KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 2001-41

Geology of South-central Kansas Field Trip
Public Field Trip in Celebration of Earth Science Week

by

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Introduction

This field trip focuses on the rocks and fossils of south-central Kansas, specifically those that crop out in several locations in Butler, Greenwood, Woodson, and Wilson counties (see map, p. 14). Most of the rocks we will see at our stops were deposited during the Pennsylvanian Period of geologic time, about 300 million years ago. Although we will be in the Osage Cuestas physiographic region for most of our stops, on Stop 3 we will be in the Chautauqua Hills region (see factsheets).

This field trip is part of the Kansas Geological Survey's participation in Earth Science Week (October 7–13), a national celebration of the earth sciences, established in 1998 by the American Geophysical Institute, based in Alexandria, Virginia. Earth Science Week is a time to increase public awareness and understanding of the earth sciences. For more information about Earth Science Week, visit their web site at **www.earthsciweek.org.**

From El Dorado to Stop 1

We begin our field trip in El Dorado in East Park, just east of the Kansas Oil Museum, which is operated by the Butler County Historical Society. East Park is just west of the Walnut River, and it was the Walnut River valley that inspired an early settler to exclaim, "El Dorado!" when he saw the area. El Dorado is Spanish for "land of gold" and was the legendary quest of many early explorers in the New World.

It wasn't until many years later that this region, in fact, did become the land of gold—black gold. In 1915 oil was discovered about 3 miles northwest of East Park on the Stapleton lease (in two sandstones 590 and 670 feet below the surface). The El Dorado field was born.

However, the story begins about three years earlier when Erasmus Haworth, an early director of the Kansas Geological Survey, and his son did detailed mapping of the surface rocks in the area around El Dorado. Oil and gas had previously been discovered in the Augusta area, in association with what geologists call an anticline (an upward bulge in the earth's strata). Haworth discovered a large anticline near El Dorado and recommended it as a site for oil exploration. On October 6, 1915, Haworth's prediction became a reality when a well belonging to Cities Service struck oil. This was the first discovery of a major oil field using scientific methods—namely, detailed geologic mapping of the surface rocks.

In a short time, El Dorado became the largest oil field in Kansas, a distinction it held until just a few years ago. By 1918 oil from the El Dorado field accounted for 12.8% of the nation's production and 9% of the world's production. This field helped fuel our entry into World War I and thus was a factor in the Allied victory.

From East Park we travel east along U.S. Highway 54 (Central Ave), crossing the Walnut River. The elevation here is about 1,260 feet above sea level. As we continue east, we will slowly gain elevation as we climb the gentle western slope of the escarpment formed on the limestones of the Barneston Limestone. Like most of the rocks in eastern Kansas, the Barneston dips very slightly to the west. It also caps the highest ridges of the Flint Hills, the physiographic region in which El Dorado and most of Butler County lie (see factsheet). However, it is not until we reach the edge of the Barneston escarpment that the scenery takes on the rugged appearance we associate with the Flint Hills.

For the first 12 miles of the route, until we get close to the small town of Rosalia, the limestone that we see at the surface is the Fort Riley Limestone Member, the uppermost unit of the Barneston Limestone. The Fort Riley is an important limestone resource, and there are several quarries in the El Dorado area where it is quarried for aggregate and rip-rap. The Fort Riley has also been used as a building stone; part of the state capitol in Topeka is built from Fort Riley limestone quarried near Junction City. In Cowley County, to the south, the Fort Riley is known locally as the Silverdale limestone because of large quarries near the small town of that name.

From Rosalia, we continue eastward through an area in which the Florence Limestone Member is at the surface. The Florence is the lowermost unit in the Barneston and is one of the limestones containing large amounts of the chert, or flint, that give this region its name. Chert is chemically similar to quartz, but lacks quartz's crystalline properties and has water as part of its chemical make-up. Flint Hills chert is usually white, gray, pale blue, or brown. Because chert is more resistant to weathering than the surrounding limestone, it remains after the limestone has been worn or dissolved away and litters much of the countryside where it crops out.

Near mile marker 269, U.S. Highway 54 crosses the crest of the Flint Hills escarpment; the elevation here is 1,610 feet, 350 feet above the Walnut River in El Dorado. To the south, the gentle western dip of the rocks is reflected in the dipping horizon formed by the hills.

As we continue east on Highway 54, we cross into Greenwood County and leave the Flint Hills behind, entering the physiographic region called the Osage Cuestas, characterized by limestones and shales that form small, eastward-facing escarpments, or cuestas (see factsheet). When we crossed into Greenwood County, we also crossed a time boundary, leaving behind rocks formed during the Permian Period (less than 290 million years ago) and entering a region where the surface rocks were formed during the Pennsylvanian Period (more than 290 million years ago). Because the deposition of alternating limestones and shales was almost continuous in this area 290 million years ago, geologists debate just where to put the boundary between the two periods. In fact, this boundary has been moved a number of times.

At about mile marker 281, the highway drops off a small escarpment formed on the Bern Limestone (fig. 1). We will see this formation exposed at Stop 1.

As the route continues through Eureka, it crosses Fall River, where the elevation is 1,010 feet, or 250 feet below the Walnut River in El Dorado and 600 feet below the crest of the Flint Hills in Butler County. Eureka is the county seat of Greenwood County.

In Eureka, turn left (north) on Main Street and go 1 mile to 13th Street, passing the Greenwood County courthouse. Turn right (east) on 13th Street and go 0.4 mile to North State Street and turn left (north). Continue north 4.5 miles to the entrance of a park-like area near the north end of the dam at Eureka City Lake. We will park here and walk a short distance south to the spillway (Stop 1).

STOP 1—Eureka City Lake Spillway

The spillway at Eureka City Lake is a good place to learn about the basic bedrock geology in south-central Kansas. Eureka City Lake was built in the 1930's as a Works Progress Administration (WPA) project and is a water supply lake for Eureka, about 5 miles to the south. The spillway is a means by which water can move out of the lake during times of extremely high water levels.

Several distinctive rock layers are visible at the spillway; in fact, this site has exposures of limestone, shale, and sandstone, the three common rock types in Kansas (fig. 2). These rocks were deposited during the Pennsylvanian Period of geologic history (also known as the Coal Age), from about 323 to 290 million years ago. During that time, Kansas was near the equator, the climate was warmer, and a shallow sea advanced and retreated repeatedly across eastern Kansas (figs. 3, 4).

At times the sea left behind minerals that eventually became limestone, the brown and tan rocks in the spillway. Limestone is made up of calcium carbonate, debris composed of sea shells and other marine life, and minerals that were deposited onto the shallow ocean floor. Some of those limestones contain fossils of the invertebrate animals that were common during the Pennsylvanian—corals, clams, brachiopods, and crinoids. These creatures secreted calcium carbonate to form shells and other hard body parts that make up these limestones.

At other times, rivers deposited mud into the oceans; these muds eventually formed shales, the softer, thinly layered, gray rocks in between the limestones. Occasionally, this area was at or slightly above sea level and sandstone was deposited by rivers flowing into estuaries and deltas, and coal was deposited in marshes. Limestone, shale, and sandstone are sedimentary rocks—that is, they are made up of fragments of rock or shells that were deposited by wind or water. Except for rare exceptions (one of which we will see at Stop 2), rocks at the surface in Kansas are exclusively sedimentary in origin.

In order to identify different rock layers, geologists have given each of them a name, based on the location where it was first described (see factsheet for more information about how rocks are named). Here at the spillway, overflow from Eureka City Lake has formed a waterfall over two layers in the formation called the Bern Limestone. The uppermost layer is the Wakarusa Limestone Member; the

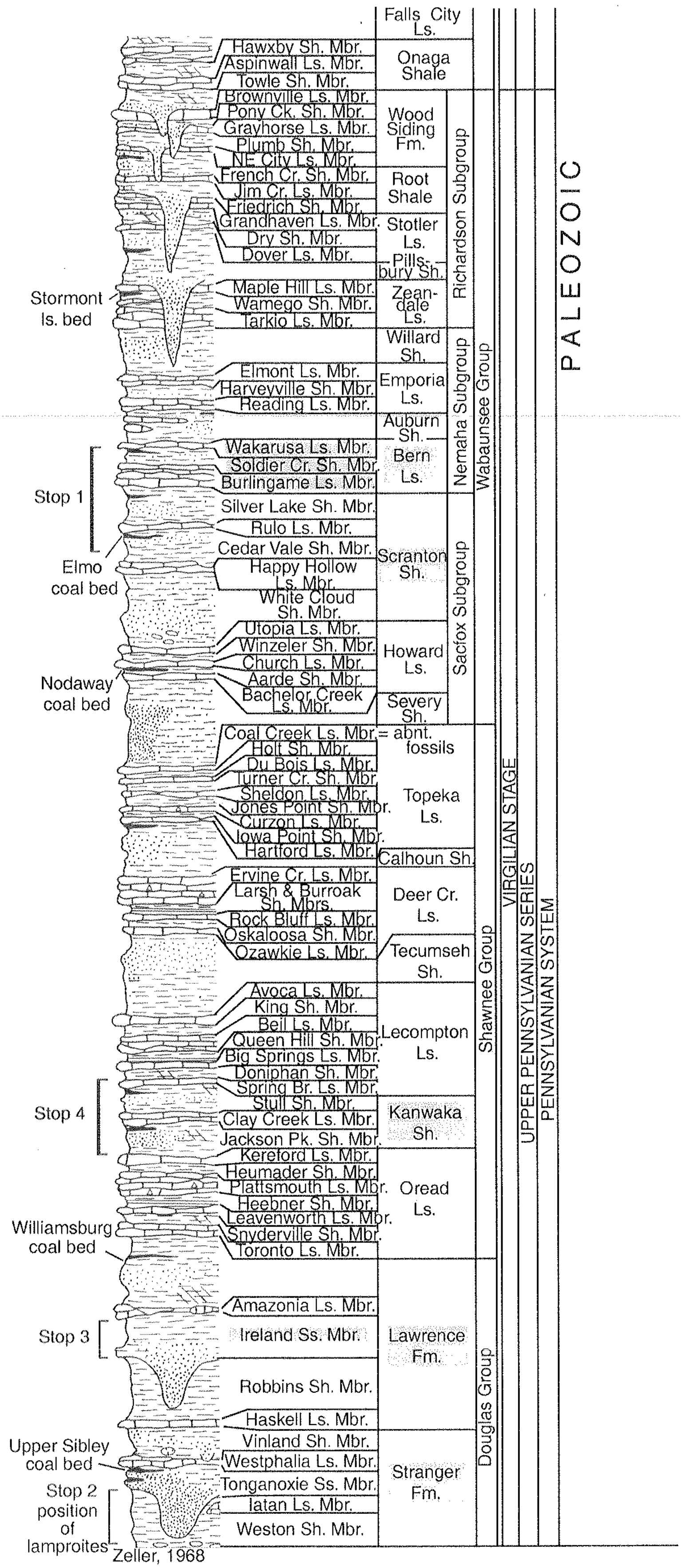

Fig. 1—Stratigraphic classification of Upper Pennsylvanian rocks in Kansas (from Zeller, 1968).

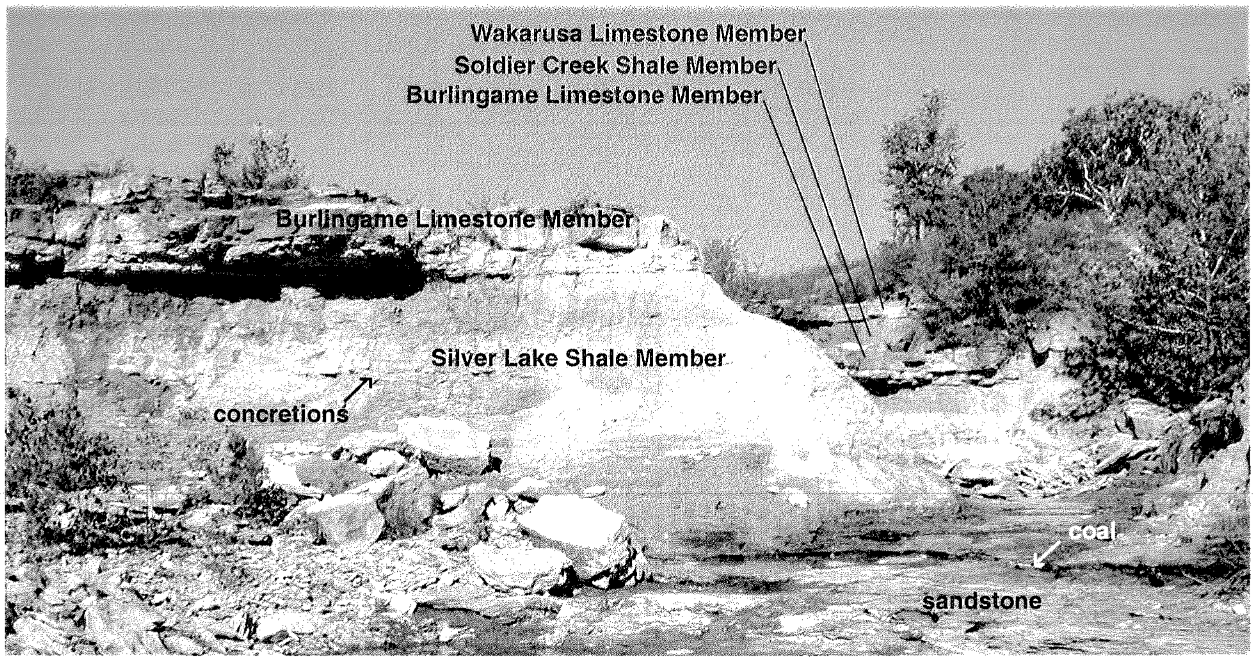

Fig. 2—Spillway at Eureka City Lake and the different rock units that are exposed there.

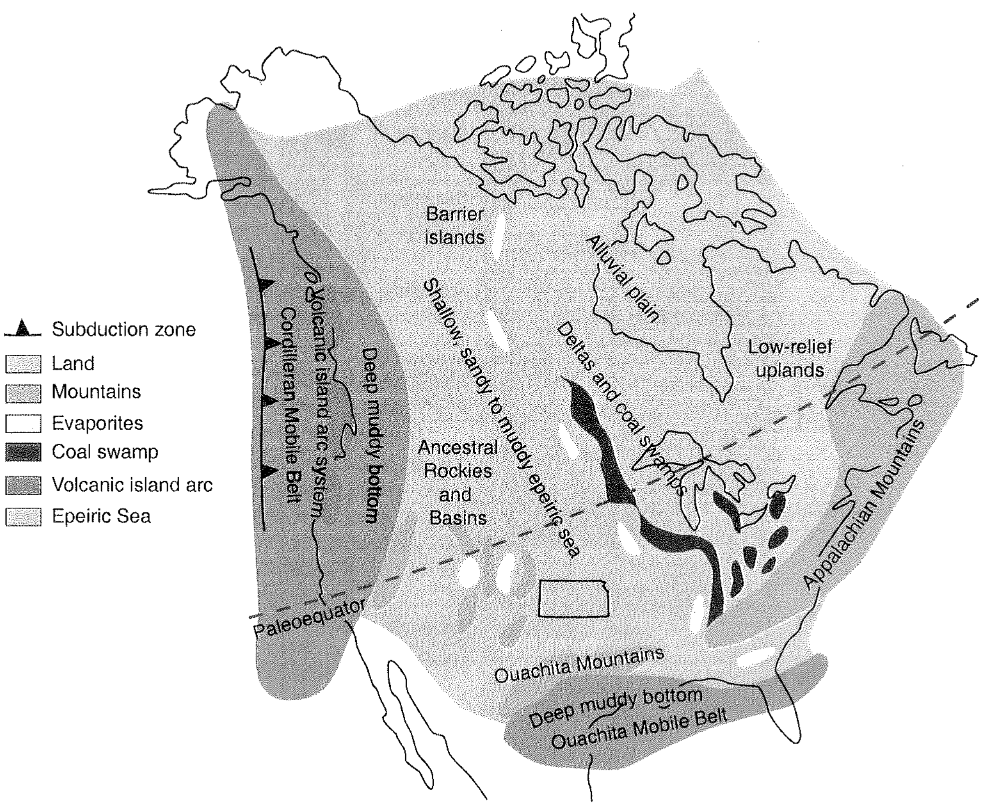

Fig. 3—Geography of North America during the Pennsylvanian Period, about 300 million years ago. Present-day Kansas was near the shore of the shallow sea (from Wicander and Monroe, 1989).

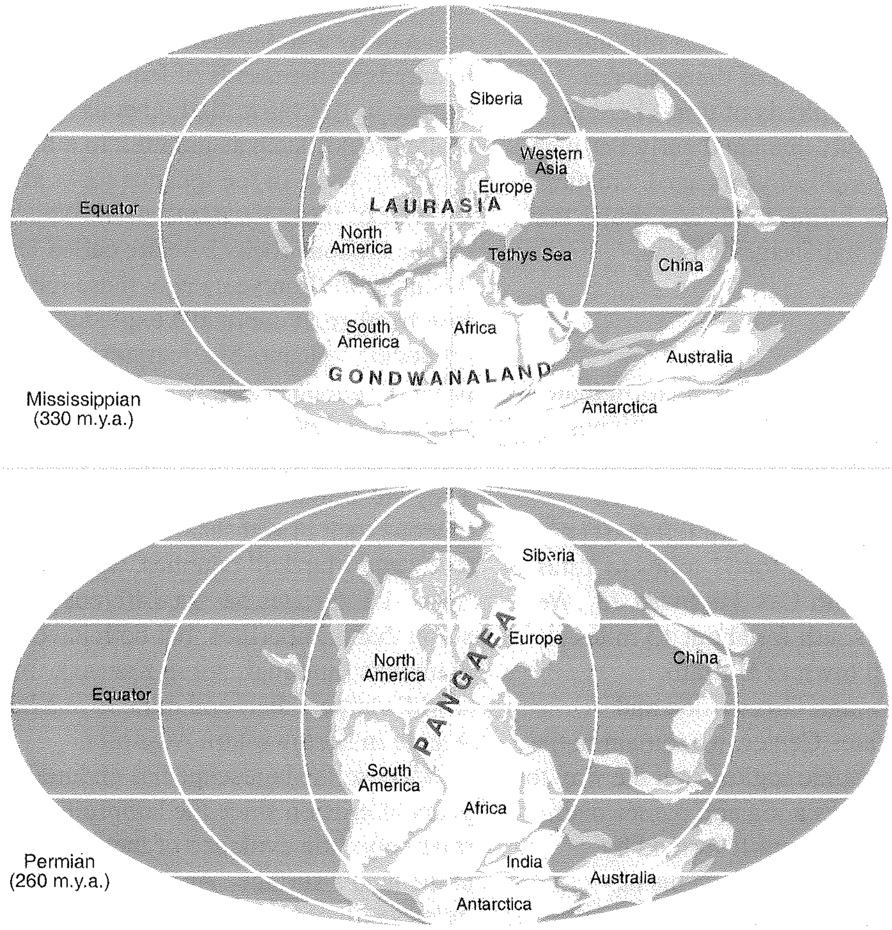

Fig. 4—Positions of the plates during the Mississippian and Permian periods, the two periods bracketting the Pennsylvanian Period. During the Pennsylvanian, Kansas lay near the equator (from Tarbuck and Lutgens, 2000).

lower one is the Burlingame Limestone Member. Both members are named for outcrops near towns south of Topeka. These limestones are separated by the Soldier Creek Shale Member.

Below the Burlingame is a thick sequence of gray shale and sandstone in the upper part of the Scranton Shale, the Silver Lake Shale Member. Below the Silver Lake is a sandstone layer, which is also part of the Scranton Shale. The sandstone contains mica flakes and woody fragments and also displays various sedimentary structures, including ripple marks (fig. 5). A thin coal layer can also be found in the Scranton.

The different sedimentary rocks in this sequence indicate changing environments of deposition. The coal and ripple-marked sandstone were formed slightly above sea-level, perhaps in a swampy delta. The shale most likely was deposited as sea level rose slightly. As water got deeper and the shoreline was farther away, the influx of sediment decreases. The water cleared up enough for shell-secreting

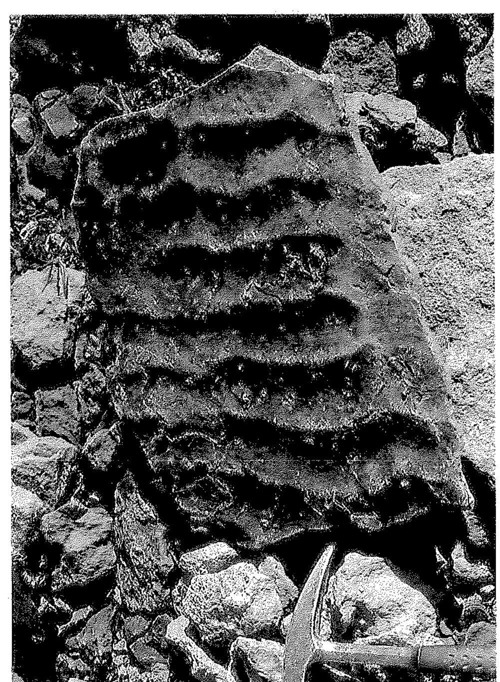

Fig. 5—Ripple marks in sandstone at Eureka City Lake.

invertebrates to flourish. The calcium carbonate shells they formed are the raw materials making up the limestones we see at the top of the sequence. This sequence recurred hundreds of times here in Kansas during the Pennsylvanian and early Permian (from about 323 to 275 million years ago), creating the repetitive sequence of limestones and shales that make up the Flint Hills and Osage Cuestas.

STOP 1 to STOP 2

From Stop 1, we backtrack south on North State Street to Eureka and turn left (east) on 7th Street. We take 7th Street for 0.4 miles to Jefferson Street and turn right (south) for one-half mile to U.S. Highway 54 or River Street. We turn left (east) on Highway 54 and continue east for 31 miles to Yates Center and the junction with U.S. Highway 75. We take Highway 75 to the south for about 13 miles until we reach the small town of Buffalo.

As we travel east through Greenwood and Woodson counties to Yates Center, we remain in the Osage Cuestas physiographic region. On the way to Buffalo, the highway makes a jog and passes over Rose Dome—a broad, gentle uplift formed by igneous intrusion below the surface. This has brought limestone in the Stanton Formation to the surface, and it is quarried near the highway. The Stanton can be traced northward to the Kansas City area. In this quarry, gentle dips can be seen in the limestone beds, reflecting the arching of the bedrock.

When we reach Buffalo, we turn right (west) at the Micro-Lite sign and proceed through town on Micro-Lite Street. The Micro-Lite plant is located on the west edge of town, along the railroad tracks.

From the Micro-Lite plant, we head west, passing clay pits in the Weston Shale Member of the Stranger Formation, which provided raw material for a brick plant that once operated in Buffalo. After about 4 miles, we turn right (north), passing the Wildcat Ranch. Proceed 1.25 miles and then turn left (west) and go 0.5 mile and turn right (north) at the entrance to the mine and proceed about 0.75 miles to the loading area, where we will park the bus and then walk into the quarry area (Stop 2).

STOP 2—Micro-Lite Quarry/ Silver City Dome

Most of the rocks at the surface of Kansas are sedimentary in nature—that is, they are made up of sediments usually deposited at the bottom of an ocean or by a stream. In general, you have to drill hundreds or thousands of feet below the land's surface in Kansas to find igneous rocks, those once-molten rocks, such as granite. In a few places, however, you can see igneous rocks at the surface, and two of those locations are in Woodson County.

The igneous rocks here are called lamproites. About 90 million years ago, these igneous rocks rose from great depth and exploded to the surface, producing volcano-like features. Lamproites are pipes of igneous rock, which was highly charged with gas and pushed its way up through faults, fractures, and zones of crustal weakness (fig. 6). They are similar to kimberlites, another type of igneous rock in Kansas, found at 13 locations in Riley and Marshall counties, west of Tuttle Creek Lake. Lamproites have a different chemical composition than kimberlites, but both have produced diamonds (although not in Kansas). In fact, the world's largest diamond mine is in a lamproite at Argyle in northwestern Australia.

Because the landscape has endured millions of years of erosion since the lamproites here erupted, relatively little evidence of these features is visible at the land's surface. At Rose Dome, about five miles south of Yates Center, the intrusion of the lamproite created a broad dome that is apparent at the land's surface and on topographic maps. In addition to the pipe of molten rock that blew to the surface, other lamproite intruded itself into the

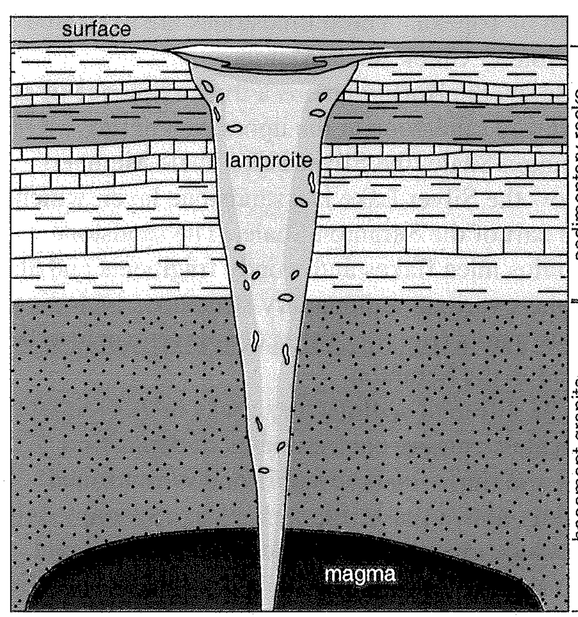

Fig. 6—Generalized diagram of a lamproite pipe.

underground rock (because lamproite and kimberlite intrude themselves into rock that is already in place, they are sometimes referred to as "intrusives"). Horizontal sheets of lamproite branch off the main pipe. These layers, or sills, extend away from the main pipe and have been encountered at depths of about 1,300 feet during core drilling, and drilling for oil and gas, in the area around the dome.

The lamproite itself is not visible at the surface of Rose Dome, but a number of granite boulders litter a pasture west of U.S. Highway 75. These granite boulders, which are generally surrounded by trees that have grown up around them, probably came along for the ride with the lamproite when it exploded to the surface. The granite was probably originally part of the crystalline basement rock that is about 2,500 feet deep here, and lies beneath the overlying sedimentary rocks. These granites are about 1.2 billion years old, formed during ancient Precambrian times. Geologists use the term "xenolith" for rock fragments, such as these chunks of granite, that are "foreign rocks," or not part of the intrusive but mixed in with the lamproite, like chocolate chips in cookie dough. These granites seem so out-of-place here that early geologists thought they might have been carried in by glaciers, though we now know that glaciers did not extend this far south in Kansas.

The lamproite we will visit today is at the Silver City dome, southwest of Rose Dome. The Silver City lamproite is very similar to the Rose Dome. The actual topographic dome at Silver City is more subtle and a little more difficult to visualize than at Rose Dome; however, the lamproite itself is exposed at Silver City. The lamproite contains shiny flakes of mica; that led to early reports that the rock contained silver and a short burst of mining in the 1870's that produced a settlement called Silver City. While there is no silver here, the lamproite has been mined intermittently since then, and steadily since 1982 when Micro-Lite began quarrying one of the lamproite sills. The lamproite is quarried and hauled to the nearby town of Buffalo, where it is bagged and eventually used as a mineral supplement for cattle feed. The rock contains small amounts of the essential minerals magnesium, potassium, and iron. In 1996, Micro-Lite mined about 70,000 tons of lamproite.

While much igneous rock is very hard, the lamproite exposed at the surface here is soft and powdery, weathering to an olive brown. The rock itself is called peridotite (pronounced pah-RID-oh-tight); it is coarse grained and high in the minerals olivine and pyroxene. Surrounding the lamproite are sedimentary rocks that were deposited in Pennsylvanian times, about 300 million years ago, before the lamproite came to the surface. When the lamproite exploded to the surface, it was extremely hot, as much as 800 degrees Celsius, cooking the limestones and shales that it contacted. This process is called "contact metamorphism"—the high heat of the molten rock cooks and changes the existing sedimentary rocks (these previously in-place sedimentary rocks are sometimes referred to as "country rock" a term that, in this context, has nothing to do with music). Thus, some of these sedimentary rocks (such as the Weston Shale Member and the Tonganoxie Sandstone Member of the Stranger Formation) are now extremely hard and have a far different character than the much softer rocks that we have seen in the other stops on this field trip.

STOP 2 to STOP 3

From the Micro-Lite Quarry, we backtrack about 0.75 mile to the east-west gravel road, where we turn right (west) for 1 mile, and then left (south) for another mile, passing a quarry in the Stanton Limestone on the south flank of the Silver City Dome. At the T-intersection, we turn right (west) for 1.5 miles until we come to Middletown. The hills along this stretch mark the southwest rim of the Silver City Dome. At Middletown, we turn left (south) again for 1 mile. At the T-intersection, we turn right (west) and travel 2 miles to the crossroads, where we turn left (south) and curve to the right (west), crossing the Verdigris River. The elevation of the river is about 845 feet—the lowest point on the trip. We'll continue west for about 1.5 miles to the junction with a blacktop road, where we turn right (north) and travel 3 miles to the junction with Kansas Highway 105.

On K-105 we continue north and eventually west for about 5.3 miles, passing along the east side of Toronto Lake. On the east edge of the town of Toronto, we turn left (south) on Point Road and continue for a little less than 2 miles to the Toronto Point area of Toronto Lake State Park (Stop 3).

STOP 3—Toronto Lake

Toronto Lake was completed in 1960 and occupies approximately 2,800 acres. The park encompasses an additional 1,075 acres and offers visitors recreational activities such as swimming, fishing, water skiing, camping, hiking, picnicking, and wildlife observation.

Located in the gently rolling terrain of the Verdigris River valley, Toronto Lake marks the northernmost reaches of the Chautauqua Hills physiographic region, a region of sandstone hills formed on thick sandstones in the Lawrence and Stranger Formations. These sandstones were deposited in deep, alluvial valleys during the Pennsylvanian Period, at a time when the area was above sea level. A patchwork of oak woodlands and tallgrass prairie cover the hills in this region; as a result, they are sometimes known as the Cross Timbers, a vegetative complex that extends southward into Oklahoma and central Texas.

This stop gives us a chance to see one of the sandstones that characterizes this region, the Ireland Sandstone Member of the Lawrence Formation. The Ireland Sandstone was deposited in an ancient river valley that existed in eastern Kansas during the Pennsylvanian Period. At that time this part of Kansas was above sea level, and the seashore was southwest of here. This stream flowed in a south-southwest direction and deposited sand in a broad deep valley several miles in width that can be traced north-northeastward into the Leavenworth area. This stream valley was filled with sand up to at least 160 feet in depth, which has since been cemented into sandstone.

Where this sandstone is at or close to the surface, rain and runoff have soaked into the pores between the sand grains and created a freshwater aquifer that supplies water to farms and some small towns in its vicinity. This sandstone contains structures such as ripple marks and cross-bedding which are indicative of deposition by running water. Usually limestone and shale have horizontal bedding planes, but high-energy streams create dunelike structures on their streambeds. Sandstones deposited under these conditions have bedding planes in a confusing array of angles and directions.

STOP 3 to STOP 4

From Toronto Lake, we'll backtrack north to K-105 and turn left (west), following the highway west and north through Toronto, until we meet U.S. Highway 54. We take Highway 54 west for about 7 milesto the gravel road on the east side of the small town of Neal. We turn left on the gravel road and follow it south and east in a stairstep fashion to the roadcut in the prominent hill just north of the road. This is Round Mound (Stop 4).

STOP 4—Round Mound

The rocks that crop out in the roadcut at Round Mound are in the Kanwaka Shale. The type locality of the Kanwaka Shale is just west of the community of Kanwaka, which is a little west of Lawrence. Numerous fossils of invertebrate marine animals have weathered out of the shale and thin limestones and can be collected here.

Fossils are the ancient remains or evidence of once-living plants and animals, and invertebrates are animals without backbones. In Kansas, invertebrate fossils are much more common than vertebrate fossils. Even so, these fossils represent only a tiny sampling of the animals that once inhabited this part of the earth, most of which lived and died leaving no visible trace. The fossils here give an idea of the variety of animals that lived in the Pennsylvanian seas, roughly 300 million years ago. Among the fossils found at this site are bryozoans, brachiopods, bivalves (oysters, clams, scallops), corals, and trilobites.

Bryozoans are some of the most abundant fossils found in sedimentary rocks, and they are also widespread today, both in marine and freshwater environments. Bryozoans are small animals (just large enough to be seen with the naked eye) that live exclusively in colonies. Bryozoans are sometimes called moss animals—the name comes from two Greek words, *bryon* (moss) and *zoon* (animal)—because some bryozoans form colonies of bushy tufts that resemble mosses. Bryozoan colonies can also resemble colonies of some corals. Like corals, most bryozoans secrete external skeletons made of calcium carbonate, but unlike corals, bryozoans generally don't build reefs. Each bryozoan colony starts out with a single individual, called a zooid. Each zooid is essentially cylindrical and has a ring of tentacles that it uses to feed, drawing tiny plants and animals towards its mouth. As the first zooid begins feeding, it buds to form additional zooids, each of which has its own feeding tentacles. The new zooids also bud, forming the colony. Large colonies may consist of hundreds of thousands or even millions of zooids. Fossil bryozoan colonies come in a variety of shapes (figs. 7, 8). Some bryozoans built colonies that grew from the seafloor in branching structures; these fossils look like

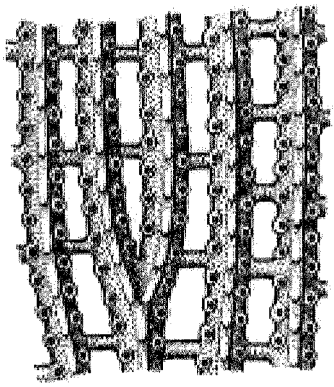

Fig. 7—*Fenestella* is one bryozoan found in Kansas rocks; its colonies had a netlike structure.

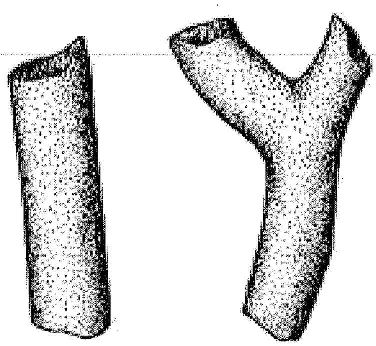

Fig. 8—This bryozoan, *Rhombopora,* is also common in Kansas rocks. It is characterized by upright, branching stems that resemble small twigs.

something like twigs. Other species erected netlike frameworks, while still other spread like a crust on shells, rocks, plants, and even other bryozoan colonies.

Brachiopods have a shell consisting of two parts called valves. Their fossils are common in the Pennsylvanian and Permian limestones of eastern Kansas. Brachiopods have an extensive fossil record. They first appear in rocks dating back to the early part of the Cambrian Period, about 545 million years ago, and were extremely abundant until the end of the Permian Period, about 250 million years ago, when they were decimated in the mass extinction that killed more than 90 percent of all living species and was the largest of all extinction events (larger than the major extinction at the end of the Cretaceous that killed off the dinosaurs). A distinctive feature of all brachiopods is that their valves are bilaterally symmetrical—that is, the right half is a mirror image of the left half. (Humans are also bilaterally symmetrical.) The bilateral symmetry of the individual valves differentiates brachiopods from clams and other bivalved mollusks, with which they are sometimes confused. Unlike brachiopods, clam valves are not bilaterally symmetrical; instead, the right and left valves are mirror images of each other. Brachiopod shells come in a variety of shapes and sizes (fig. 10). The outer surface of the valves

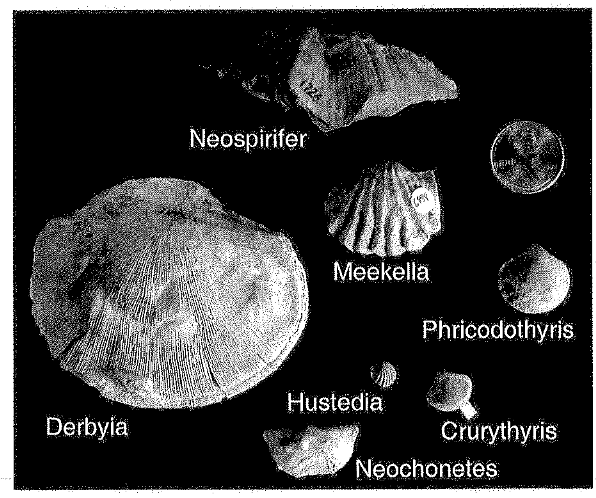

Fig. 9—Fossil brachiopods common in Kansas rocks.

may be marked by concentric wrinkles or radial ribs. Some brachiopods have prominent spines, but these are generally broken off and incorporated separately in the sediment.

Clams and other bivalves are generally easy to recognize because they look a lot like the shells scattered along modern seashores. Clams and their relatives (oysters, scallops, mussels) are often called bivalves (or bivalved mollusks) because their shell is composed of two parts called valves. Like their living relatives, fossil bivalves come in many different shapes and sizes. Typically, the right and left valves are symmetrical, in contrast to the bilateral symmetry of individual brachiopod valves (fig. 10). Some bivalves, however, such as oysters, have valves that are not symmetrical. In western Kansas, fossil clams found in younger rocks from

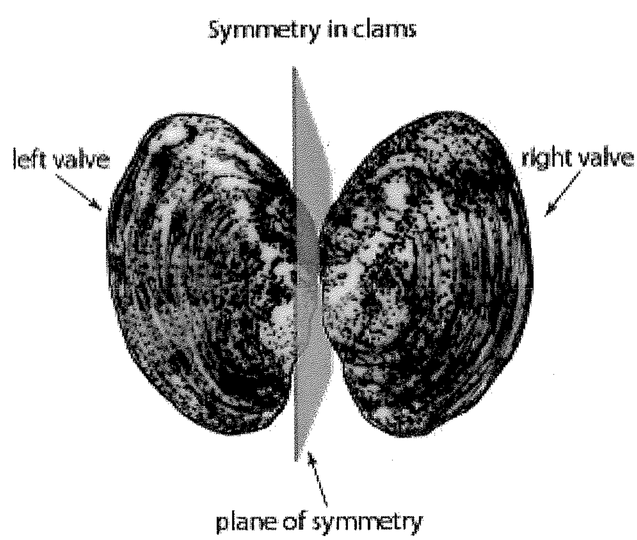

Fig. 10—Symmetry in clams.

the Cretaceous Period are even more common. Some of these—the inoceramid clams from western Kansas—are huge, as much as 6 feet in diameter.

Corals are close relatives of sea anemones and jellyfish and are the main reef builders in modern oceans. Corals can be either colonial or solitary. As fossils, corals are found worldwide in sedimentary rocks; the oldest are from rocks deposited during the Middle Cambrian, over 525 million years ago. Corals are among the simplest multicellular animals and are characterized by their radial symmetry and lack of well-developed organs. Corals live attached to the seafloor and feed by trapping small animals with their tentacles. They reproduce both sexually and asexually. Budding, a kind of asexual reproduction, occurs when the parent polyp splits off new polyps. Evidence of budding can be seen in fossil corals. Two groups of corals were important inhabitants of the Pennsylvanian and Permian seas—tabulate and rugose corals (fig. 11). Tabulate corals were exclusively colonial and produced calcium carbonate skeletons in a variety of shapes (moundlike, sheetlike, chainlike, or branching). Tabulate corals get their name from horizontal internal partitions known as tabulae. Some tabulate corals were probably reef builders (but not in Kansas). A common characteristic of rugose corals, from which they get their name, is the wrinkled appearance of their outer surface. (Rugose comes from the Latin word for wrinkled.) Rugose corals may be either solitary or colonial. Because solitary rugose corals are commonly shaped like a horn, these fossils are sometimes called horn corals. Both tabulate and rugose corals died out in the major extinction that occurred at the end of the Permian Period, roughly 250 million years ago. This extinction marked the end of the Paleozoic Era.

The corals that inhabited the post-Paleozoic seas differ significantly from the earlier corals. Because of this, many specialists argue that these later corals may not be closely related to the Paleozoic corals.

Trilobites are an extinct group of arthropods, relatives of insects, spiders, ticks, crabs, shrimp, lobsters, and numerous other organisms. They were exclusively marine organisms. Trilobites first appear in the fossil record in rocks deposited during the Lower Cambrian, about 540 million years ago. Although they were extremely abundant during their first 100 million years or so, by the Pennsylvanian and Permian Periods (when the surface rocks in eastern Kansas were deposited), trilobites were much less dominant. They became extinct, along with many other species, at the end of the Permian. The bodies of trilobites, like insects, have three parts: the head (or cephalon), the thorax, and the tail (or pygidium). Leg-like appendages attached to all three parts, but these are rarely preserved. Because of this, and the fact that trilobites have no living counterpart, paleontologists are hesitant to speculate about how trilobites lived. Trilobite pygidia are sometimes found in eastern Kansas (fig. 12).

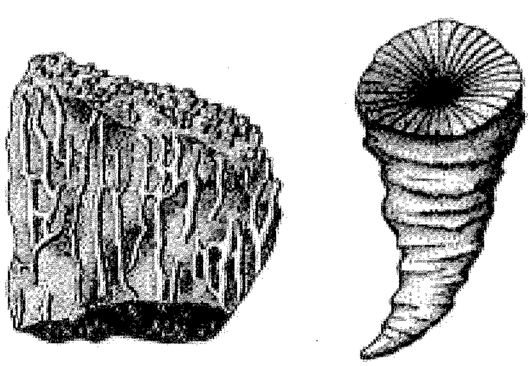

Fig. 11—The colonial tabulate coral *Syringopora* (on the left) shows the structure of the hard parts that protected the polyps and formed the framework of the colony. Note the pores on the surface of the colony, from which the polyps extended their tentacles to feed. The solitary rugose coral *Caninia* (on the right) is common in eastern Kansas.

Fig. 12—This tail, or pygidium, of the trilobite *Ameura,* came from the Pennsylvanian Drum Limestone, near Independence, Kansas. Most Kansas trilobites belong to the genus *Ameura* or *Ditomopyge.*

STOP 5 to El Dorado

As we leave Round Mound, we'll travel west and north along the major gravel road 3 miles to the town of Neal and U.S. Highway 54, which will take us back to El Dorado, about 43 miles to the west. The Kansas Oil Museum, located next to our rendezvous point in East Park, will be open when we return. It is considered the best oil museum in the state and has exhibits that explain the various means of petroleum exploration and production and the ways they've changed over the years. In addition, the museum has exhibits that show what life was like in El Dorado and the company towns that sprang up during the oil boom that followed the discovery of the El Dorado field.

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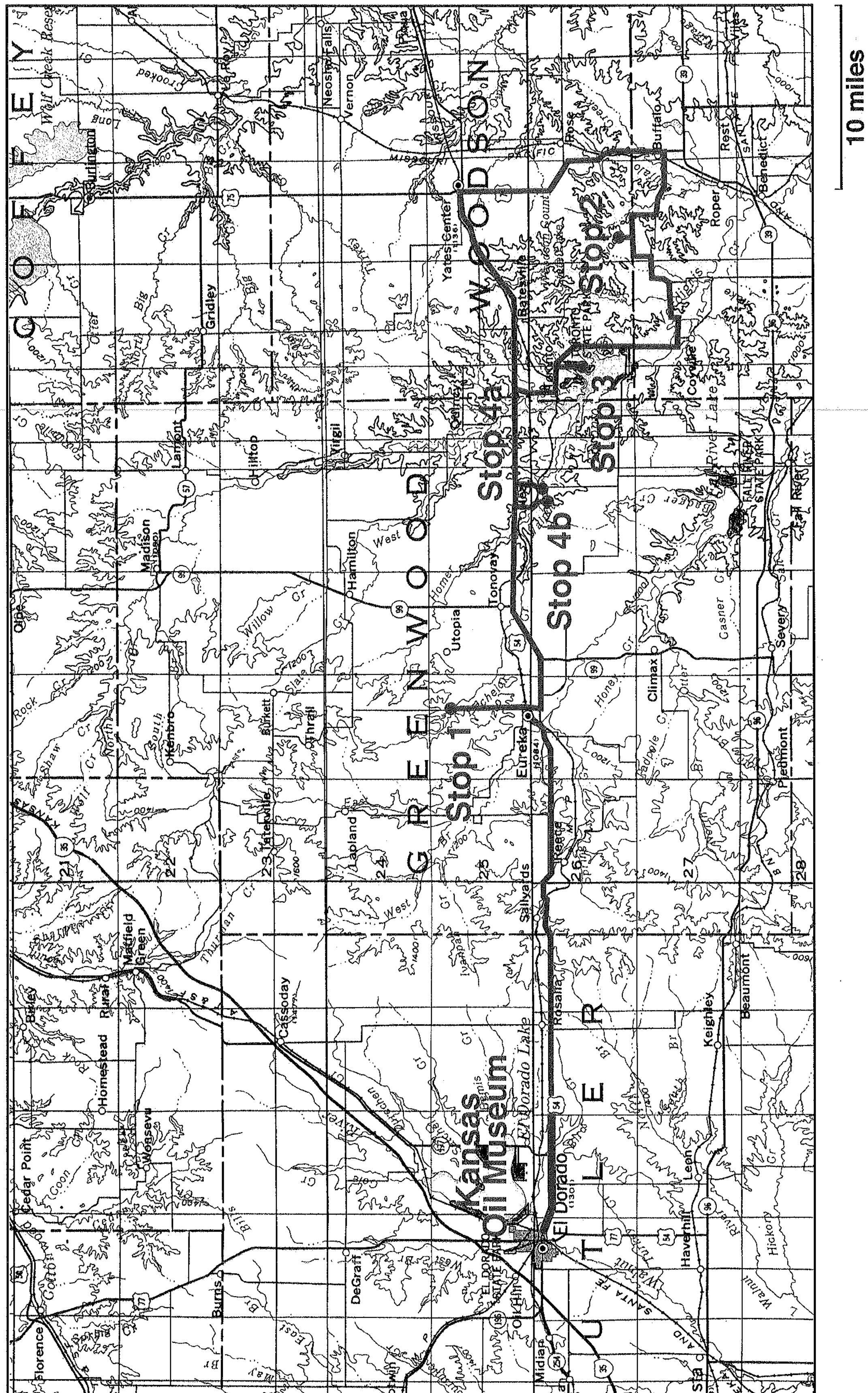
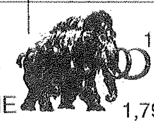
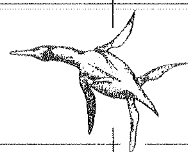
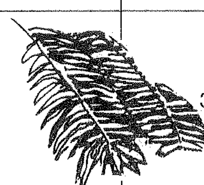
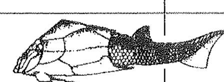
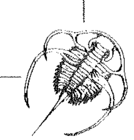

Kansas Oil Museum
Stop 1
Stop 2
Stop 3
Stop 4a
Stop 4b
COFFEY
GREENWOOD
WOODSON
BUTLER
El Dorado
Eureka
Yates Center
Augusta
10 miles

KANSAS GEOLOGIC TIMETABLE

(Not scaled for geologic time or thickness of deposits)

ERAS	PERIODS	EPOCHS	EST. LENGTH (YEARS)*	DESCRIPTION	MILLION YEARS PAST
CENOZOIC	QUATERNARY	HOLOCENE	 10,000+	Early, the land was stable with some erosion. Glaciers moved into the northeast at least twice. Later the climate was dry. Sand dunes were formed by wind in the west. Volcanic ash was blown in from California, New Mexico, and Wyoming.	
		PLEISTOCENE	1,790,000		1.8
	TERTIARY	PLIOCENE	 3,500,000	Western third of the state covered by terrestrial (nonmarine) sand and gravel deposits which contain large quantities of ground water. No rocks formed in eastern Kansas.	
		MIOCENE	18,500,000		
		OLIGOCENE	9,900,000		
		EOCENE	21,100,000		
		PALEOCENE	10,200,000		65
MESOZOIC	CRETACEOUS		 77,000,000	Much of the western half was covered by seas. Limestone, sandstone, and chalk formed from sea deposits. Fossils can be found in these rocks, which crop out in central and western Kansas.	142
	JURASSIC		63,700,000	Western one-fifth of the state; subsurface only. Terrestrial (nonmarine) deposits mainly shale and sandstone.	205.7
	TRIASSIC		42,500,000	Only extreme southwestern part of state, mostly in subsurface. A few small outcrops. Red sandstones and conglomerates, terrestrial deposits (nonmarine).	248.2
PALEOZOIC	PERMIAN		 41,800,000	Seas rose and fell across much of Kansas depositing the limestone, shale, and chert that form the Flint Hills. Later, shale, siltstone, sandstone, dolomite, salt, and gypsum—rocks that form the Red Hills—were deposited. Salt now is mined in central Kansas.	290
	PENNSYLVANIAN		 33,000,000	Seas rose and fell across most of Kansas depositing shale, limestone, sandstone, chert, conglomerates, and coal; coal formed in swamps from dead plants. Two ridges of hills, the Nemaha uplift and the Central Kansas uplift, appeared; both now are buried. Pennsylvanian rocks are found at the surface in eastern Kansas.	323
	MISSISSIPPIAN		31,000,000	Repeated layers of limestone, shale, and sandstone indicate that seas rose and fell. Mississippian rocks are the oldest found at the surface and are in the southeast corner; elsewhere these rocks are underground only.	354
	DEVONIAN		 63,000,000	Seas covered Kansas during much of the period. Limestone, shale, and sandstone deposits are underground only.	417
	SILURIAN		26,000,000	Land was uplifted and seas disappeared. Limestone deposits are found underground only.	443
	ORDOVICIAN		 52,000,000	Seas covered parts of Kansas during much of the period. Dolomite and sandstone are underground only.	495
	CAMBRIAN		50,000,000	Early, the climate was dry and many rocks eroded. Later, parts of Kansas were covered by seas. Dolomite, sandstone, limestone, and shale are underground now.	545
PRECAMBRIAN			4,055,000,000	These rocks are the oldest on earth. In Kansas, they are found deep below the surface and little is known about them. Many are igneous and metamorphic rocks that have gone through many changes.	4,600?

Eons not shown

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Kansas Geological Survey, 1999

GEOFACTS from the Kansas Geological Survey

Flint Hills: Rocks and Minerals

Springtime in the Flint Hills, Greenwood County.

The Flint Hills are familiar to many travelers since this part of the state is traversed by both I-70 and the Kansas Turnpike. Despite disagreement about the exact boundaries of the Flint Hills, most geologists agree that the hills extend from Marshall County, in the north, to Cowley County, in the south. (Of course, the hills don't end abruptly at the state line; they continue into Oklahoma, where they are known as the Osage Hills.)

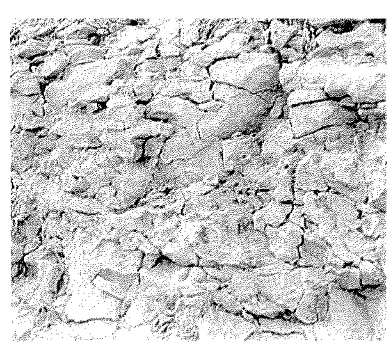
The Flint Hills were formed by the erosion of Permian-age limestones and shales. During the early part of the Permian Period (which lasted from about 286 to 245 million years ago), shallow seas covered much of the state, as they did during Pennsylvanian times. Unlike the Pennsylvanian limestones to the east, however, the limestones in the Flint Hills contain numerous bands of chert, or flint. Because chert is much less soluble than the limestone around it, the weathering of the limestone has left behind a clayey soil full of cherty gravel. This gravel-filled soil covers the rocky uplands and slows the process of erosion. Most of the hilltops in this region are capped with this cherty gravel.

Because of the cherty soil, the land is better suited to ranching than farming. Because of this, the Flint Hills is still largely native prairie grassland, one of the last great preserves of tallgrass prairie in the country.

The tall grasses in this region are mostly big and little bluestem, switch grass, and Indian grass. Except along stream and river bottoms, trees are rare. The streams in the Flint Hills have cut deep, precipitous channels. Streams cut in chert-bearing strata are narrow, boxlike channels, whereas those cut in weaker shales are wider, more gently sloping valleys.

Common Rocks and Minerals

Chert.—Commonly known as flint, chert is found in many Kansas limestones as nodules or continuous beds. It is a sedimentary rock composed of microscopic crystals of quartz (silica, SiO_2). It is opaque and ranges in color from white to dull gray or brown to black. Chert breaks with a shell-like (conchoidal) fracture, and the edges of the broken pieces are sharp. Because of this, people have used chert for thousands of years to make tools and weapons. In the Flint Hills, a bluish-gray chert is commonly seen in roadcut exposures of the Florence Limestone Member (part of the formation called the Barneston Limestone).



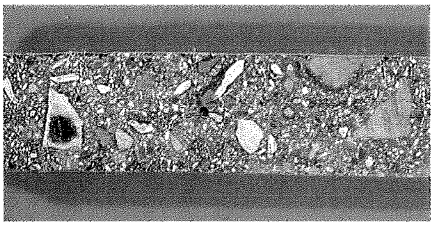
Chert in limestone, Riley County.

Limestone.—Limestone is a sedimentary rock composed mostly of calcite (calcium carbonate, $CaCO_3$). It is formed (largely in marine environments) by organic means—that is, from the remains of animals or plants—or by chemical deposition. Many animals and plants (such as oysters, corals, some sponges, sea urchins, plankton, and algae) take calcium carbonate out of the water and secrete it to form shells or skeletons. As these organisms die, they drop to the bottom of the ocean, lake, or river. Over time, the organic parts decay and the calcium carbonate accumulates to form limestone. Chemically deposited limestones are formed when calcium carbonate dissolved in water falls out of solution and settles to the bottom.

One of the prominent limestones in the Flint Hills is the Fort Riley Limestone Member (the lowest member of the Barneston Limestone). Known in southern Kansas as Silverdale limestone, the Fort Riley is 30 to 45 feet thick and is riddled with caves and solution cavities. At Silverdale, where it is quarried in southern Cowley County, the Fort Riley is nearly 60 feet thick. The Cowley County courthouse in Winfield, Kansas, is built out of this limestone.

Another characteristic limestone in the Flint Hills is the Florence Limestone Member (of the Barneston Limestone). Ranging from 12 to 45 feet in thickness, this limestone often contains a variety of fossils, including brachiopods, pelecypods, bryozoans, and fusulinids.

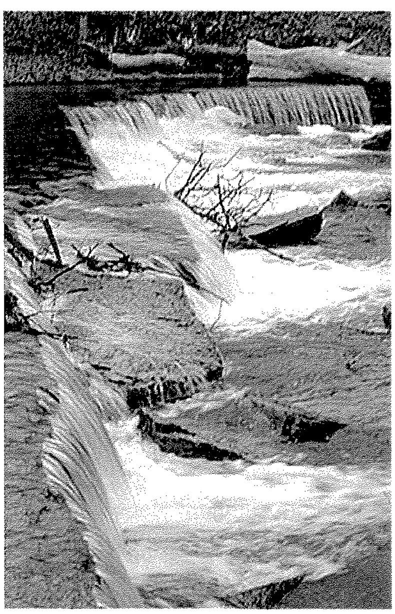
Kimberlites.—One of the rare examples of native igneous rock in the state, kimberlites occur at the surface in Riley County. Kimberlite is a soft, dull-gray rock with thin white veins of calcite and magnetite. Associated with ancient volcanic activity, kimberlites are called intrusive igneous rocks because they were forced through other rocks as they pushed to the surface of the earth. Because kimberlites are the only known source of diamonds, the Riley County kimberlites have generated much interest. To date, however, no diamonds have been found in association with these kimberlites. Even without diamonds, kimberlites are interesting because they provide a glimpse of the rocks that come from deep underground, perhaps as deep as 150 miles. These rocks pushed to the surface about 100 million years ago, during the Cretaceous Period. Garnet, a mineral with many faceted crystals and a glassy luster, has been found in Riley County kimberlites and in streams flowing near the kimberlites.



Core sample of Riley County kimberlite.

Places to Visit

Pillsbury Crossing.—South of the town of Zeandale in Riley County, Deep Creek flows over a ledge in the Elmont Limestone Member (of the Emporia Limestone). Known as Pillsbury Crossing, the waterfall is nearly 40 feet wide and has a drop of approximately five feet. To get to Pillsbury Crossing from I-70, take Deep Creek Road (exit 316) north to Pillsbury Crossing Road. Follow Pillsbury Crossing Road to the east approximately 2 miles.



Pillsbury Crossing, Riley County.

Scenic Drives in the Flint Hills.—The Flint Hills Scenic Byway is an 80-mile stretch of Kansas Highway 177 between Cassoday in northeastern Butler County and the junction with I-70 in Geary County. The road passes through Cottonwood Falls (home of the Chase County Courthouse described above) and goes by the Z Bar Ranch at the Tallgrass Prairie National Preserve. Two miles north of Strong City, the Tallgrass Prairie National Preserve protects a portion of pristine grassland. The ranchhouse and many of the buildings on the preserve are built with Cottonwood Limestone, which contains numerous fusulinids, a one-celled animal with a shell shaped like a grain of wheat.

Roadcut near Council Grove.—A roadcut on U.S. Highway 56 is a good place to see limestone and shale strata. Between highway markers 353 and 354, three different units are exposed: the Funston Limestone is at the bottom, overlain by the Speiser Shale and the Threemile Limestone Member (of the Wreford Limestone). The Funston Limestone is a light-gray to bluish-gray limestone that occasionally contains layers of shale and chert. It is quarried near Onaga and was used in the Eisenhower Museum in Abilene and in the Topeka Public Library. The Speiser Shale comes in a variety of colors and varies in thickness from 18 to 35 feet. The Threemile member is one of the chert-bearing limestones that crop out to form the Flint Hills.

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This fact sheet was compiled by Kansas Geological Survey staff (April 1999). More information is available on the World Wide Web:
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GEOFACTS from the Kansas Geological Survey

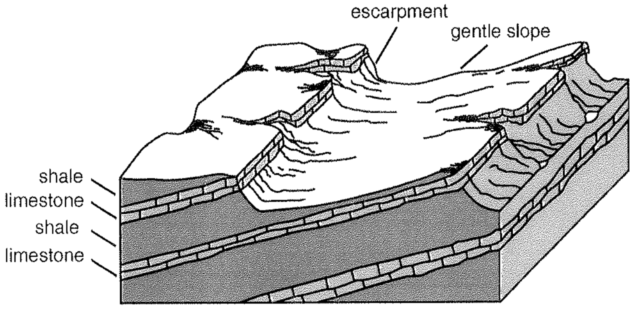
Osage Cuestas: Rocks and Minerals

The Osage Cuestas region occupies nearly all of eastern Kansas south of the Kansas River and is characterized by a series of east-facing ridges (or escarpments), between which are flat to gently rolling plains. *Cuesta,* Spanish for hill or cliff, is the term geologists use to describe ridges with steep, clifflike faces on one side and gentle slopes on the other.

In the Osage Cuestas, the underlying strata are Pennsylvanian-age limestones and shales that dip gently to the west and northwest. Each cuesta consists of a striking east-facing ridge or escarpment and a gently inclined surface that slopes in the direction of the dip of the strata. Each escarpment is capped by the more-resistant limestone, while the gentle slopes are underlain by thick layers of shale. The steep faces of the cuestas range in height from approximately 50 feet to 200 feet.

Common Rocks and Minerals

Sandstone.—Like sand, sandstone is made up largely of quartz grains, which are held together by some natural cement such as calcium carbonate, iron oxide, or silica. It is a common sedimentary rock in Kansas. In eastern Kansas, sandstone is often interbedded with shale and limestone. It also occurs as channel deposits, cutting through older deposits of shale and limestone. The Tonganoxie Sandstone Member of the Stranger Formation, which crops out in Franklin, Douglas, and Leavenworth counties, is an example of a channel deposit; it was deposited in a large river valley about 300 million years ago. Today the Tonganoxie is an important aquifer. Another sandstone in this region, the Bandera Quarry Shale Member, is quarried in Bourbon County, near the town of Redfield. This sandstone, part of the Bandera Shale formation, separates easily along natural bedding planes and is used as flagstone for walkways and veneer.

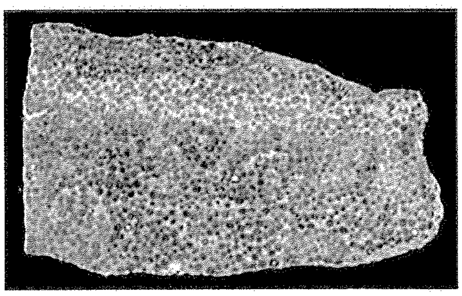


Cuesta topography developed in gently dipping, alternating hard and soft rock layers.

Shale.—Another common sedimentary rock, shale is composed of hardened, compacted clay or silt that commonly breaks along bedding planes. Its particles are too small to be seen without a microscope. Shales erode easily, and most are soft enough to be cut with a knife. Though usually gray, shale can be black, green, red, or buff. When heated, shale changes to the familiar brick-red color. In eastern Kansas, shale has been used for making bricks. Black, platy shales found in Labette, Crawford, Bourbon, Douglas, Linn, and Neosho counties contain large amounts of organic matter. Called oil shale, this rock can yield oil when distilled; small slivers can be ignited with a match.

Limestone.—Limestone is a sedimentary rock composed mostly of calcite (calcium carbonate, $CaCO_3$), usually deposited in marine environments. It is formed by organic means or chemical deposition. Many animals and plants (such as oysters, corals, some sponges, sea urchins, plankton, and algae) take calcium carbonate out of the water and secrete it to form shells or skeletons. As these organisms die, they drop to the bottom of the ocean, lake, or river. Over time, the organic parts decay and the calcium carbonate accumulates to form limestone. Chemically deposited limestones are formed when calcium carbonate dissolved in water falls out of solution and settles to the bottom of the ocean, lake, or river.

The limestones and shales in the Osage Cuestas were deposited in shallow seas that lapped onto this area between about 290 and 310 million years ago. The outcrops in this region contain a variety of fossils, evidence of the abundant life that populated the seas during the Pennsylvanian Period. The Beil Limestone Member in Osage County, for example, contains brachiopods, bryozoans, fusulinids, mollusks, and cornucopia-shaped horn coral. Some limestones in this region contain oolites, small spheres of calcium carbonate that formed around some sort of nucleus, such as a grain of sand or shell fragment. Oolitic limestones can be seen in Johnson, Miami, Osage, Linn, Bourbon, and Labette counties, and near the towns of Independence and Cherryvale in Montgomery County.



Oolitic limestone, Montgomery County.

Lamproites.—Almost all rocks at the surface in Kansas are sedimentary in origin, but this region is also known for exposures of igneous rocks in Woodson and Wilson counties. These rocks, which geologists called lamproites, crop out in sill-like masses about one mile long and several hundred yards wide. Lamproites are dark-colored igneous rocks rich in potassium and magnesium, which formed from the cooling of molten magma. Geologists refer to these rocks as intrusive because they were forced into other rocks below the surface of the earth. These lamproites formed during the Cretaceous Period, about 100 million years ago. They contain irregular spots of hardened or altered shale. When the hot, molten igneous rock came in contact with the Paleozoic shale, pieces of the shale broke off and fell into the liquid mass.

Lamproites, Woodson County.

Places to Visit

Elk Falls.—At Elk Falls, near the town of the same name in Elk County, the Elk River drops four to six feet over a sandstone ledge. This sandstone, informally known as the Elgin Sandstone for exposures near the town of Elgin in Chautauqua County, is Pennsylvanian in age. The remains of an old mill are located near the waterfall. Downstream from the falls is an iron bridge built in 1893 that is now on the National Register of Historic Places.

Elk Falls.

Johnston Geology Museum.—This museum at Emporia State University contains a wide range of material on Kansas geology, including fossils from different parts of the state, minerals exhibits, and Indian artifacts. The museum is open 8:00 a.m. to 10:00 p.m. Monday-Friday and 8:00 to noon Saturday when the university is in session (316) 341-5330.

Clinton Spillway.—A good place to get a look at the limestones and shales of this region is at the spillway near Clinton Lake dam, 3.5 miles west of Lawrence. The spillway provides a dramatic illustration of the cycles of deposition common during the Pennsylvanian Period, about 300 million years ago. The interbedded limestone and shale sequence exposed here, which is part of the Oread Limestone, is common throughout eastern Kansas, and is probably the result of changing sea levels during Pennsylvanian time. The strata exposed on the north face of the spillway include the interval from the Plattsmouth Limestone Member of the Oread Limestone down to the Amazonia Member of the Lawrence Shale.

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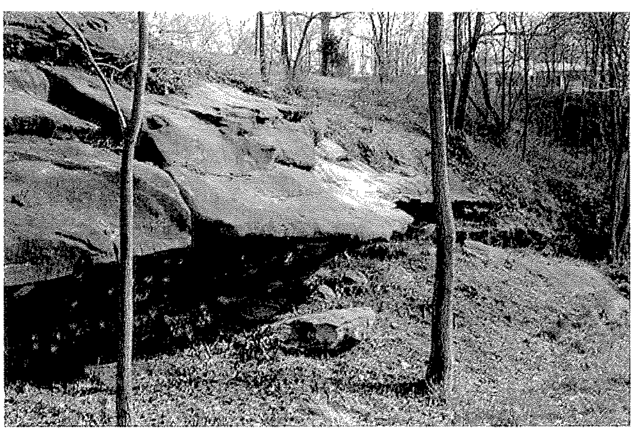
GEOFACTS from the Kansas Geological Survey

Chautauqua Hills: Rocks and Minerals

The Chautauqua Hills are a sandstone-capped rolling upland that extends into the Osage Cuestas from the southern Kansas border. Approximately 10 miles wide, these hills extend as far north as Yates Center in Woodson County. Small patches of similar terrain can be found as far north as Leavenworth County.

The Chautauqua Hills formed primarily in the thick sandstones of the Douglas Group. During the Pennsylvanian Period, about 286 million to 320 million years ago, rivers and streams flowed into the sea in this area. Sand and other sediments collected in the estuaries and at the mouths of the rivers in deltas. When the seas dried up, the sediments were buried and compacted—the sands became sandstone and the muds became shale. Over millions of years, uplift and erosion exposed the sandstone and shale at the earth's surface. Further erosion has dissected the area into a series of low hills, capped by more resistant sandstone.



Sandstone outcrop in the Chautauqua Hills.

Because of rock outcrops in this region, the hills are generally not cultivated but are used instead for pasture. The Verdigris, Fall, and Elk rivers cross the area in narrow valleys walled by sandstone bluffs. Topographic relief in the region is never more than 250 feet.

Many of the hills are covered by stands of black jack oaks, scrub oaks, and other hardwood species. This mix of medium-tall grasslands and scattered stands of deciduous trees is called the Cross Timbers by scientists who map vegetation. In Kansas, the extent of the Cross Timbers is almost identical to the extent of the Chautauqua Hills physiographic region.

Common Rocks and Minerals

Sandstone.—The characteristic rocks in the Chautauqua Hills are the thick sandstones that cap the hills and are exposed along creek and river valleys. Sandstone is a common sedimentary rock, made up largely of quartz grains cemented together by calcium carbonate, iron oxide, or silica. In eastern Kansas, sandstone is often interbedded with shale and limestone. It also occurs as channel deposits, cutting through older deposits of shale and limestone.

The sandstones capping the Chautauqua Hills are the Tonganoxie Sandstone Member of the Stranger Formation and Ireland Sandstone Member of the Lawrence Formation. Both are thick rock formations, the remains of deposits that filled a large, ancient river valley during the Pennsylvanian Period.

Some sandstones are marked by ridges and troughs that look like the ripples often seen in loose sand in a stream, shallow lake, sea, or sand dune. By studying ripple marks preserved in sandstone and comparing them with similar marks found in today's sand, geologists can make shrewd assumptions about what the environment was like when these sandstones were deposited. Fossil ripple marks provide information about the direction of the current, the environment, and, to a degree, the depth of the water. Some researchers believe that wind-created ripples are not preserved and that virtually all fossil ripple marks were formed in water.

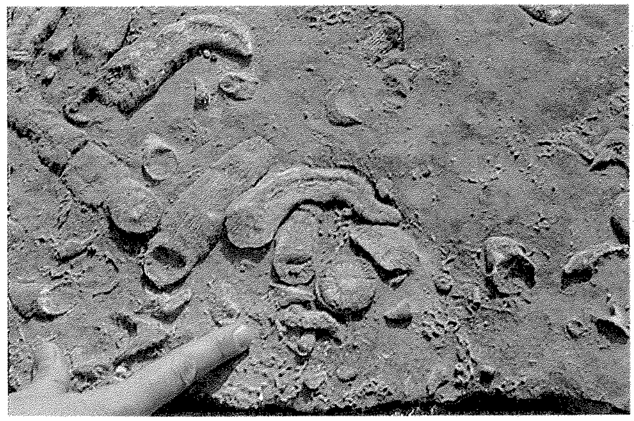
Ripple marks in Chautauqua Hills sandstone.

Places to Visit

U.S. Highway 160.—The characteristic sandstone-capped hills of the region can be seen along a stretch of U.S. Highway 160, between the town of Longton in Elk County and the junction with Kansas Highway 39 in Montgomery County. The sandstones capping the hills along this route are the Tonganoxie Sandstone Member of the Stranger Formation and Ireland Sandstone Member of the Lawrence Formation. Both are the remains of deposits that filled a large, ancient river valley during the Pennsylvanian.

Redbud Trail.—One way to get a feel for the beautiful scenery of the region is to drive the Redbud Trail during the annual Redbud Tour. Hosted by the Sedan Area Chamber of Commerce, a mapped route takes visitors through the county, winding through the Chautauqua Hills and Osage Cuestas regions. The tour takes place when the redbuds are in full bloom, usually in April. For exact dates and more information, contact the Sedan Area Chamber of Commerce, P.O. Box 182, Sedan, KS, 67361 (316) 725-5221 or go to their website at **http://skyways.lib.ks.us/kansas/towns/Sedan/events.html.**

Redbuds blooming in Chautauqua Hills.



Fossiliferous limestone on display at The Hollow in Sedan, Kansas. The majority of fossils are Pennsylvanian rugose coral.

City Park in Sedan.—Located just a block from downtown Sedan, The Hollow is a good place to see Douglas Group sandstones. At the park's entrance is a display of Chautauqua County limestone containing numerous fossils of rugose coral. These corals lived at the bottom of shallow seas during the Pennsylvanian Period.

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This fact sheet was compiled by Kansas Geological Survey staff (April 1999). More information is available on the World Wide Web:
http://www.kgs.ukans.edu/Extension/home.html

GEOFACTS from the Kansas Geological Survey

How Rocks are Named

To identify layers of rock, geologists have created several categories, the most common of which are called formations, groups, and members. In the same way that biologists use the categories of families, genera, and species to identify animals and plants (Homo sapiens is a familiar genus and species), geologists use formations, groups, and members to distinguish one rock layer from another.

The basic unit in this system of classification is the formation. A formation is a rock unit that has a distinctive appearance—in other words, a geologist can tell it apart from the rock layers around it. Formations must also be thick enough and extensive enough to plot on a map.

The **sedimentary rocks** of Kansas have been formally divided into many different formations, each named for the geographic locality where it was first recognized and described. The Oread Limestone, a formation common in eastern Kansas, was named in 1894 by Erasmus Haworth, the first Director of the Kansas Geological Survey, for outcrops on Mount Oread, the hill on which the University of Kansas is located. A familiar formation in central Kansas, the Dakota Formation, takes its name from a county in Nebraska, where it was first described. A rock formation keeps its name no matter where it is found.

Another important thing to remember about formations is that they often encompass a variety of rock types. For example, the Dakota Formation, although often associated with sandstone, also includes clay and shale layers. And the Oread Limestone, despite its name, contains layers of shale as well as limestone.

Formations can be lumped together into larger units called groups. For example, the Chase Group, which crops out at the surface in the Flint Hills region of Kansas, includes several different formations deposited during part of the **Permian Period.**

Formations can also be subdivided into smaller units called members. For example, the Oread Limestone is divided into seven such members. One of these, the Leavenworth Limestone Member, is a foot-thick layer that can be traced for hundreds of miles. It was named for outcrops near Leavenworth, Kansas. Like formations, members keep their name no matter where they are found in Kansas.

Members make up formations. Formations make up groups. And the rocks of different groups are included under one system, according to the age of deposition. Thus, the Leavenworth Limestone Member is part of the Oread Formation, which is part of the Shawnee Group, which is part of the Pennsylvanian System.

When geologists propose a new name, they must publish a formal description of the rock unit and the location of the type locality. The procedures for classifying and naming rock units are contained in the North American Stratigraphic Code, prepared by the North American Commission on Stratigraphic Nomenclature (www.agiweb.org/nacsn/).

Glossary

Permian Period—The interval of geologic time from 290 to 245 million years ago. In Kansas, rocks from the early part of the Permian include many of the limestones and shales that form the Flint Hills; later Permian deposits include the red beds of south-central Kansas.

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

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