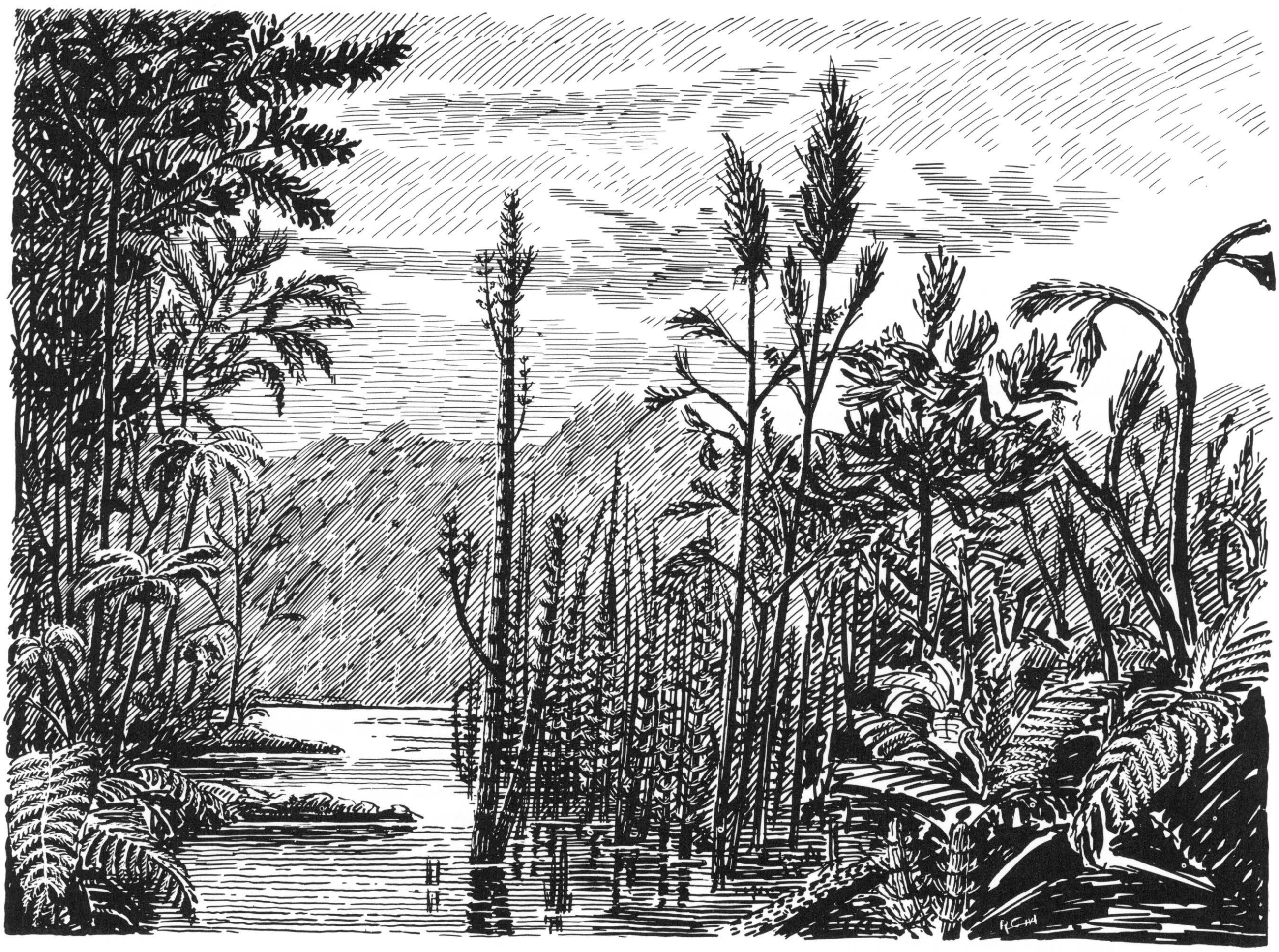
Over the years, many meteorites have been found in Kansas. Lack of vegetation, predominance of sedimentary rocks, and widespread plowing are factors that have led to record finds.

Mineral fuels

Coal and lignite

Coal is a general name applied to black deposits consisting chiefly of carbon compounds derived from plants and plant debris that have been compacted into firm, brittle rocks showing either a dull or shiny luster. The three main types of coal are anthracite, or hard coal; bituminous, or soft coal; and lignite, a soft, low-grade impure type. Anthracite, which is not found in Kansas, is a dense, brittle coal with either a shiny or dull luster and a shell-like fracture. It burns with a pale-blue, smokeless flame. Bituminous coal, although soft, does not crumble on exposure to air. It breaks into irregularly shaped blocks, has a luster varying from dull to fairly bright, and burns with a yellow flame. Lignite contains well-preserved plant structures (such as ferns, horsetails, and club mosses), showing that it originated in swamps.

Kansas coal is mainly bituminous and is found in the eastern third of the state. It has played an important role in Kansas economy and has been mined in Anderson, Atchison, Bourbon, Brown, Cherokee, Coffey, Crawford, Chautauqua, Doniphan, Douglas, Elk, Franklin, Geary, Jackson, Jefferson, Labette, Leavenworth, Linn, Lyon, Montgomery, Nemaha, Neosho, Osage, Shawnee, Wabaunsee, and Wilson counties. Most of it originated during the Pennsylvanian Period, sometimes referred to as the ''Great Coal Age,'' but a few beds are in Permian rocks. Originally this coal was probably vegetation in freshwater swamps similar to those found on parts of the Atlantic coast today. After the plants died and were buried under muds and sands, they began to decay. The first stage in the formation of coal is the development of peat. The passing of geologic time changes peat into lignite, or ''brown coal,'' and eventually into bituminous coal. Had Kansas coal undergone even more heat and pressure than it has, it might have become anthracite.



SKETCH OF A NONMARINE COAL SWAMP DURING PENNSYLVANIAN PERIOD IN EASTERN KANSAS; SKETCH BY R. C. MOORE, A FORMER DIRECTOR OF THE KANSAS GEOLOGICAL SURVEY.

''Brown coal'' (lignite) is found in Kansas in younger rocks of Cretaceous age. Small quantities occur in the Dakota Formation in Clay, Cloud, Dickinson, Ellsworth, Ford, Hodgeman, Jewell, Lincoln, Mitchell, Republic, Russell, Washington, and perhaps a few other counties. Lignite coal, woody in appearance, is intermediate in quality between peat and bituminous coal. Its water content is as much as 40%, and when exposed to air it dries out and crumbles.

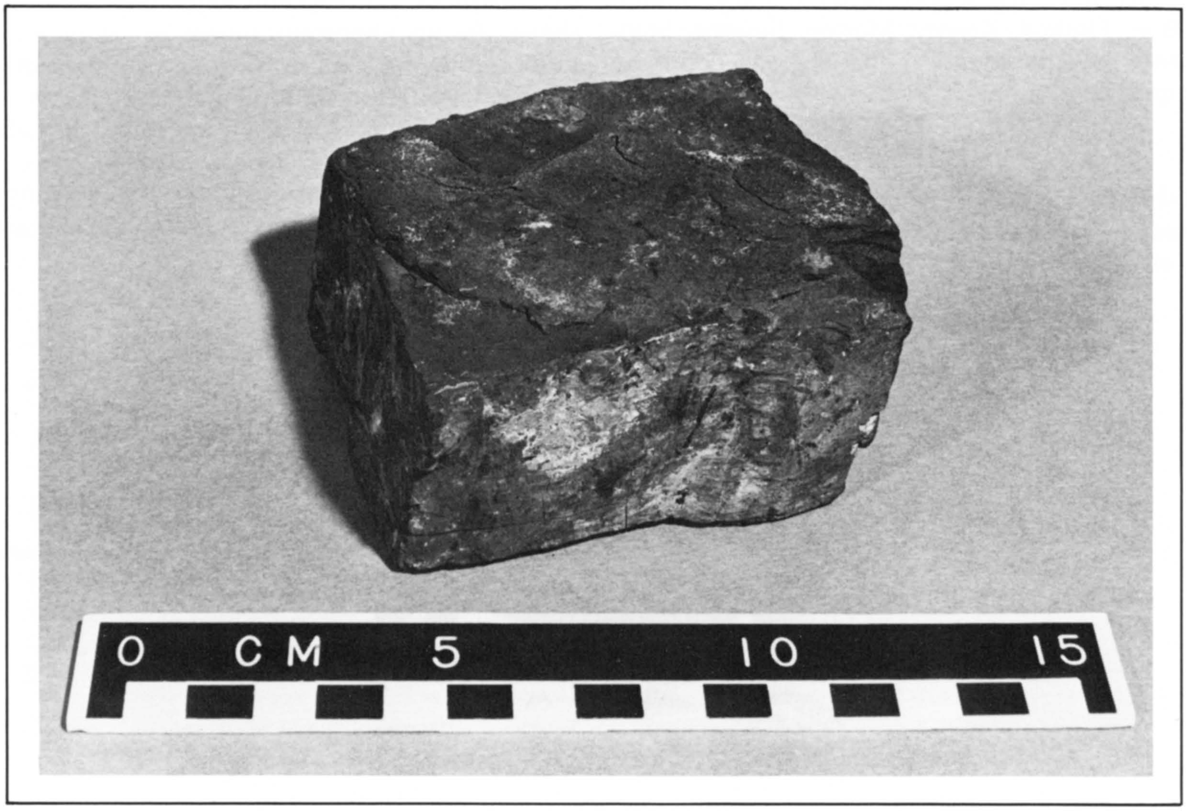
Petroleum and natural gas

Petroleum is an oily liquid consisting of many compounds of hydrogen and carbon. Most of it is found by drilling to subsurface deposits in rock formations. Rarely, some may be seen oozing from cracks in rocks or floating on the surface of water. Oil seeps have been reported in southeastern Kansas and a few other places where oil coverings have been found on the surface of water in wells and ponds.

Oil, like coal, is formed from the remains of living organisms. It is formed by gradual geothermal ''cooking'' that transforms the most mobile hydrocarbon chemicals over a few million years. Unlike coal, however, oil usually moves from the source rock to a ''reservoir rock'' after its formation. For example, geologists theorize that much of the oil in central Kansas was formed in Oklahoma and migrated north, where it was trapped. Oil in the reservoir rock occurs in the pore spaces in limestone or dolomite or between sand grains; it is not found in underground pools or lakes. Oil wells are drilled with the hope of finding a porous reservoir rock containing a commercial accumulation of oil. Kansas has produced oil since the 1860's, and regularly ranks among the leading states in the nation in terms of oil production and exploration.

Kansas oil production began in southeastern Kansas where oil was produced from shallow rocks of Pennsylvanian age. In the early 1900's, however, oil was discovered near El Dorado, kicking off one of the biggest oil booms in the history of the state. In 1918, the El Dorado field alone produced an estimated 6% of all oil pumped in the United States. By the 1920's and 1930's, exploration had moved west, concentrating on fields along the Central Kansas uplift, a buried arch of rocks that extends from central Kansas to the northwest. Counties near that feature such as Ellis and Russell are still the leading oil producers in the state.

Natural gas is associated with oil in most oil fields. In some places—such as the Hugoton Gas Area, one



Coal sample from southeastern Kansas.

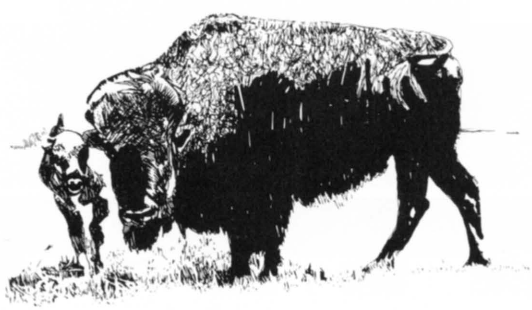
COMANCHE COUNTY OIL WELL.

of the world's largest gas fields (Finney, Grant, Hamilton, Haskell, Kearny, Morton, Seward, Stanton, and Stevens counties)—natural gas occurs in huge quantities.

Oil shale

Oil shale is a compact, laminated, sedimentary rock containing a large amount of organic matter that can yield oil when distilled. The organic matter came from partially decomposed algae and animals. Oil shales are an important source of oil in parts of Europe, but deposits in the United States may be regarded as a reserve supply for future needs.

Deposits of black oil shale are found in Labette, Crawford, Bourbon, Douglas, Linn, Neosho, Wallace, and Franklin counties. They occur in Pennsylvanian shales in the eastern counties and in Cretaceous shales in western Kansas.



Minerals

All rocks are composed of one or more minerals. Because most of the rocks at the surface of Kansas are sedimentary in origin, so are most of the minerals. Salt, a common mineral, was deposited at the bottom of an ancient sea. So was calcite, the mineral that is the primary component of limestone.

What is a mineral? A mineral is a natural, inorganic substance with a characteristic chemical composition and definite physical properties. Natural means that it occurs in nature and is not manmade. Inorganic means that the minerals have not been formed directly by any kind of life, either plant or animal. A characteristic chemical composition means that no matter where a mineral is found, it contains the same types and quantities of chemical elements. Quartz, for instance, is always composed of the two elements silicon and oxygen which combine in the proportion of one atom of silicon to two of oxygen to form silicon dioxide, SiO_2. Fool's gold, or pyrite, always consists of iron and sulfur together, forming iron sulfide, FeS_2, and sphalerite is always zinc sulfide, ZnS.

The definite physical properties of a mineral depend on its chemical composition and its molecular arrangement. Describing a mineral without describing its physical properties is difficult. The following are terms commonly used to describe minerals.

Color, the easiest physical property to describe, is one of the easiest means of identifying certain pure minerals. For example, gold is always yellow; turquoise, always light blue. Impurities, however, often change the color of minerals.

Luster concerns the character of the light that is reflected by the mineral. Metallic, glassy, earthy, pearly, silky, and similar terms are used to describe luster.

When a mineral is rubbed on a piece of unglazed porcelain, it leaves a ***streak*** of finely powdered material. This streak may have a different color from that of the mineral itself and is an excellent check in identifying many minerals. Hematite, the common iron ore, invariably has a red-brown streak.

Some minerals are very soft; others very hard. The degree of ***hardness*** is an aid in identifying the minerals. Diamonds are harder than quartz and will therefore scratch quartz, quartz will scratch calcite, calcite will scratch gypsum, and so on. To help identify minerals, geologists have assigned numbers to the hardness of several minerals. In this hardness scale, the softer minerals are assigned a low number and the harder minerals a higher number.

Rankings on Mohs' scale of hardness:

1. Talc	6. Orthoclase
2. Gypsum	7. Quartz
3. Calcite	8. Topaz
4. Fluorite	9. Corundum
5. Apatite	10. Diamond

In the field, an easy way of estimating the hardness of a mineral is by trying to scratch it with common objects such as a fingernail with a hardness of 2.5, or a pocketknife blade, hardness 5.5. Glass has a hardness of slightly less than 6 and will scratch most minerals. To test a mineral for hardness, try to scratch it with one of these common objects. Minerals with a hardness of 6 or more will easily scratch a piece of glass. A sample such as calcite is too soft to scratch glass but is hard enough to scratch a fingernail. Therefore it has a hardness between 6 and 2.5. Hardness is another clue in identifying minerals, and in this book the hardness for each mineral is listed alongside its name.

Transparency is when light passes through a small piece of a mineral so that objects can be seen through it. If no light passes through and nothing can be seen through a small piece, the mineral is called ***opaque.*** Minerals that are neither opaque nor transparent, those through which light passes but through which no objects can be seen, are said to be ***translucent.***

Minerals always take on definite shapes, geometric forms, which may not be visible to the naked eye. The ***crystal forms*** depend on the arrangement of the atoms and molecules of the mineral. Unfortunately, large and visible crystals only form sporadically, mainly because growing crystals compete for space and crowd each other. Perfect crystals generally are found where they project or grow slowly in open space, such as in fractures or veins. When good crystals are found, they are extremely valuable in identifying minerals. Some crystals are flat and are called tabular; some are long and thin like needles or fibers and are described as either needlelike or fibrous; still others are shaped like pyramids, prisms, cubes, and many other forms or combinations of forms. If the crystal outlines cannot be distinguished and the mineral is composed of compact material with indefinite form, the structure is called massive. Crystals may be grouped into a globular shape that looks like a cluster of grapes. A few minerals seemingly have no crystal structure at all.

When struck with a hard blow, some minerals break only along certain planes. Other minerals break just as easily in one direction as in another. When a mineral has a tendency to break along certain planes,

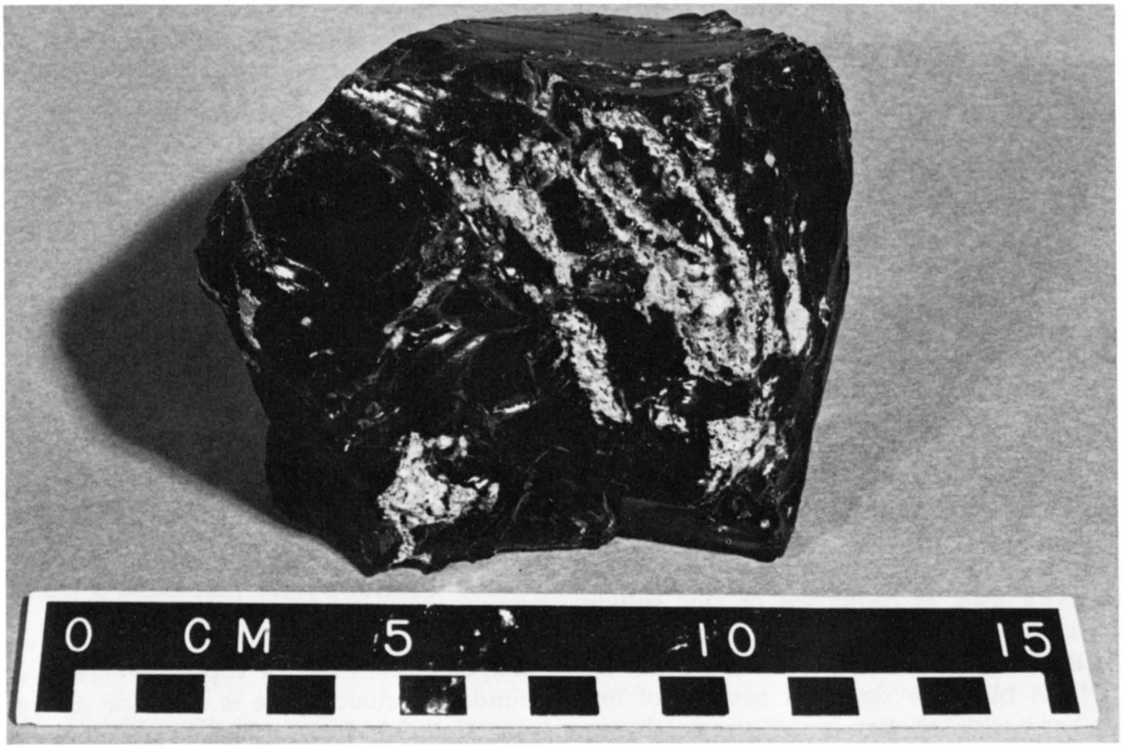
QUARTZ CRYSTALS.

it is said to have ***cleavage,*** resulting from the arrangement of the bonds between different molecules and atoms. Minerals may have only one plane of weakness or cleavage or they may have two, three, or more. The second type of breaking, that not determined by any arrangement of molecules, is called ***fracture,*** and this also varies among different minerals. Various types of fracture are described as smooth, uneven, ragged, and conchoidal or shell-like.

The following descriptions of minerals have been divided into several groups based primarily on the chemical composition of the mineral. For example, any mineral that is found in nature in its native state—that is, not combined with any other element—is called a native element. While gold and silver are two well-known native minerals, the only native mineral commonly found in Kansas is sulfur.

All other minerals are combinations of elements. Sulfide minerals, which are fairly common in Kansas, are formed by the direct union of an element with sulfur. The combination of zinc and sulfur, for example, produces the sulfide mineral called sphalerite (ZnS). Another common type of mineral in Kansas is the silicates, complex compounds composed of silicon, oxygen, and one or more metals. One form of mica, the mineral muscovite, is a silicate that is composed of silicon, oxygen, aluminum, and potassium ions.

All the common minerals in Kansas fall into seven classes of minerals. The following descriptions of minerals show their classification, where they are found, what they look like, and other information.



Obsidian, an igneous rock from New Mexico, illustrates conchoidal fracturing.

Native elements

As mentioned before, minerals that are found in nature in their native state—not combined with other minerals—are called native elements. Only about 20 of these native minerals exist, and sulfur is the only one common in Kansas.

Sulfur (hardness 1 1/2–2 1/2)

Sulfur (S) occurs as irregular masses, as earthy coatings on other substances, and as fine crystals. It is bright yellow, so soft that it can be scratched by a fingernail, and burns with a blue flame.

Sulfur in Kansas has been reported on the surfaces of coal dumps as slender, needle-shaped crystals resulting from the decomposition of pyrite. Small quantities of the earthy variety are present in many Kansas rocks that contain pyrite. Most of it is impure and mixed with clay and limonite.

Sulfides

Nearly all sulfide minerals are formed by the direct union of atoms of an element with sulfur atoms. For example, the combination of lead and sulfur forms a sulfide mineral called galena. Many of the sulfide minerals are valuable ores, such as galena and sphalerite, the sulfide minerals that produce lead and zinc ore. In Kansas, many of the sulfide minerals are found in the southeastern corner of the state.

Galena (hardness 2 1/2)

Galena, the principal ore of lead, is composed of lead sulfide (PbS). It is found in metallic to lead-gray, cube-shaped crystals that break into cubic, right-angled fragments. Some galena crystals are very large. Galena is heavy, has a metallic luster on fresh surfaces, has a gray-black streak, and is so soft that it will mark on paper.

Galena was once mined in southeastern Kansas in the Tri-State district, which was the most important lead- and zinc-producing area in the world in the early part of this century. In the late 1800's, hundreds of small lead and zinc mines operated in Cherokee County. Today these mines are closed. However, galena is still found with sphalerite, chalcopyrite, cerussite, dolomite, calcite, quartz, barite, and other minerals, especially at old mine dump sites. Galena is also found near Pleasanton, Linn County, and has been reported from Chautauqua, Douglas, Elk, and Sumner counties and in rock fragments brought to the surface during drilling for oil in many other counties.

Sphalerite (hardness 3 1/2–4)

Sphalerite, also called zinc blende, blende, black-jack, and mock lead, is composed of zinc sulfide (ZnS) and is the most important ore of zinc. Pure sphalerite is nearly colorless, but it is commonly brown, yellow, black, or dark red because of impurities. It has a white to dark-brown streak, always much lighter than the color of the specimen. As a rule the mineral crystals are shaped like triangular pyramids, with three sides and a base. Because it has good cleavage in six directions, sphalerite will break into 12-sided blocks. It has a brilliant resinous or almost metallic luster, and it can be scratched by a knife.

Some sphalerite is found as massive deposits varying from coarse to fine grained. In warm hydrochloric acid, powdered sphalerite breaks down and forms hydrogen sulfide, which has a decidedly unpleasant odor, something like the smell of a rotten egg. Sphalerite is easily identified by its cleavage and its resinous luster.

The best specimens of sphalerite found in Kansas are from the lead and zinc mines of Cherokee County. Sphalerite is also found as small crystals in clay-ironstone concretions in the Pennsylvanian shales of eastern Kansas.

Chalcopyrite (hardness 3 1/2–4)

An important ore of copper where it occurs in abundance, chalcopyrite is a sulfide of copper and iron ($CuFeS_2$). It is a brassy yellow mineral that makes a greenish-black streak and has a metallic luster. It is brittle, may be tarnished, and can be

Galena from Tri-State district of southeastern Kansas.

scratched by a knife. It occurs normally as four-sided pyramidlike crystals, but the crystals are usually poorly formed when the mineral occurs as massive sulfide ore. Chalcopyrite is very similar in appearance to pyrite, but they can be distinguished because each has a characteristic color and hardness.

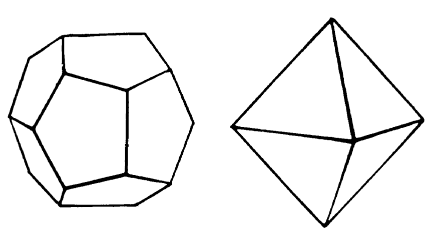
Chalcopyrite occurs with lead and zinc ores in the Tri-State district in Cherokee County. Although chalcopyrite is mined throughout the world as a copper ore, commercial quantities of the mineral are not known in Kansas.

Greenockite (hardness 3–3 1/2)

Greenockite, a rare mineral, is composed of cadmium sulfide (CdS). It has a yellow color, resinous to earthy luster, and cannot be scratched by a fingernail. Thin films of greenockite sometimes coat sphalerite and other minerals in the lead and zinc mines of Cherokee County.

Pyrite (hardness 6–6 1/2)

Pyrite (iron sulfide, FeS_2) is a pale, brass-yellow, opaque mineral that is brittle and has a metallic luster. It makes a black streak and is so hard that it can scratch glass. Most pyrite crystals are cube-shaped (like galena), but they also occur in other forms such as octahedrons. Pyrite is also found as granular masses, as cones and globules, and as nodules in shale, limestone, and sandstone. It is called "fool's gold" because its color is yellow like gold; however, pyrite is brittle, has a greenish tinge, and tarnishes, whereas gold is softer, leaves a yellow streak instead of a black one, and does not tarnish easily.



In Kansas, pyrite occurs in rocks of all ages, but it is especially abundant in coal deposits and in areas where lead and zinc occur in the Tri-State district. It is also found with gypsum in the dark shales. For a few years it was produced as a byproduct of coal at West Mineral southwest of Pittsburg and was used in making sulfuric acid.

Marcasite (hardness 6–6 1/2)

Marcasite, sometimes called white iron pyrite, is a mineral composed, like pyrite, of iron sulfide (FeS_2). Marcasite is a secondary mineral—it forms by chemical alteration of a primary mineral such as chalcopyrite. On fresh surfaces it is pale yellow to almost white and has a bright metallic luster. It tarnishes to a yellowish or brownish color and gives a black streak. It is a brittle mineral that cannot be scratched by a knife. The thin, flat, tabular crystals, when joined in groups, are called "cockscombs." When combined into balls or nodules, or into more complicated groups, they are marcasite rosettes. The mineral can be distinguished from pyrite by its crystal form. Marcasite weathers readily to form secondary minerals such as limonite and melanterite.

In Kansas marcasite occurs as concretions in coal, shale, and limestone. Well-developed crystals have been taken from the lead and zinc mines of the Tri-State district in Cherokee County and can be found in all of the coal mines in southeastern Kansas.

Oxides

Oxide minerals are those natural compounds in which oxygen is combined with one or more metals. An example of an oxide mineral found in Kansas is hematite (Fe_2O_3), a combination of molecules of iron and oxygen. The oxide minerals usually are harder than any other class of mineral except for the silicates, and they are generally heavier than the other classes except for sulfides.

Hematite (hardness 5 1/2–6 1/2)

Hematite is a compound of iron and oxygen (Fe_2O_3) that may be either red and earthy or black with a dull or metallic luster. Both types have a red-brown or Indian-red streak by which the mineral is readily identified. The earthy variety marks paper easily.

Pure hematite is rare in the surface rocks of Kansas. Most Kansas hematite is of the red variety and is found scattered in clays and shales. It is the cementing material in red sandstones. Small patches of impure hematite mixed with beds of hematite sand are found in the Dakota Formation in eastern Russell County and in Lincoln County near Juniata.

Hematite was once the chief source of iron ore in other parts of the United States, such as northern Minnesota, Michigan, Wisconsin, Pennsylvania, and Alabama.

Ilmenite (hardness 5 1/2–6)

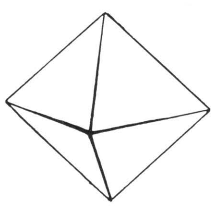
Ilmenite, named for the Ilmen Mountains in the Soviet Union, is an ironlike mineral composed of iron, titanium, and oxygen ($FeTiO_3$). It makes a black to brownish-black streak and cannot be scratched by a knife. Most large specimens of ilmenite are dense, granular masses, but the mineral may occur as platy crystals and as grains in sand. Specimens of the massive variety of ilmenite have been found in the kimberlite near Stockdale in Riley County. In New York state, ilmenite is mined as an ore for its titanium content. Some of the largest deposits of ilmenite occur as beach sands in many parts of the world.

Pyrolusite (hardness 1–2) and psilomelane (hardness 5–6)

Pyrolusite and psilomelane are both oxides of manganese (MnO_2), although psilomelane contains varying amounts of other elements. Pyrolusite is a black mineral that is so soft that it will easily make a black streak on paper. It usually occurs in radiating fibers or as treelike patterns (dendrites) on rock surfaces and in the moss agate of Wallace, Trego, and Logan counties. Psilomelane, also a black mineral that makes a very dark brown to black streak, is much harder than pyrolusite—it cannot be scratched by a knife. An earthy form of psilomelane, however, is known as wad, and is soft enough to soil the fingers. Wad forms the coating around pebbles in some gravel deposits, and it also occurs as soft black lumps in gravels and in some soils in southwestern Kansas. Pyrolusite and psilomelane are often found together in the same deposit. Both are sources of manganese ore.

Magnetite (hardness 6)

Magnetite (iron oxide, Fe_3O_4) is so named because it is readily attracted by a weak magnet and because some magnetite specimens called lodestones are in themselves magnets. The mineral is black, has metallic luster, and makes a black streak. It is so hard that it cannot be scratched with a knife. It is found as granular masses, but, especially in igneous rocks, it occurs as individual crystals, most of which have eight triangular faces and are called octahedrons. Magnetite is an important ore of iron.



Kansas magnetite is found in the kimberlite near Bala in Riley County, where it occurs as tiny, black, shining octahedrons imbedded in the rock. Occasional grains of magnetite may be found in many river sands.

Limonite (hardness varies)

Limonite, a compound of iron, oxygen, and water [$FeO(OH) \cdot nH_20 + Fe_2O_3 \cdot nH_2O$], is a yellow-brown to dark-brown or black, seemingly noncrystalline mineral. It is formed by the alteration of other minerals that contain iron. Limonite has a characteristic yellow-brown streak, but its hardness depends on the form in which it occurs. The yellow-brown, earthy form of limonite, really a mixture of limonite and clay called yellow ochre, is so soft that it easily leaves a mark on paper. The dark-brown to black variety (bog iron ore) is so hard that it cannot be scratched by a knife. Small quantities of limonite give a yellowish or buff color to most sandstones and to many clays, shales, and limestones. As a scum on quiet water, it may be mistaken for oil. It was once an iron ore of minor importance in some states, but Kansas does not have commercial deposits.

Much of the limonite in Kansas is in the form of concretions (particularly in the Dakota Formation) and in the form of impurities in sedimentary rocks. Limonite which has taken the place of and which has kept the crystal form of pyrite (a pseudomorph after pyrite) has been reported from northeast of Lincolnville in Marion County.

Halides

Halides are compounds that are characterized by atoms of a chemical group called halogens. Halogens include the elements chlorine, iodine, bromine, and fluorine. Because of their chemical makeup, halides are usually soft minerals that have moderate to high boiling points. The only common halide mineral in Kansas is halite, known more commonly as salt.

Halite (hardness 2 1/2)

Halite, common table salt, is composed of sodium chloride ($NaCl$). Most of its crystals are transparent, colorless cubes, but various impurities in the salt may give halite a brilliant red, blue, or yellow color. Normally halite has three good cleavages at right angles to each other, so broken fragments also may be very nearly cube-shaped. Some red halite has a fibrous or columnar structure. Halite is easy to identify because it has a salty taste and because it dissolves rapidly in water.

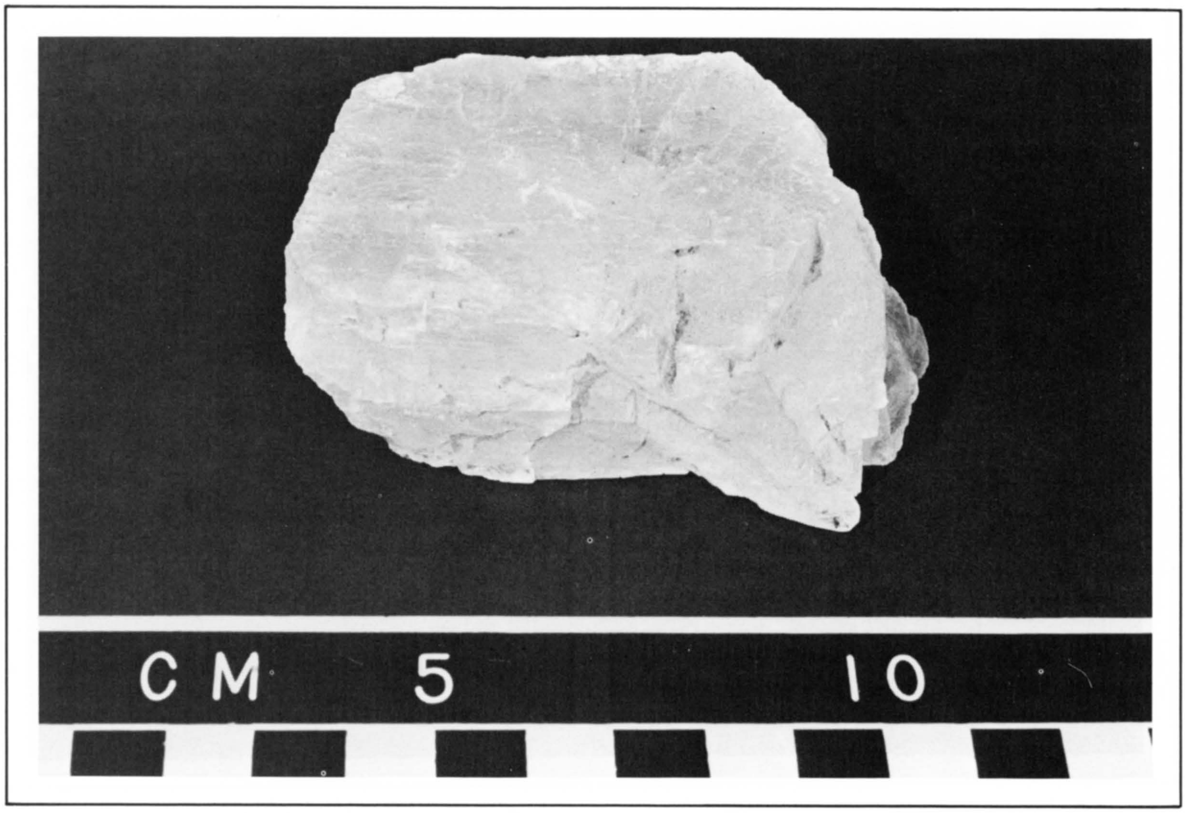
Salt in Kansas is found in thick beds in Permian rocks deep in the ground. It does not form outcrops because rain and ground water dissolve salt from the surface exposures. Most of the salt is found in the Hutchinson salt bed, which underlies approximately 37,000 square miles in central Kansas. The formation averages about 250 feet in thickness and contains a staggering 13 trillion tons of salt, enough to make a block measuring 10 miles on each side. It is mined at Hutchinson, Kanopolis, and Lyons and is used in chemical industries, in meat packing, for livestock, and as common table salt. Each year Kansas produces over a million tons of salt.

Carbonates

This group includes some of the most common minerals in Kansas, such as calcite and dolomite. The carbonate minerals are distinguished by a complex chemical makeup that includes an element combined with atoms of carbon and oxygen. Calcite, for example, is composed of atoms of calcium, carbon, and oxygen.

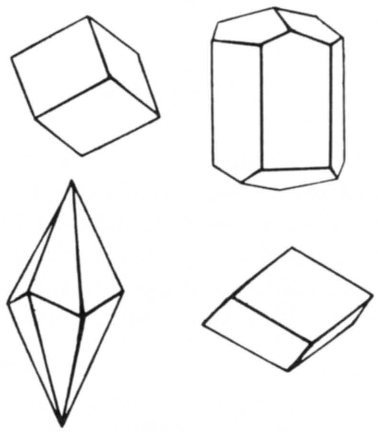
Calcite (hardness 3)

Calcite (calcium carbonate, $CaCO_3$) is the primary constituent of limestone and is therefore one of the most common minerals in Kansas. Generally it is white or colorless, but it may be tinted gray, red, green, or blue. It occurs in many varieties of crystal forms (more than 300 have been described). It also



Salt from central Kansas.

may be granular, coarse to fine, or even so fine grained that it has an earthy appearance. Calcite can be scratched by a knife, but not by a fingernail, and it fizzes freely in cold dilute hydrochloric acid. If a large piece of calcite is shattered with a hammer, it breaks into small rhomb-shaped blocks because it has perfect cleavage in three directions.

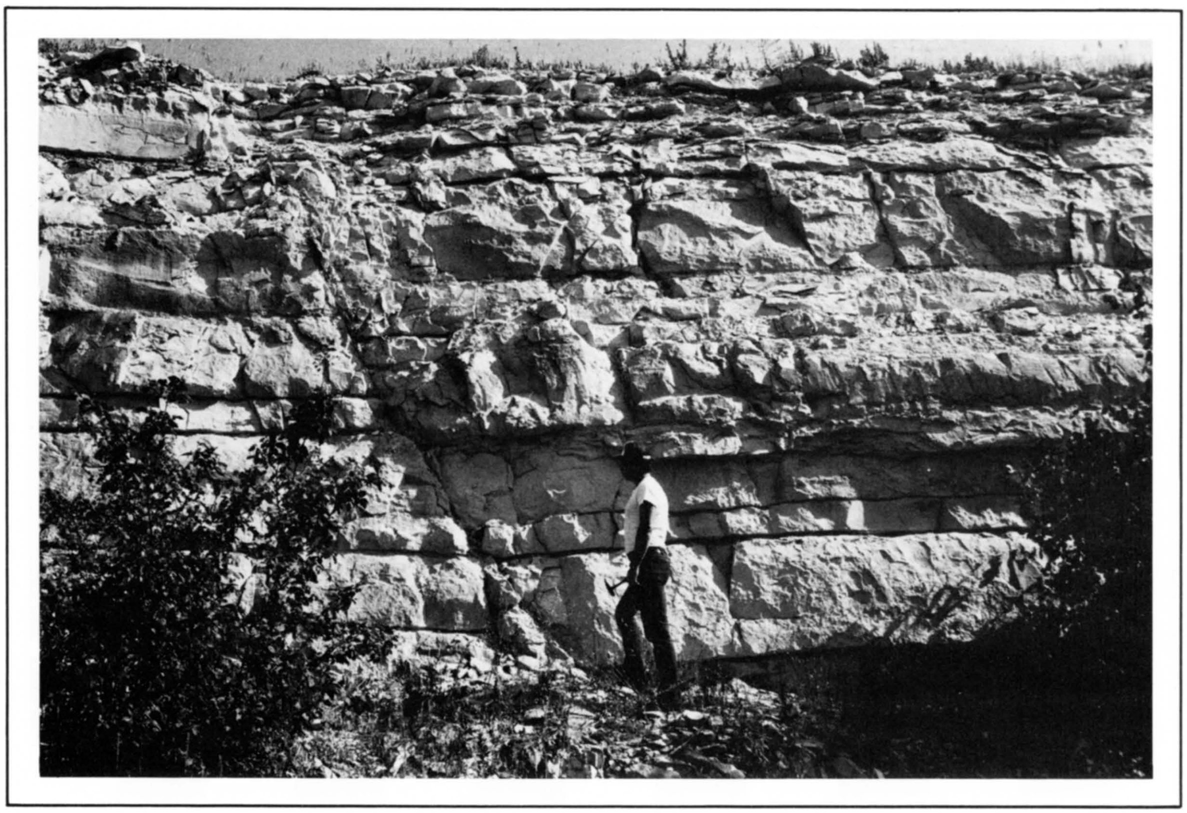


Besides being the mineral that forms limestone, calcite occurs as a common cementing material in many Kansas sandstones. It is found in calcareous shales and clays and as veins in the igneous rocks of Riley County. In the Cretaceous Niobrara Chalk and other Cretaceous rocks, it has formed fairly large veins. Calcite is an important part of many concretions. Brown calcite and colorless-to-yellow calcite crystals are common in the septarian concretions of the Pierre Shale in Wallace and other counties. Tiny calcite crystals form the lining of geodes in certain limestones and shales, and they coat the insides of many fossil shells. Among the finest calcite crystals in Kansas are those from the lead and zinc mines of Cherokee County, most of these being pale yellow and some of them very large. The most important use of calcite is in the manufacture of cements, limes for mortar, in the chemical industry, and in fertilizers.

Siderite (hardness 3 1/2–4)

Siderite is a common mineral composed of iron carbonate ($FeCO_3$). It is light to dark brown, and some of it occurs as rhomb-shaped crystals with curved faces (like dolomite). Most siderite, however, is granular or earthy. The mineral can be scratched by a knife. It fizzes in hot hydrochloric acid but reacts more slowly in cold acid. Weathered surfaces change to limonite and turn dark brown.

Most siderite in Kansas is in the impure form called clay ironstone. This is a mixture of siderite with limonite, clay, and silt, forming small nodules or whole beds in clays, shales, and sandstones.



LIMESTONE IN FORT HAYS LIMESTONE IN JEWELL COUNTY.

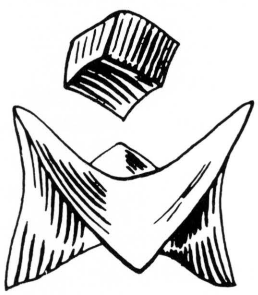
Smithsonite (hardness 4–5)

Smithsonite (a secondary zinc carbonate, $ZnCO_3$) is commonly brown in color, but it may be green, blue, pink, or white. Although it does occur as rough, curved, rhomb-shaped crystals, its occurrence as rounded, globular forms or as honeycomb masses is more common. Smithsonite is harder than most carbonate minerals, but it can be scratched by a knife. It fizzes in dilute cold hydrochloric acid.

Smithsonite is common in the near-surface parts of the zinc deposits in easternmost Cherokee County, where it has formed as the result of the action of carbonated water on sphalerite. Smithsonite is a zinc ore and was named in honor of the Englishman James Smithson, who also supplied funds for the founding of the Smithsonian Institution.

Dolomite (hardness 3 1/2–4)

The mineral dolomite is composed of calcium magnesium carbonate [$CaMg(CO_3)_2$] and is closely related to calcite. In large masses the mineral forms the rock called dolomite. It may be white, gray, greenish gray, brown, or pink, and it has a glassy to pearly luster. It occurs in coarse- to fine-grained granular masses and in crystals. Most dolomite crystals are rhomb-shaped like calcite cleavage blocks, but, unlike most other minerals, the crystal faces are typically curved. Dolomite is slightly harder than calcite, although it can easily be scratched by a knife. It will not fizz readily in dilute cold hydrochloric acid unless first ground to a powder.



Curved white crystals of dolomite are common in lead and zinc mines of Cherokee County, where they occur with sphalerite, chalcopyrite, galena, and several other minerals. Dolomite crystals also have been found in Pennsylvanian limestones in the Ross quarry near Ottawa in Franklin County, about two miles north of Williamsburg in Franklin County, and three miles north of Garnett in Anderson County. They also are found in the rock dolomite formations and certain red and green shales of McPherson, Rice, Reno, Kingman, and Clark counties.

Aragonite (hardness 3 1/2–4)

Aragonite has the same chemical composition as calcite ($CaCO_3$), but it has poorer cleavage and a different crystal form than calcite. Aragonite crystals commonly occur as radiating groups of fibrous or needlelike shapes. Like calcite, aragonite fizzes and dissolves readily in cold dilute hydrochloric acid and can be scratched with a knife. This mineral is colorless to white, gray, yellow, green, brown, and violet and is ordinarily found as a vein mineral, in cave deposits, and as the pearly layer of many types of shells.

Aragonite is much less common than calcite because it changes easily to calcite without altering its external shape. It is difficult to identify in the field. The mineral has been reported from several areas in Kansas: as nodules in a clay deposit in northern McPherson County and in a sand pit two miles southeast of McPherson; as veinlets cutting country rock at Silver City in southern Woodson County; as small crystals in vugs, or cavities, in the limestone of the Ross quarry near Ottawa in Franklin County; and in many concretions in the Cretaceous shales of western Kansas. This mineral is named for the region of Aragon in Spain.

Cerussite (hardness 3–3 1/2)

Cerussite (lead carbonate, $PbCO_3$) occurs as granular masses and as platy crystals which commonly cross each other to form a latticelike effect. Cerussite has a brilliant, glassy luster and is colorless or white. It fizzes slightly in cold dilute hydrochloric acid and is very heavy for a nonmetallic mineral.

In Kansas, small amounts of cerussite are occasionally found as a result of the chemical change of galena (lead sulfide) in the near-surface parts of lead deposits in easternmost Cherokee County.

Malachite (hardness 3 1/2–4)

Malachite, a copper ore, is a bright-green copper carbonate mineral having the composition $Cu_2CO_3(OH)_2$. It has a dull to glassy luster and a light-green streak. The mineral fizzes in cold dilute hydrochloric acid and can be scratched by a knife.

Malachite occurs in Sedgwick, Sumner, and Harper counties, where it is associated with copper mineralization in the Permian shales and carbonate rocks. It occurs as tiny, brilliant-green specks in some thin dolomite beds near the top of the Wellington shale and in a few other Permian rocks. It may be found, among other places, at the bridge crossing the Ninnescah River two miles south of Milan, Sumner County. It also occurs in the Tri-State district in southeastern Kansas.

Sulfates

Another common group of Kansas minerals is the sulfates. These minerals consist of an element combined with atoms of sulfur and oxygen. One of the widespread sulfate minerals is gypsum, composed of atoms of calcium combined with atoms of sulfur and oxygen.

Barite (hardness 3–3 1/2)

Barite (barium sulfate, $BaSO_4$) is a common mineral in Kansas, but it is not found in large quantities. Because of its high density, it is sometimes called "heavy spar." It occurs as flat, tabular crystals, either singly or in groups, and it also occurs in granular or earthy forms. The individual crystals are transparent to opaque, have a glassy luster, and have perfect cleavage in two directions. Barite is usually colorless or white but may be light shades of blue, yellow, or red. It can be scratched with a knife but not with a fingernail. In appearance, it resembles gypsum, calcite, or celestite. However, aside from its relatively heavy weight, barite can be distinguished from gypsum by its greater hardness and from calcite because it does not fizz in hydrochloric acid. A flame test is the best means of distinguishing between barite and celestite. If powdered barite is heated on a clean platinum wire in a Bunsen burner, the flame will become green, but celestite will turn the flame bright red.

Barite has been found in Kansas in some of the Pennsylvanian and Permian limestones, especially in Brown, Anderson, Franklin, and Chase counties; in septarian concretions of the Cretaceous Pierre Shale in Logan and Wallace counties; in petrified wood; and occasionally in the lead and zinc mines of Cherokee County. It occurs in veins a few millimeters thick in the Niobrara Chalk in north-central and northwestern Kansas. It also occurs as a cementing material between sand grains in peculiar roselike concretions called "desert roses" or "petrified walnuts" in certain sandstones of the Cretaceous Kiowa Shale. These barite "roses" and "walnuts" are found in an area near Bavaria in Saline County and are abundant near Horsethief Canyon in Ellsworth County.

Barite is used in paint pigments, as a filler in paper and cloth, in making glazes for pottery, and in the refining of sugar. It has not been found in commercial quantities in Kansas but has been mined in Missouri and Arkansas.

Barite rose from Oklahoma.

Celestite (hardness 3–3 1/2)

Celestite (strontium sulfate, $SrSO_4$) is similar to barite in appearance, in geologic occurrence, and in crystal form. It has a glassy luster and its crystals are colorless, white, or a faint blue or red. This mineral is found in Kansas as radiating pink fibers, as vein fillings, and as scattered particles. Celestite cannot be scratched by a fingernail. It differs from barite in its lighter weight and in its property of coloring a flame red.

Celestite has been found in solid blue or pink crystals and as pink to white radiating fibers at Kanopolis dam near the water's edge below the spillway outlet. It also has been found as pink crystals and as veins in Brown County north and west of Morrill, and in Chase and other counties. Celestite has been found in the weathered zone at the top of Permian rocks below Cretaceous sands and shales.

Anhydrite (hardness 3–3 1/2)

Anhydrite, composed of calcium sulfate ($CaSO_4$), constitutes one of the three main evaporite deposits, the other two being gypsum and halite. It occurs commonly as light-gray, crystalline masses, although some anhydrite has a fibrous structure. It may occur as individual crystals in other rocks, particularly in dolomite. It has a glassy luster and is translucent. It is harder and heavier than gypsum; although it can be scratched easily with a knife, it cannot be scratched with a fingernail. Anhydrite may change into gypsum if water is added, a common occurrence in near-surface exposures. Fine-grained dolomite and anhydrite look somewhat similar but can be distinguished from one another because cold hydrochloric (muriatic) acid will not act on anhydrite.

Kansas anhydrite is found in Permian-age deposits associated with beds of gypsum, dolomite, and red silt. With gypsum, it caps many of the Red Hills of Barber and other counties.

Gypsum (hardness 2)

Gypsum is calcium sulfate containing water ($CaSO_4 \cdot 2H_2O$). The same chemical compound without water is anhydrite, a quite different mineral. Gypsum is a common mineral that is widely distributed in the sedimentary rocks of Kansas in the form of thick beds, well-formed single crystals, and joint or crack fillings. It is colorless to white or light gray, rarely bright red, and is so soft that it can be scratched by a fingernail.

Selenite from Red Hills of south-central Kansas.

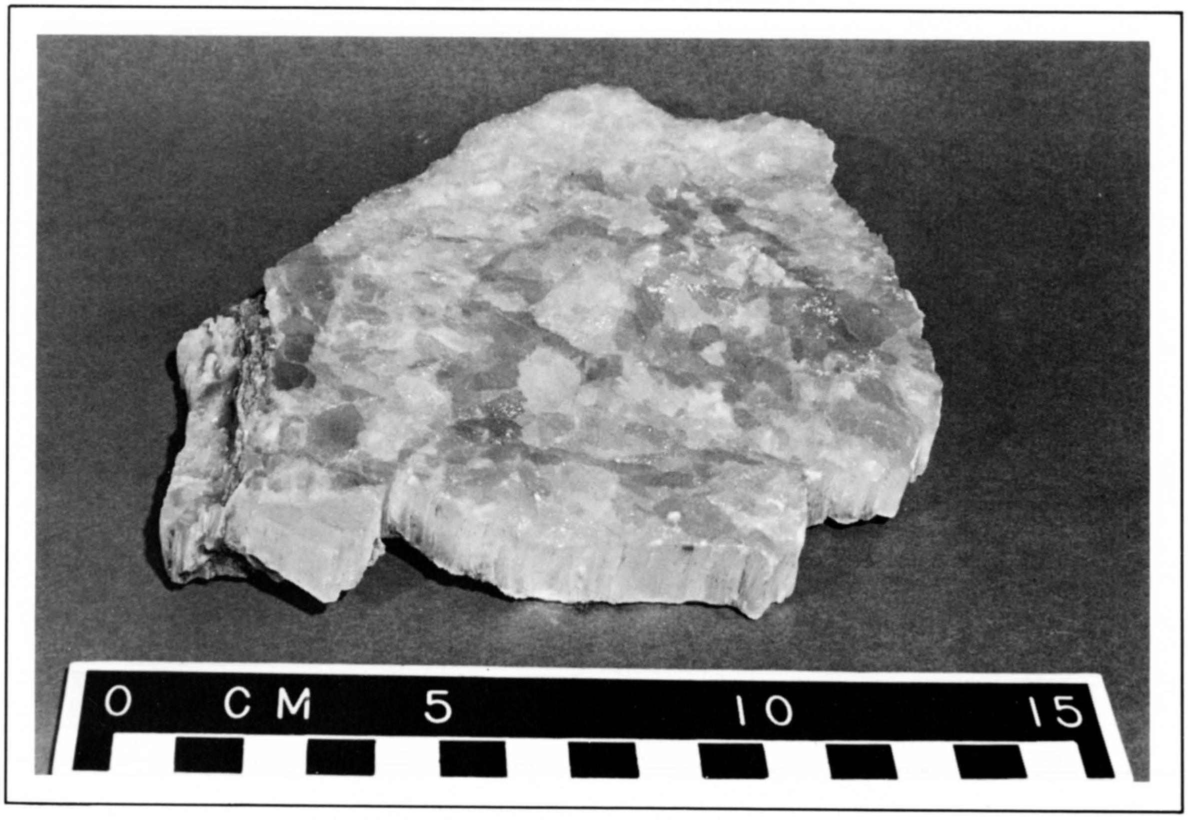
Three varieties of gypsum are recognized. The type of most interest to collectors is the coarsely crystalline, transparent variety called selenite. It consists of flat, diamond-shaped crystals having such perfect cleavage that they can be split into thin sheets. Selenite is common in dark shales such as the Kiowa, Carlile, and Pierre shales of Cretaceous age in western Kansas. Most selenite crystals found on weathered shale slopes have irregular or etched surfaces, but fresh, clear crystals can be uncovered by careful digging into the hillside. Occasionally one finds specimens consisting of two crystals grown together into what is known as a "fish-tail twin." In some places a network of selenite crystals is found in thin joint fillings, and some of the crystals may be grown together in a pattern called "gypsum flowers." Small quantities of bright-red selenite are found in some of the stream banks on the outskirts of Wichita in Sedgwick County.

Satin spar is another variety of gypsum. It is white or pink, fibrous, and has a silky luster. It is found as thin layers in beds of rock gypsum and in certain shales. The third recognized variety is massive or rock gypsum. It is coarsely to finely granular, white to gray, and contains various amounts of impurities. A good outcrop of rock gypsum can be seen about 10 miles west of Medicine Lodge along Highway 160. Alabaster, which rarely occurs in Kansas, is a very fine grained type of massive gypsum. Gypsite, or gypsum dirt, is formed in the soil or in shallow lakes, and consequently it is a sandy or earthy deposit, although it contains a large amount of the mineral gypsum. It is found in Clay, Saline, Dickinson, Marion, Harvey, and Sedgwick counties.

Large quantities of rock gypsum are mined in Barber and Marshall counties and large deposits also are found in Permian rocks in Saline, Dickinson, and Comanche counties. It is used in making plaster of Paris, Portland cement, various wall plasters and mortars, wallboard, and as a fertilizer.

Goslarite (hardness 2)

Goslarite ($ZnSO_4 \cdot 7H_2O$) is zinc sulfate containing water and is formed by chemical action on sphalerite. It is found occasionally in the Tri-State area as long, slender, needlelike crystals. Goslarite not uncommonly develops on the mine walls. It has a white, reddish, or yellowish color.



Satin spar from Barber County.

Silicates

More than 90% of the rock-forming minerals are silicates, compounds containing silicon and oxygen as quartz or combined with one or more metals in more complex molecules. These minerals make up about 95% of the earth's crust and some silicates, such as quartz and feldspar, are especially common.

Garnet (hardness 6 1/2–7 1/2)

Garnets are a group of minerals whose crystals have many faces, all of about equal size. They have a glassy luster and are hard enough to scratch window glass. Most garnets are red to brown, but some are black, green, or colorless. In chemical composition they are silicates of calcium, magnesium, iron, manganese, aluminum, and chromium in various combinations, with the aluminum-silicate varieties predominating.

Small red and brown garnets occur in the kimberlite outcrop near Stockdale in Riley County, and they may be found in the bed of the small stream that cuts across this outcrop. Garnets also have been found in other Riley County kimberlites and in the streams flowing near the kimberlites.

Hemimorphite (hardness 4 1/2–5)

Hemimorphite, sometimes called calamine, is a silicate of zinc containing water. Its chemical formula can be written $Zn_4Si_2O_7(OH)_2 \cdot H_2O$. It is a white mineral found in radiating crystal groups and in globular forms. It can be scratched by a knife. Hemimorphite usually occurs with zinc ores, and in Kansas it is fairly common in the upper parts of the sphalerite deposits of the Tri-State area in Cherokee County. In some parts of the world, hemimorphite is mined for zinc ore, although not in Kansas.

Mica (hardness 1 1/2–3)

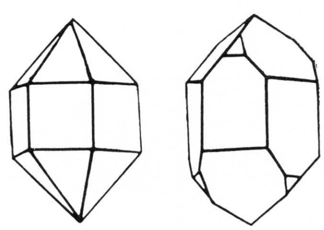
Mica is the name of a group of several minerals that are unusual because they split into thin, flat, flexible sheets. These minerals split this way because they have one perfect cleavage. They are composed of aluminum silicates of several elements. Muscovite, or common "white" mica, is transparent and colorless. In some igneous rocks (outside Kansas), it occurs in crystals several feet wide, large enough that they were once used as windows in coal stoves. In Kansas it is usually seen as tiny, flat, shining flakes in sandstones, siltstones, and shales, and as small crystals in boulders of metamorphic and igneous rocks. In some sands of the Ogallala Formation, muscovite has weathered to resemble gold flakes. Muscovite was so named because it was used as a substitute for glass in old Russia (Muscovy).

Biotite (black mica), rarer in Kansas than muscovite, may be seen in some of the Tertiary and Quaternary sands. The color of biotite is caused by iron and magnesium. Phlogopite and vermiculite mica are yellowish brown, have a copperlike luster on the cleavage surfaces, and often are mistaken for flakes of gold. Phlogopite is found in the kimberlites of Riley County and near Silver City in Woodson County.

Quartz (hardness 7)

Quartz, the most common of all minerals, is composed of silicon and oxygen (silica, SiO_2) and is found in many different varieties. When pure it is colorless, but it also assumes various shades of yellow, pink, purple, brown, green, blue, or gray. It has no good cleavage and has a glassy to greasy luster. One of the hardest of the common minerals, it will easily scratch window glass. In fact, quartz can be distinguished from calcite, another extremely common rock, by its hardness. The knife will scratch calcite but not quartz.

The two primary types of quartz are the coarsely crystalline and the fine or cryptocrystalline forms. The crystals of the first type are six-sided prisms with pyramids capping one or both ends. Well-formed, colorless quartz crystals of this type are found in geodes and as a lining on the inside of fossils in many parts of the state, particularly in the Lone Star quarry at Bonner Springs in Wyandotte County and in an area of eastern Chase County. Quartz crystals with a bluish cast are found in the igneous rock south of Yates Center in Woodson County. Nearly all sands and sandstones are composed of tiny, worn particles of crystalline quartz.



The second primary type of quartz is called cryptocrystalline because the crystals are so small they can only be seen with a microscope. One of the best-known varieties of this group is flint or chert, which is common in many Kansas limestones as nodules or beds. Chert is opaque and is dull gray, brown, or black in color. It breaks with a shell-like fracture, and the edges of the broken pieces are sharp. The famous "chat mountains" at the lead and zinc mines of Cherokee County consist almost entirely of chert fragments. Chalcedony is a cryptocrystalline quartz with a waxy luster that forms banded layers or globular masses. Agate is a many-colored, banded form of chalcedony that has been deposited in cavities or in veins and that is used for ornamental purposes. Beautiful agates, doubtless from the Lake Superior region, have been found in the glaciated district in Kansas.

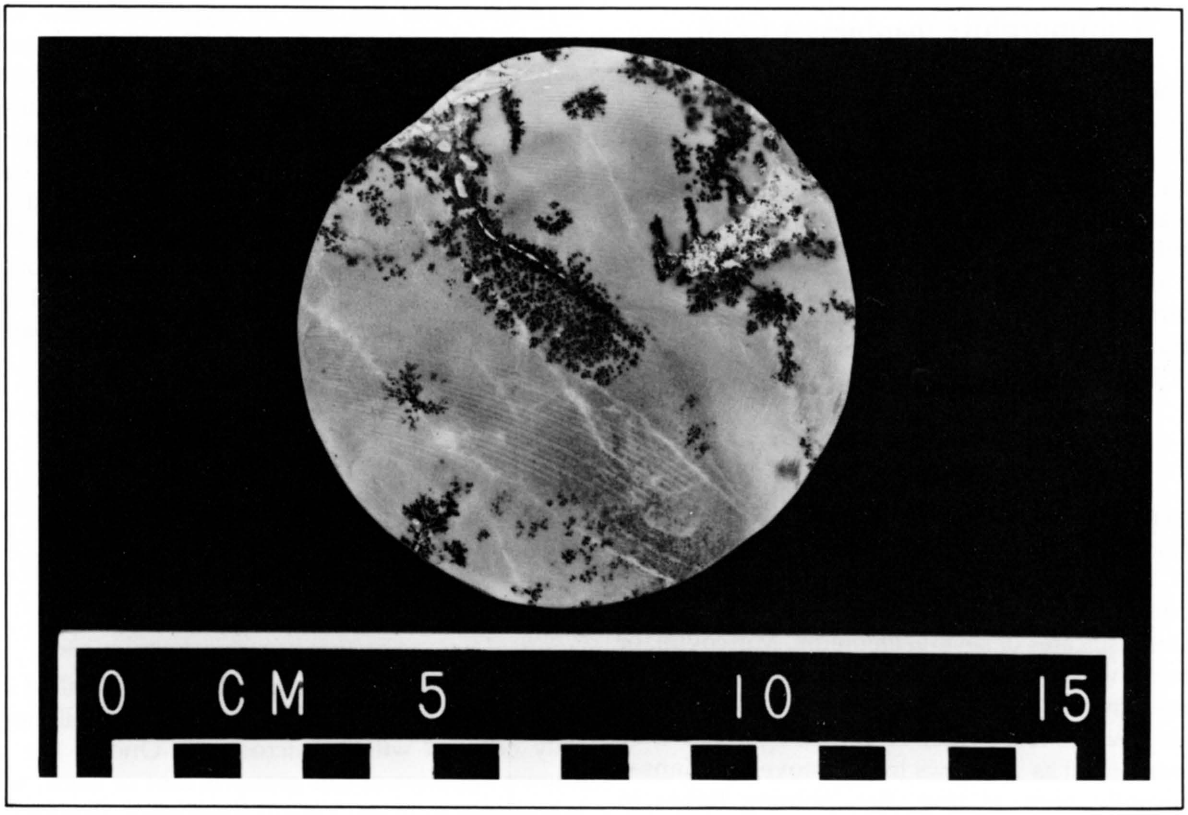
Opal (hardness 5–6)

Opal consists of silicon dioxide, like quartz, plus an indefinite amount of water ($SiO_2 \cdot nH_2O$). It never forms as crystals, but probably is deposited as a jellylike substance that later hardens. The mineral may be white, yellow, red, brown, green, gray, blue, or transparent and colorless. Precious opal, which is not found in Kansas, shows a beautiful play of colors and is highly prized as a gemstone. Opal cannot be scratched by a knife, but is slightly softer than quartz. It is found as a lining or filling in cavities in some rocks, as a deposit formed by hot springs, and as the petrifying material in much fossil wood.

A common Kansas mineral, opal is widespread in the Ogallala Formation in Clark, Ellis, Logan, Ness, and Rawlins counties. This Ogallala opal is colorless to white or gray and is found with a white, cherty, calcareous rock. Some of it is called "moss opal" because it contains an impurity, manganese oxide, that forms dark, branching deposits like small mosses in the opal. Moss opal (or moss agate) has been found in Trego and Wallace counties. Opalized fossil bones and shells of diatoms also are found in the Ogallala Formation, as is a green opal that acts as a cement in hard, erosion-resistant sandstones.

Feldspar (hardness 6)

The term feldspar applies to all members of a group of minerals composed of aluminum silicates carrying principally potassium, sodium, or calcium. The feldspars are light in color (pink, green, white, and gray), have a glassy or satiny luster, and have good cleavage in two directions, almost at right angles to each other. They cannot be scratched by a knife. Feldspars commonly occur in igneous rocks. Granite boulders found in Woodson County intrusives (mica-peridotite) are largely made up of white feldspar and quartz. The feldspar found in sedimentary rocks in Kansas was brought in as pebbles in streams and in



Moss opal from Wallace County.

boulders of igneous rocks in the glacial till or boulder clay. Feldspar pebbles may be distinguished from quartz pebbles by their good cleavage.

Sedimentary structures

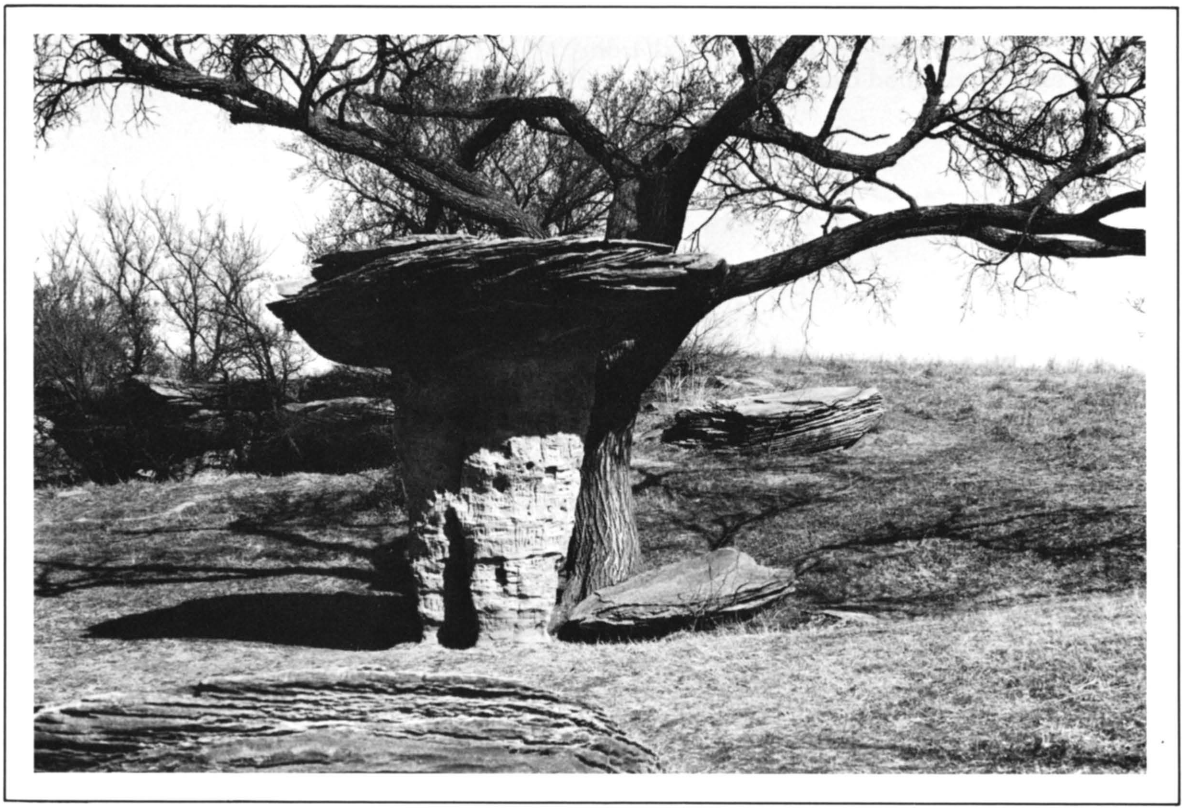
In addition to rocks and minerals, Kansas has a number of other formations that are best labeled ''sedimentary structures.'' These formations, although composed of Kansas rocks and minerals, require additional explanation. Some, such as concretions or cone-in-cone, may be mistaken for fossils. Others, such as geodes, can be spectacularly beautiful. Some structures, such as ripple marks, give clues about the climate and geology during geologic history.

Concretions

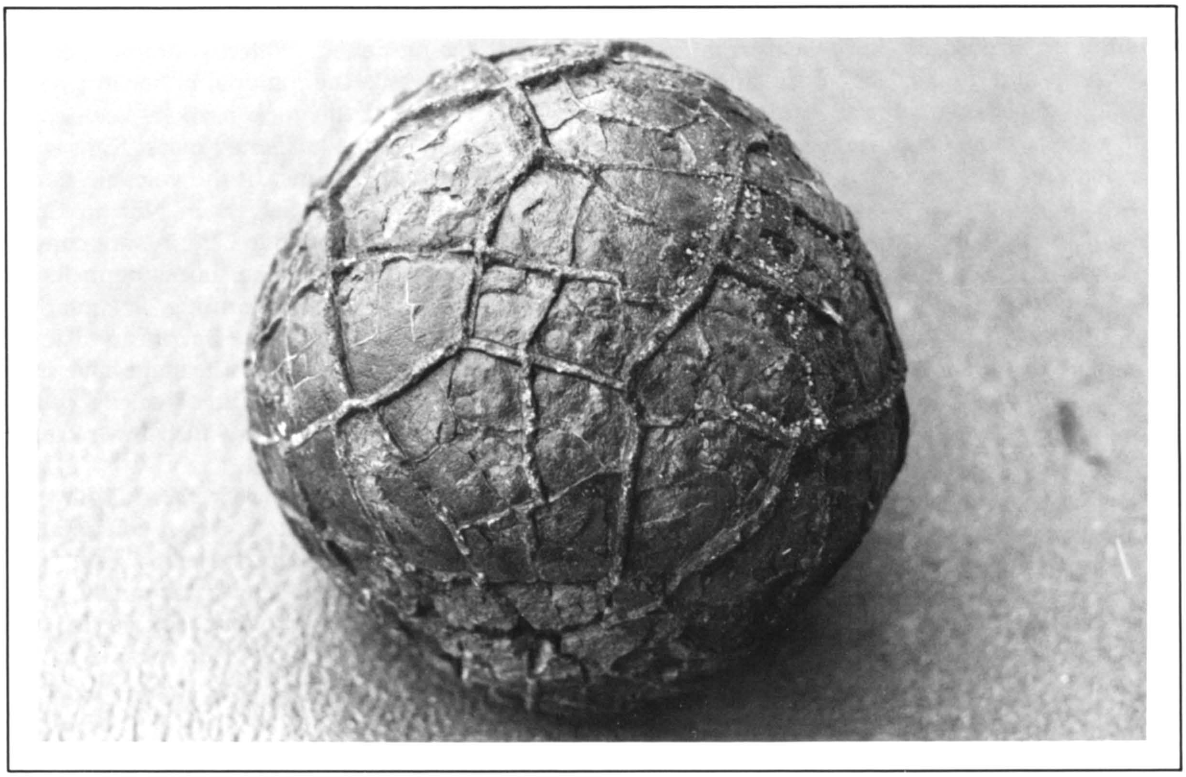
Concretions are masses of inorganic sedimentary materials in other sediments. They are generally harder than the rocks surrounding them, and therefore many of them are weathered out of the rocks. Concretions may be formed from any of a number of minerals. In Kansas they consist of calcite, limonite, barite, pyrite, or silica, the last in the form of opal, chert, chalcedony, or quartz. The shapes vary from round to oval or long and narrow. Many of them have irregular shapes that can be described as lumpy or globular. The smallest concretions are oolites, which measure less than two millimeters in diameter (or smaller than the head of a pin); the largest are many feet across.

Concretions are formed at the time the sediment is deposited, shortly after deposition, or after the sediment has hardened. Water, containing chemical elements, deposits the material either in cavities in the rock or around the rock particles, cementing them together to form a hardened mass. Kansas has many interesting concretions. In the volcanic-ash deposits, such as those near Calvert in Norton County and south of Quinter in Gove County, are concretions of ash cemented with calcite. Loess deposits also have small areas of calcite forming irregularly shaped nodules. Sandstones in the Dakota and Kiowa formations of the central part of the state have many large concretions, also the result of calcite cement. The largest of these (at Rock City in Ottawa County) have diameters of up to 27 feet.

The dark shales of the Cretaceous have a special type called septaria or septarian concretions. These are large concretions cut by many veins filled with yellow to brown calcite and occasionally other minerals, such as barite, gypsum, sphalerite, or quartz. They are thought to have been formed by shrinkage of concretions, causing cracks in the outer layers and thus opening spaces in which minerals were deposited. Small septarian concretions are sometimes called ''thunder-eggs.'' They can be found in many places; one of the best localities is one-half mile south of Hobbie Lake in Osborne County.



Mushroom Rocks State Park in Ellsworth County.



Septarian concretion, about the size of a volleyball, from north-central Kansas.

Geodes

Geodes, a type of concretion, are crystal-lined cavities in rocks. Geodes are formed by ground water that deposits minerals in solution on the walls of rock cavities. This type of deposition usually forms good crystals, most of which point toward the center of the cavity. Geodelike forms occur in fossil shells, and the entire shell may become lined with crystals. The minerals deposited may be quartz, calcite, barite, pyrite, galena, sphalerite, celestite, or dolomite.

Kansas geodes consist mostly of quartz, chalcedony, and calcite. Geodes are quite common and can be found in many localities. They have been reported near the town of Rock along the Walnut River in Cowley County; from the rocks on the hill just north of the Walnut River north of the town of Douglass in Butler County; near Chapman in Dickinson County; and from Riley, Cherokee, Marshall, Logan, Trego, Brown, and Wallace counties. Many good quartz geodes have been reported from Chase County.

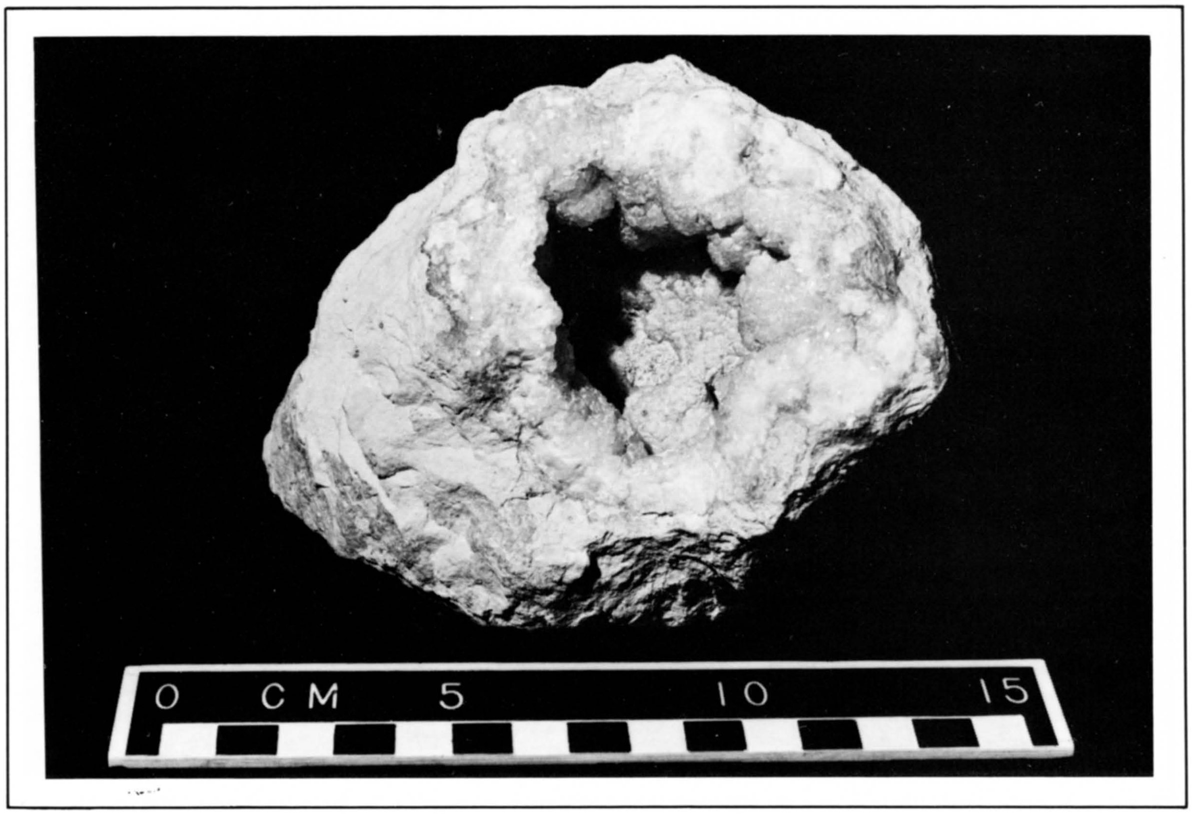
Cone-in-cone

Cone-in-cone is a peculiar structure consisting of nests of cones, one inside another, standing vertically and arranged either in thin beds or at the edges of large concretions. Some cones are less than an inch in height, and others are as much as 10 inches high. They have a ribbed or scaly appearance. Most cone-in-cone is composed of impure calcium carbonate, but occasionally the structure has been found in gypsum, siderite, and hard coal.

In Kansas cone-in-cone is abundant in the Kiowa Shale of Cretaceous age, where it occurs as beds extending laterally for many feet. When eroded or weathered out, it breaks into small pieces that may easily be mistaken for "chopwood" or petrified wood. Although cone-in-cone may look like fossilized wood, it is an inorganic structure, not the result of any fossil. Good specimens may be found in the banks of the Smoky Hill River and along the edge of Kanopolis Lake in Ellsworth County. Cone-in-cone also has been reported from the limestones in Montgomery, Lyon, McPherson, Washington, and other counties.

Mud cracks and rain prints

When muddy sediments are formed in shallow water, they are often exposed long enough at low tides or in dry seasons to permit drying and cracking. Fossil mud cracks are very similar to present-day mud cracks, except that further deposition has filled in the cracks and preserved them. Fossil mud cracks, when



Geode from Creswell formation in Dickinson County.

uncovered by erosion, may look like a honeycomb of ridges on a bedding plane.

Raindrop impressions may be preserved under the same conditions. Raindrops may make pits in soft sediments; the shape of the minute rim around the pit may indicate the direction from which the rain came.

Casts of salt crystals

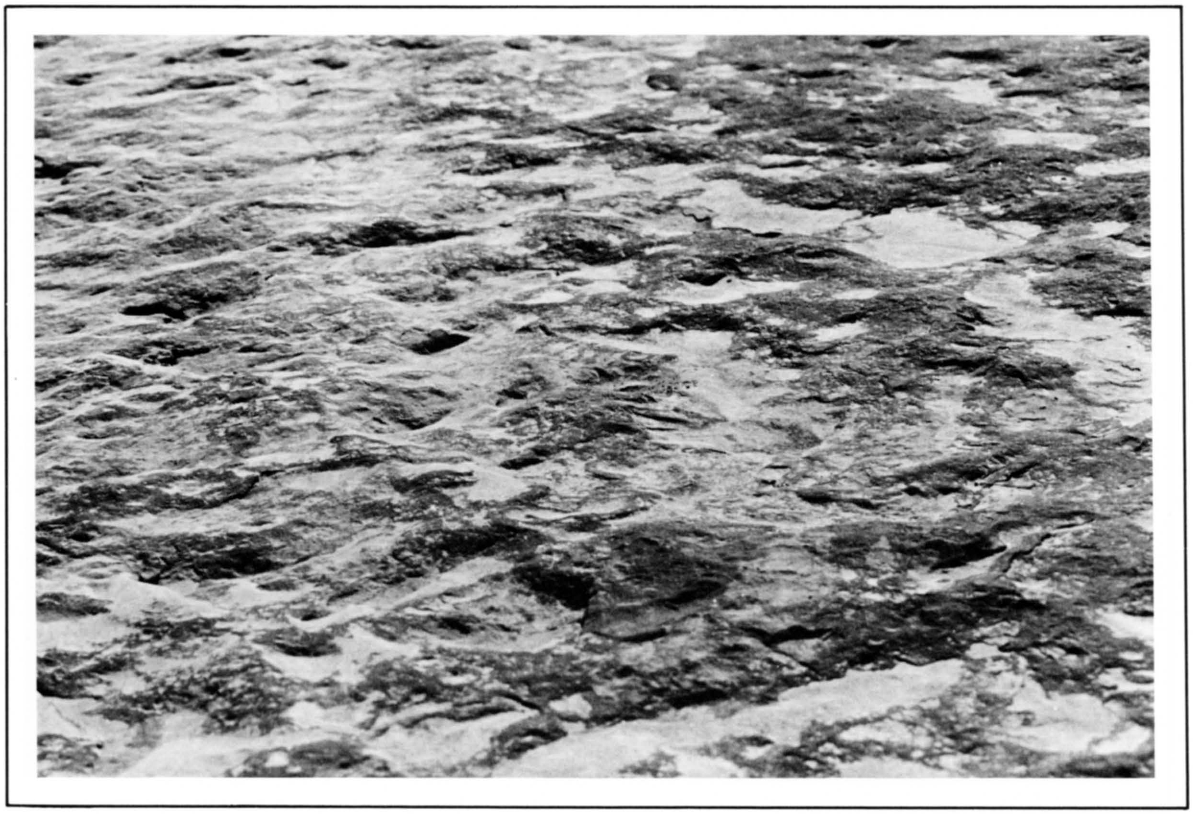
When salty mud dries, its surface becomes more or less covered with crystals of halite. Many of these crystals are cubes, but some have hollow faces and are known as "hopper" crystals. As they are covered up by more sediments, the salt itself may be dissolved, but the crystal outlines are commonly preserved (filled with mud or silt) and are known as salt casts. These features are found in many shales and siltstones, and they are particularly common in some of the Permian red beds of south-central Kansas.

Ripple marks

Ripple marks in many sandstones and siltstones are troughs and ridges that look like the ripples in loose sand in a stream, shallow lake, sea, or sand dune. Because of this similarity, observers can make shrewd guesses about the rock's origin and direction of prevailing winds. Other fossil ripple marks may be similar to the ripples in dune sand, indicating that the sandstone in which they are found was deposited by the wind.

Some of the water-type ripple marks are symmetrical from crest to crest, and some are not. The symmetrical ripple marks have been formed by waves in standing water, whereas the asymmetrical ripples were formed by water currents. Water-current ripple marks will tell observers what direction the water came from because the gentle slope faces the current and the steep slope is away from it, or downstream.

Ripple marks are common in Kansas sandstones, but some of the best can be found in a sandstone in the Bandera Shale in Bourbon County.



Ripple marks in Chautauqua County sandstone.

References

More information about Kansas rocks and minerals is available from a number of books and articles. Below is a list of sources that are helpful in studying rocks and minerals in general and the geology of Kansas in particular. In addition to these books, the Kansas Geological Survey has published hundreds of technical reports about the state's geology; a list of those books and maps is available upon request. Several periodical publications are also available, including the *Transactions of the Kansas Academy of Science* and the magazines *Rocks and Minerals, Earth Science,* and *Geotimes.*

DICTIONARY OF GEOLOGICAL TERMS (rev. ed.), by the *American Geological Institute,* 1976, Garden City, New York, Anchor Books, 472 p.

KANSAS GEOLOGY: AN INTRODUCTION TO LANDSCAPES, ROCKS, MINERALS, AND FOSSILS, by *Rex Buchanan* (ed.), 1984, Lawrence, Kansas, University Press of Kansas, 208 p.

HISTORY OF THE EARTH, by *Don L. Eicher* and *A. Lee McAlester,* 1980, Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 413 p.

DANA'S MANUAL OF MINERALOGY, by *C. S. Hurlbut, Jr.,* and *C. Klein,* 1977, New York, New York, John Wiley and Sons, Inc., 544 p.

LAND OF THE POST ROCK: ITS ORIGINS, HISTORY, AND PEOPLE, by *Grace Muilenburg* and *Ada Swineford,* 1975, Lawrence, Kansas, University Press of Kansas, 207 p.

EARTH (2nd ed.), by *Frank Press* and *Raymond Siever,* 1978, San Francisco, W. H. Freeman and Co., 649 p.

SIMON AND SCHUSTER'S GUIDE TO ROCKS AND MINERALS, by *Martin Prinz, George Harolow,* and *Joseph Peters* (eds.), 1978, New York, Simon and Schuster, 607 p.

THE GEOLOGIC STORY OF THE GREAT PLAINS, by *Donald E. Trimble,* 1980, Washington, D.C., U.S. Geological Survey, Bulletin 1493, 55 p.

Tables for identification of Kansas minerals

In the following pages are brief tables that may be useful in identifying Kansas minerals. So far as minerals from other states are concerned, the tables may be of no value and actually can be misleading. Therefore, published tables (such as those in Dana's *Manual of Mineralogy*) are strongly recommended for consultation for identification of any non-Kansas mineral.

Before attempting to identify minerals, the beginning collector should have on hand a small bottle of dilute hydrochloric (muriatic) acid, obtainable in any drugstore; a piece of unglazed porcelain, such as a small tile, for streak tests; an inexpensive steel pocketknife; a piece of ordinary window glass; and a chunk of quartz. A candle and a small pocket magnifier also are useful.

I. Metallic or submetallic luster

A. Will mark paper (hardness less than 2½)

Streak	Color	Hardness	Remarks	Name, composition
Black	Black	1–2	May be in radiating fibrous masses	Pyrolusite, MnO_2
Gray-black	Lead-gray to blue-black	2½	In cubic crystals with perfect cleavage. May be massive granular. Small globules of metallic lead collect on surface of fragment held in candle flame	Galena, PbS
Yellow-brown	Yellow-brown	1+	Earthy. Usually much harder. Ap-	Limonite,

	(to dark-brown or black)		parently noncrystalline	$FeO(OH) \cdot nH_2O + Fe_2O_3 \cdot nH_2O$

B. Will not readily mark paper, but can be scratched by knife (hardness 2½ to 5½)

Streak	Color	Hardness	Remarks	Name, composition
Black	Brass-yellow	3½–4	Commonly massive. Associated with dolomite, galena, and sphalerite in Tri-State area	Chalcopyrite, $CuFeS_2$
Black or brownish black	Black	5–6	Massive, may occur as coatings. Associated with pyrolusite	Psilomelane, primarily MnO_2
Light- to dark-brown (lighter than specimen)	Brown to black	3½–4	Perfect cleavage in six directions. Resinous luster	Sphalerite, ZnS
Yellow-brown	Dark-brown to black	5–5½	Glassy luster. Seemingly noncrystalline	Limonite, $FeO(OH) \cdot nH_2O + Fe_2O_3 \cdot nH_2O$

C. Cannot be scratched by knife (hardness greater than 5½)

Streak	Color	Hardness	Remarks	Name, composition
Black	Pale brass-yellow	6–6½	Massive granular. Commonly in striated cubes or pyritohedrons	Pyrite, FeS_2
	Very pale yellow	6–6½	Commonly in "cockscombs" or radiating fibrous structures	Marcasite, FeS_2
	Black	6	Strongly magnetic. Crystals are small octahedrons	Magnetite, Fe_3O_4
Dark-brown to black	Black	5½–6	Commonly massive granular	Ilmenite, $FeTiO_3$
	Black	5–6	Massive, may occur as coatings. Associated with pyrolusite	Psilomelane, primarily MnO_2
Yellow-brown	Dark-brown to black	5–5½	Glassy luster. Seemingly noncrystalline	Limonite, $FeO(OH) \cdot nH_2O + Fe_2O_3 \cdot nH_2O$

II. Nonmetallic luster

A. Colored streak

Streak	Color	Hardness	Remarks	Name, composition
Red-brown; "Indian brown"	Dark reddish-brown to steel-gray to black	5½–6½	Massive; radiating. Some varieties softer. Coloring matter in some sandstones (brownish-red)	Hematite, Fe_2O_3
Yellow-brown	Yellow-brown	5–5½	Earthy to hard, with glassy luster.	Limonite,

	to black		Seemingly noncrystalline	$FeO(OH) \cdot nH_2O + Fe_2O_3 \cdot nH_2O$
Light-brown	Light to dark-brown	3½–4	Perfect cleavage in six directions. Resinous luster	Sphalerite, ZnS
Pale-yellow	Pale-yellow	1½–2½	Granular, earthy, crystallized. Burns with blue flame, giving sulfur dioxide odor	Sulfur, S
Light-green	Bright-green	3½–4	Radiating, fibrous. Occurs as small specks in some dolomite beds	Malachite, $Cu_2CO_3(OH)_2$

B. Colorless streak

1. Can be scratched by fingernail (hardness less than 2½)

Cleavage, fracture	**Color**	**Hardness**	**Remarks**	**Name, composition**
Perfect cleavage in one direction (the micas)	Golden yellow-brown; brownish-red	1–1½	As small scales or "books." Expands when heated	Vermiculite, $(Mg,Fe)_3(Si,Al,Fe)_4O_{10}(OH)_2 \cdot 4H_2O$
	Greenish-white; yellowish; colorless	2–2½	As small scales or "books"	Muscovite mica, $KAl_2Si_3O_{10}(OH)_2$
	Dark-brown, green to black	2½–3	As small scales or "books"	Biotite mica, $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$
	Yellowish-brown	2½–3	As small scales or "books" with copperlike reflection from cleavage faces	Phlogopite mica, $KMg_3AlSi_3O_{10}(OH)_2$
Perfect cleavage in one direction; good cleavage in two directions	Colorless, white, gray pink	2	In flat crystals, broad cleavage flakes (selenite) or compact massive without cleavage, or fibrous with silky luster (satin spar)	Gypsum, $CaSO_4 \cdot 2H_2O$
Uneven fracture	Pale-yellow	1½–2½	Granular, earthy, crystallized. Burns with blue flame, giving sulfur-dioxide odor	Sulfur, S
Conchoidal fracture	Light yellowish-brown	2–2½	Resinous luster. Very lightweight. Not a true mineral	Amber, oxygenated hydrocarbon
One perfect cleavage, rarely seen	White, reddish, or yellowish	2	Long needlelike crystals; on mine walls, Tri-State district	Goslarite, $ZnSO_4 \cdot 7H_2O$
Indistinct	Greenish-white to white	2	Very fine fibrous masses, associated with marcasite and pyrite. Sweetish, metallic, bitter taste	Melanterite, $FeSO_4 \cdot 7H_2O$

2. Cannot be scratched by fingernail but can be scratched by knife (hardness 2½–5½)

Cleavage, fracture	Color	Hardness	Remarks	Name, composition
Perfect cleavage in three directions at right angles	Colorless, white, red, blue	2½	Common salt, soluble in water. Salty taste. Granular cleavable masses or cubic crystals	Halite, $NaCl$
Cleavage in three directions at right angles (no cleavage if massive)	Colorless, white, bluish-gray, red	3–3½	Crystals rare. Commonly in massive fine aggregates (not showing cleavage) associated with gypsum; massive variety can be distinguished only by chemical tests	Anhydrite, $CaSO_4$
Perfect cleavage in three directions not at right angles (rhombohedral)	Colorless, white, and various tints	3	Effervesces in cold acid. Many crystal forms. Chief mineral in limestone. Fibrous, banded, and granular varieties do not show cleavage	Calcite, $CaCO_3$
Perfect cleavage in two directions at right angles; imperfect cleavage in third direction	White, blue, yellow, pink	3–3½	Commonly in aggregates of tabular crystals. Heavier than most nonmetallic minerals (differentiated from celestite). In sand-barite rosettes	Barite, $BaSO_4$
	White, blue, red	3–3½	Similar to barite. Distinguished by crimson flame test	Celestite, $SrSO_4$
Cleavage not prominent	Colorless or white	3–3½	Small splinter fusible in candle flame, producing lead globules. Hard, brilliant luster. Granular masses and platy crystals, associated with galena	Cerussite, $PbCO_3$
	Yellow	3–3½	Fine coating on sphalerite and other minerals in Tri-State district. Resinous to earthy luster	Greenockite, CdS
One cleavage direction, indistinct	Colorless, white, various tints	3½–4	Effervesces in cold acid, falls to powder in candle flame. May be in radiating needlelike crystals	Aragonite, $CaCO_3$
Three perfect cleavage directions not at right angles (rhombohedral)	Colorless, white, various tints	3	Effervesces in cold acid. Many crystal forms. Chief mineral in limestone. Fibrous, banded, and granular varieties do not show cleavage	Calcite, $CaCO_3$
	Colorless, white, pink	3½–4	Commonly in curved rhombohedral crystals with pearly luster. In granular masses as dolomite limestones. Powdered mineral effervesces mildly in cold acid	Dolomite, $CaMg(CO_3)_2$
	Light- to dark-brown	3½–4	In cleavable masses or small curved rhombohedral crystals. Also fine granular (without cleavage). Becomes magnetic after heating in candle flame. Occurs in clay ironstones	Siderite, $FeCO_3$

Perfect cleavage in six directions	Yellow, brown	3½–4	Resinous luster. In small four-sided crystals or in cleavable masses. May be massive	Sphalerite, ZnS
Conchoidal fracture	Colorless, white, yellow, red, brown, green, gray, blue	5–6	Seemingly noncrystalline. Hardness less than fine-grained quartz	Opal, $SiO_2 \cdot nH_2O$
Cleavage rarely seen	Brown, green, blue, pink, white	4–5	In rounded globular forms or honeycomb masses. Rare rhomb-shaped crystals. Effervesces in cold acid	Smithsonite, $ZnCO_3$
Cleavage in two directions, rarely seen	White, pale-green, blue	4½–5	Radiating crystal groups and globular forms	Hemimorphite, $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

3. Cannot be scratched by knife but can be scratched by quartz (hardness 5½ to 7)

Cleavage, fracture	**Color**	**Hardness**	**Remarks**	**Name, composition**
Two cleavage directions at nearly 90° angles	White, gray, bluish, pink, green	6	In cleavable masses or irregular grains in rocks. Common in stream gravel	Feldspar, $KAlSi_3O_8$, or $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$
Conchoidal fracture	Colorless, white, yellow, red, brown, green, gray, blue	5–6	Seemingly noncrystalline. Hardness less than fine-grained quartz	Opal, $SiO_2 \cdot nH_2O$
	Gray, light-brown, cream, yellow, red, green	7	Waxy to dull luster. May be banded or lining cavitites. Cryptocrystalline quartz	Chalcedony, SiO_2
	Colorless, white, amethyst, variously tinted	7	Crystals are six-sided prisms capped by pyramids. Often massive, coarsely crystalline. Glassy to greasy luster	Quartz, SiO_2

4. Cannot be scratched by quartz (hardness greater than 7)

Cleavage, fracture	**Color**	**Hardness**	**Remarks**	**Name, composition**
Conchoidal fracture	Colorless, white, amethyst, various tinted	7	Crystals are six-sided prisms capped by pyramids. Often massive, coarsely crystalline. Glassy to greasy luster.	Quartz, SiO_2
Uneven to subconchoidal fracture	Brown, red	6½–7½	Crystals have many faces of about equal size. Glassy luster	Garnet, silicates of Al, Ca, Mg, Fe, Mn, or Cr

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