

**KANSAS GEOLOGICAL SURVEY  
OPEN-FILE REPORT 2002-42**

GEOLOGY, PALEONTOLOGY, AND ARCHEOLOGY OF  
NORTHWESTERN KANSAS:  
PUBLIC FIELD TRIP

October 12, 2002

by

Liz Brosius  
Jim McCauley  
Bob Sawin  
Rex Buchanan

*Disclaimer*

The Kansas Geological Survey does not guarantee this document to be free from errors or inaccuracies and disclaims any responsibility or liability for interpretations based on data used in the production of this document or decisions based thereon. This report is intended to make results of research available at the earliest possible date, but is not intended to constitute final or formal publications.

Kansas Geological Survey  
1930 Constant Avenue  
University of Kansas  
Lawrence, KS 66047-3726

**Geology, Paleontology, and Archeology of  
Northwestern Kansas:  
Public Field Trip**

October 12, 2002

Liz Brosius  
Jim McCauley  
Bob Sawin  
Rex Buchanan

# Geology, Paleontology, and Archeology of Northwestern Kansas

Liz Brosius, Jim McCauley, Bob Sawin, and Rex Buchanan  
Kansas Geological Survey

## Introduction

This field trip will focus on the rocks and fossils (geology and paleontology), as well as the ancient human history (archeology), of northwestern Kansas. With stops in Logan, Gove, and Scott counties (fig. 1), the trip will take us through two of the state's physiographic regions: the Smoky Hills and

the High Plains (see factsheets at back of guidebook). Except for Stop 4, the field trip focuses on rocks deposited late in the Cretaceous Period, about 80 million years ago (see geologic timetable at back of guidebook), specifically, the Niobrara Chalk (fig. 2).

This field trip, cosponsored by The Nature Conservancy, Kansas Chapter, is part of the Kansas

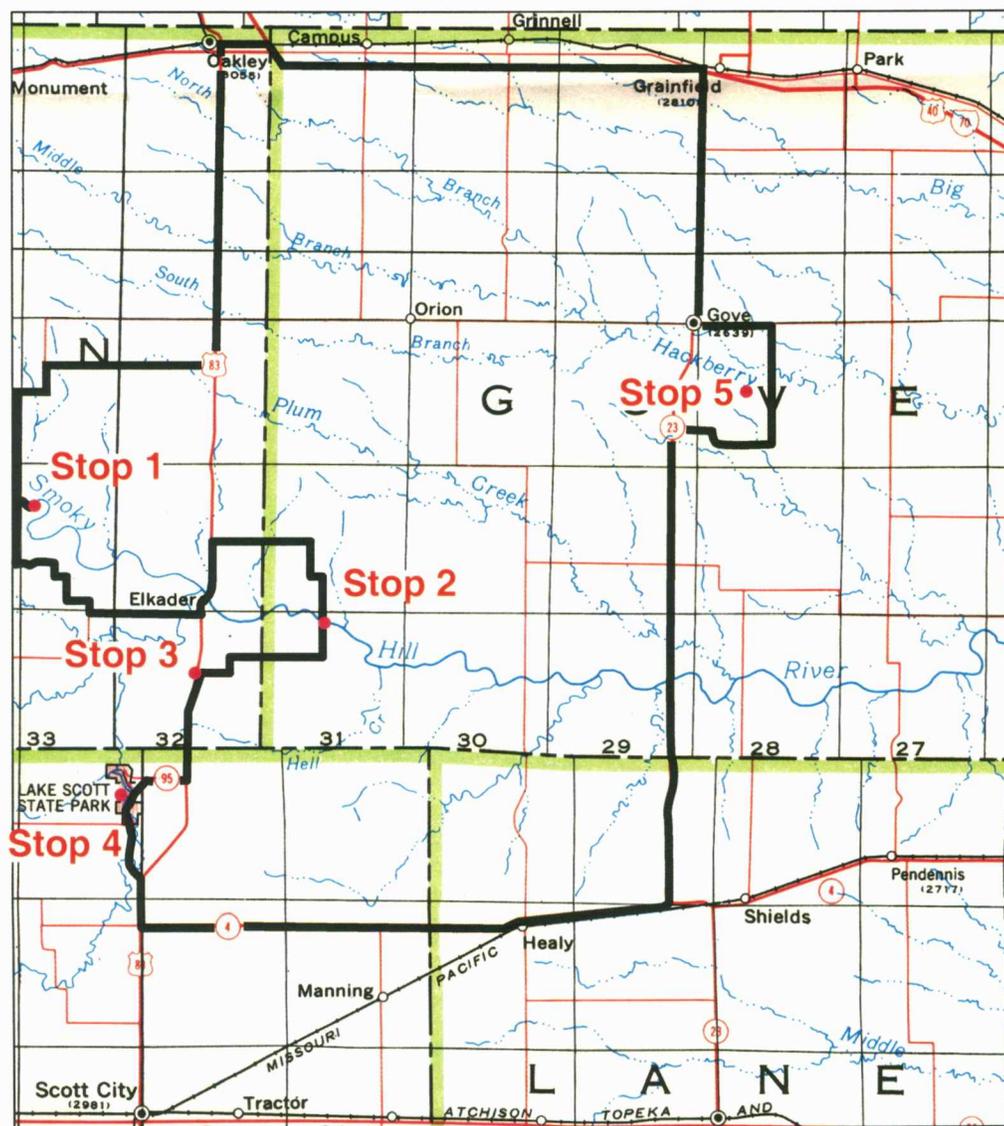


Fig. 1—Map of field trip route.

Geological Survey's participation in Earth Science Week (October 13–19, 2002). Earth Science Week is a national celebration of the earth sciences, established in 1998 by the American Geological Institute, based in Alexandria, Virginia. Earth Science Week is a time to increase public awareness and understanding of the earth sciences. Since 1998, Earth Science Week activities have taken place in every U.S. state and in several countries around the world. For more information about Earth Science Week, visit the Earth Science Week Web Site at [www.earthscienceworld.org](http://www.earthscienceworld.org).

### The Legalities of Fossil Collecting in Western Kansas

Commercial fossil collecting—collecting and restoring fossils for resale to private buyers and museums—became a contentious issue in the 1980's when a market for fossils, particularly large vertebrate fossils, began to develop. Landowners in the chalk beds became concerned that fossil hunters were trespassing on property to collect fossils, and that they were selling fossils without making landowners aware of the fossils' market value (McCauley et al., 1997).

In response, the 1990 legislature passed a law (Kansas Statutes Annotated 21-3759) requiring commercial fossil hunters to “obtain written authorization of the landowner to go upon such land for such purpose and when requesting such written authorization has identified oneself to the landowner as a commercial fossil hunter.” Commercial fossil hunters must also provide landowners with “a description of the fossil” they intend to collect and receive owner authorization, in writing, to remove it.

This legislation applies only to commercial fossil collecting. It does not apply to casual collectors who are searching for fossils for their own use or for use in a classroom, or to groups such as school children, 4-H'ers, or boy and girl scouts. Of course, such casual collectors must obey existing laws related to trespass and must secure owner permission before entering private property to search for fossils.

This permission is particularly important because some landowners in the area have signed lease agreements with fossil collectors, in essence giving those collectors exclusive right to take fossils from their property. These agreements are somewhat akin to leases for mineral rights, and allow the landowner and the fossil hunter to share in the proceeds from

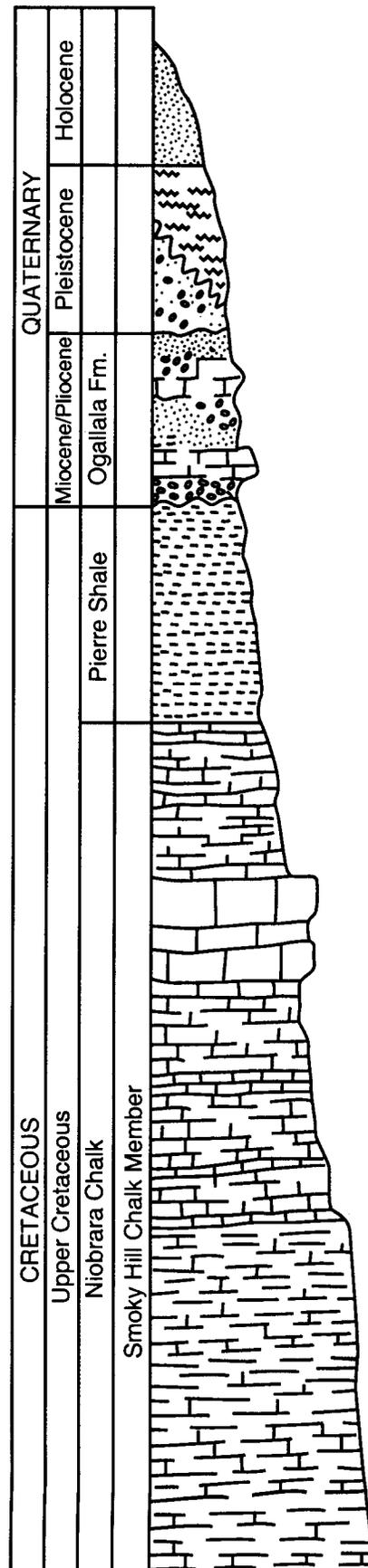


Fig. 2—Stratigraphic column of rocks encountered on this field trip.

the sale of any fossils. Because these leases may give the person holding the lease exclusive right to collect on a piece of property, landowners cannot allow other people, including casual collectors, to collect on their land.

### **From Oakley to STOP 1**

We begin our field trip in Oakley, at the crossroads of two federal highways, U.S. 40 and U.S. 83. Located in the extreme northeastern corner of Logan County, Oakley is the county seat, replacing the more centrally located former county seat of Russell Springs. Its location on major transportation routes, including I-70 and the Union Pacific Railroad, has allowed Oakley to survive, while Russell Springs has faded in importance.

Oakley is situated in the High Plains physiographic region (see factsheet); the elevation of our starting point is 3,062 feet. Beneath Oakley is up to 226 feet of Ogallala Formation, the primary component of the High Plains aquifer. As will be discussed in more detail at Stop 4, the Ogallala consists of sediments that eroded off the Rocky Mountains during the Tertiary Period.

The High Plains aquifer supplies the numerous center-pivots that irrigate the fields around Oakley. Nearly all the irrigation in Logan County occurs along the northern fringe of the county. As we proceed south along U.S. 83 toward the Smoky Hill River, we will see the landscape and agriculture change. The irrigated fields will be replaced by dryland farms and shortgrass pastures and rangeland. As we enter the Smoky Hills physiographic region (see factsheet), the topography will become more dissected and outcrops more common.

Much of the High Plains is covered by a fine, loose silt called loess. Much of this loess was deposited as windblown dust during the Ice Ages of the last few hundred thousand years. Although glaciers never reached this part of Kansas, glaciers in the Rockies to the west and in the upper Midwest and northern Plains produced large amounts of finely ground rock material that was carried by strong winds and deposited across large areas, including the High Plains of Kansas.

This loess has buried the Ogallala and older rocks that would ordinarily crop out across the High Plains. Outcrops are restricted to these areas where stream erosion has removed the overlying loess. Our first glimpse of the Ogallala occurs as we cross the Middle Branch of Hackberry Creek, about 8

miles south of Oakley. As we continue south and west, deeper into the Smoky Hill River valley, we enter an area where the Ogallala has been removed by erosion and the Niobrara Chalk from the Cretaceous Period pokes out from its loess covering.

In general, the stops we make on our trip will take us back in geologic time as we investigate progressively older rocks. Our first stop will be at the Smoky Valley Ranch Preserve, where we'll learn about the interplay between geology and archeology at a site dating back to the Ice Age.

### **STOP 1—The Smoky Valley Ranch**

With the acquisition of the Smoky Valley Ranch in Logan County in January 1999, The Nature Conservancy, Kansas Chapter, established a 16,800-acre (more than 25 square miles) preserve. This preserve is large enough to support much of the rich diversity of animals and plants that inhabited the shortgrass prairie region. Most of the shortgrass prairie that once covered western Kansas has been cultivated over the past century.

In addition to the Smoky Valley Ranch Preserve, significant remnants of native prairie remain along the Smoky Hill River and its tributaries in Wallace, Logan, and Gove counties. Many of these prairies have been well managed as grazing pastures for decades. However, periodic dislocations in the cattle market and improved dryland crop varieties have induced increasing numbers of landowners to convert their native pastures to cropland.

The ranch is characterized by chalk bluffs overlooking the Smoky Hill River, large expanses of grassland, and rocky ravines. The breaks along the upper reaches of the Smoky Hill River represent the transition zone between the mixed grass and shortgrass prairie regions.

*Geology*—The oldest rocks exposed at the Smoky Valley Ranch Preserve belong to the Smoky Hill Chalk Member of the Niobrara Chalk (fig. 2). These rocks were deposited during the later part of the Cretaceous Period, about 80 million years ago, and form the numerous chalk badlands that crop out at the preserve and elsewhere in the region.

During the later Cretaceous Period, the western United States, including Kansas, was covered by a vast inland sea that was several hundred feet deep (figs. 3, 4). Hundreds of feet of shale, limestone, and chalk (a form of limestone) were deposited on the floor of this relatively shallow sea.

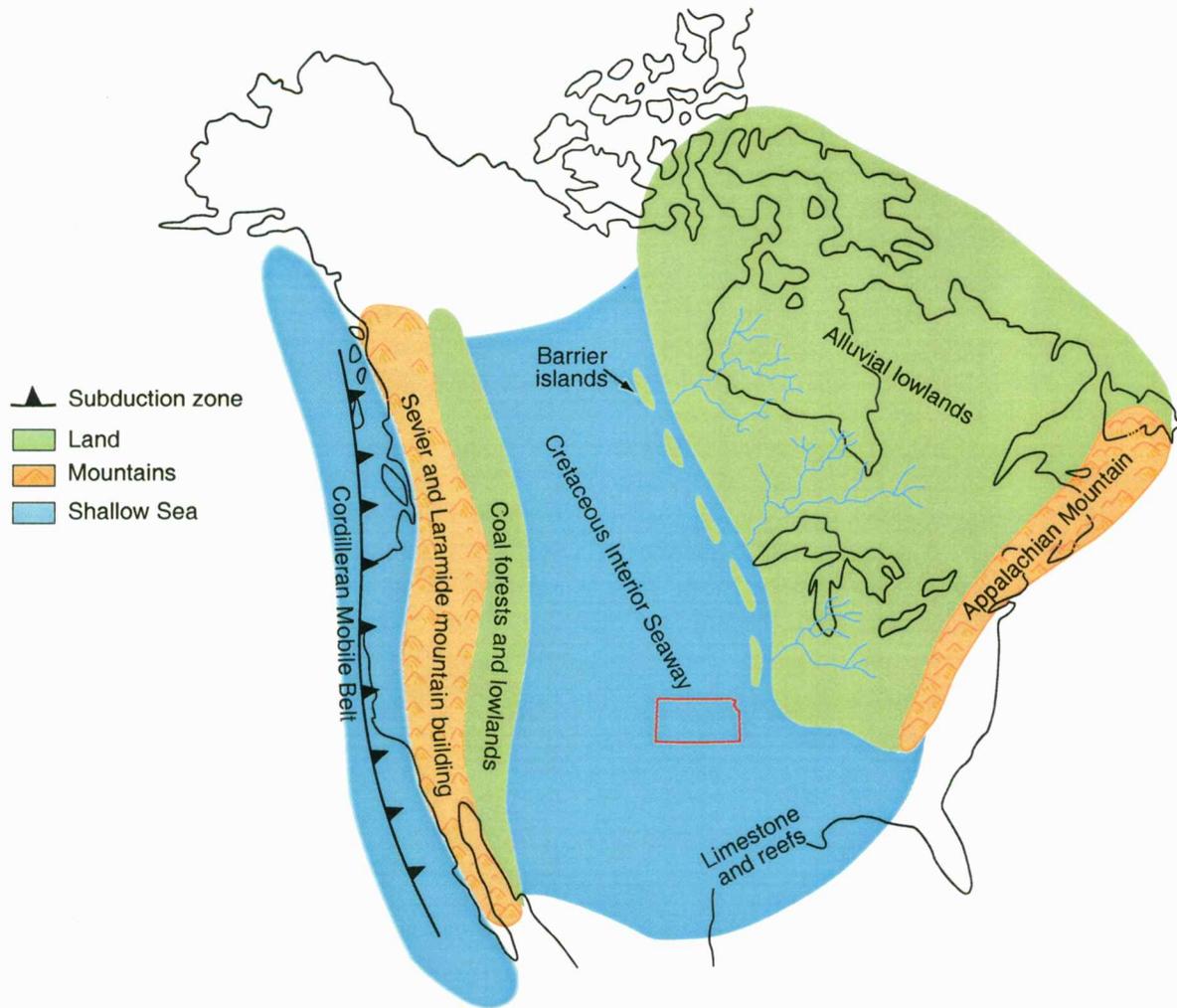


Fig. 3. Geography of North America during the Cretaceous Period, about 100 million years ago. Present-day Kansas is outlined in red (from Wicander and Monroe, 1989).

The Smoky Hill Chalk Member crops out at several localities on the preserve. The largest areas, some covering tens of acres, are found along the Smoky Hill River, but the three main north-south tributaries that cross the preserve north of the river also contain some excellent chalk exposures. These badlands offer scenic views of steep bluffs, steep-walled canyons, and pinnacles carved from the soft chalk by the action of wind and water.

Chalk is a soft, porous, very fine grained limestone that forms from the seafloor accumulation of tiny marine organisms that lived near the ocean's surface. As the tiny shells piled up, a soft limy ooze formed on the sea floor, perfect for engulfing and preserving the remains of other animals—such as fish, sharks, turtles, clams, and marine reptiles—that fell to the bottom of the sea.

The upper part of the Smoky Hill Chalk Member was quarried for building stone at several locations

about 3 miles north of the preserve's ranch house. Saw marks, cut blocks, and other remnants of the quarry operation can be seen at three different sites in this area. The cap rock, a harder, more resistant layer near the top of the Smoky Hill Chalk, was the stone of choice for building. When first uncovered, the stone is soft enough to cut with a saw; after it is exposed to the air, it becomes harder. Examples of structures built from the chalk are the ranch headquarters and the abandoned house near Blue Knob, about a mile southwest of the headquarters.

Rocks in the Pierre Shale, also Cretaceous in age, overlie the Niobrara but crop out only in the northern part of the preserve (Sawin et al., 1999). The uplands are mantled by sand and gravel and wind-blown silt (loess) deposited during the Pleistocene Epoch, which began about 1.8 million years ago. The youngest rocks on the preserve are sand dunes in the uplands and alluvium in the Smoky Hill River

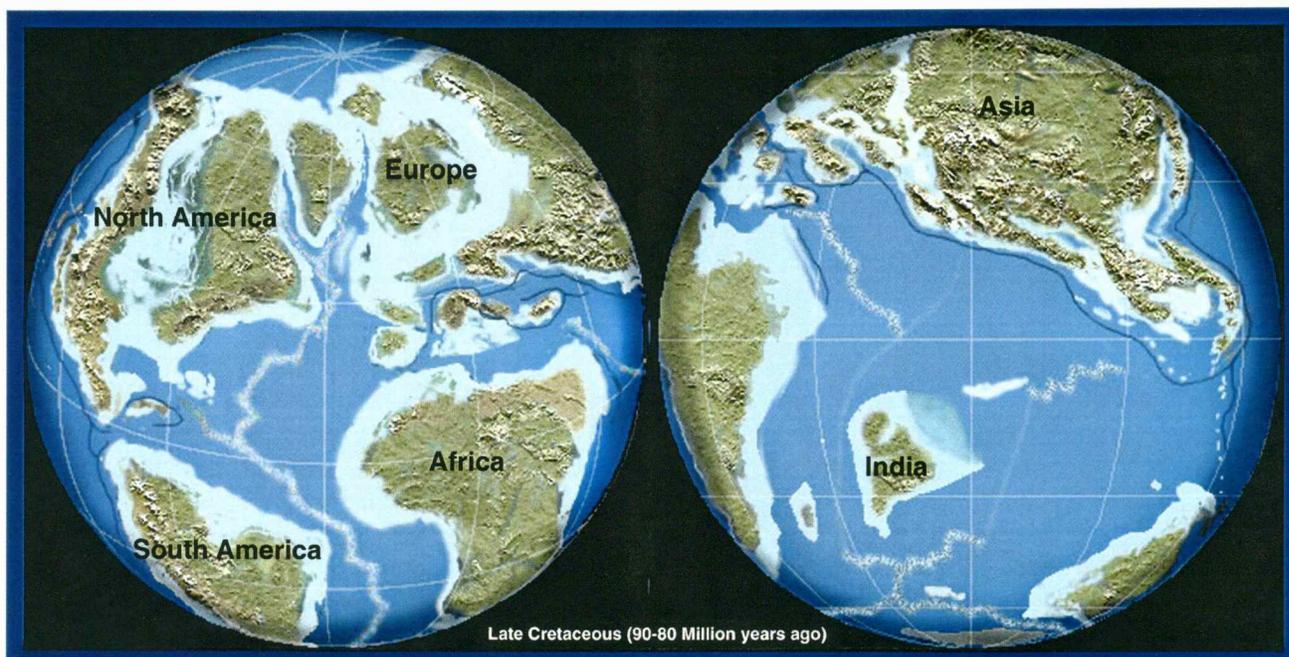


Fig. 4. Position of the continents during the later part of the Cretaceous Period (Blakey, 2001).

valley that were deposited during the last 10,000 years, during the Holocene Epoch.

*Bison Kill Site*—About one-half mile north of where 12 Mile Creek empties into the Smoky Hill River is a late 19th century archeological site, known as the 12 Mile Creek Site. Here, early hunters drove bison over the edge of a ravine (Williston, 1902). In 1895, fossil bones of several extinct bison species were found associated with a Clovis projectile point. Radiocarbon testing dated the bison bones at about 10,300 years before present, making them Pleistocene in age. Pollen analysis of the site suggests that the vegetation at the time of the bison kill consisted of open areas of grass interspersed with stands of pine trees and also that the climate was cooler (Rogers and Martin, 1984).

### From STOP 1 to STOP 2

From the Smoky Valley Ranch Preserve, we proceed south along the west edge of the ranch and cross the Smoky Hill River. This river does not have a source in the Rockies; its source is on the High Plains of eastern Colorado, about 35 miles west of the state line. The river has removed the overlying Ogallala Formation all the way west to the Colorado line. We turn east and work our way back to U.S. 83, passing several areas of badlands carved into the soft chalks of the Niobrara, including a large area known locally as Little Jerusalem.

After crossing Ladder Creek, we reach U.S. 83 and proceed north about 6 miles, passing the ghost town of Elkader and again crossing the Smoky Hill River. At Jayhawk Road we head east and south to our next stop, Monument Rocks.

### STOP 2—Monument Rocks

Monument Rocks is a series of chalk monoliths in western Gove County (fig. 5). Like Castle Rock in the eastern part of the county, Monument Rocks served as a landmark for early travelers and pioneers. It remains a popular tourist site in the Smoky Hill River valley.

Like the badlands on the Smoky Valley Ranch Preserve, Monument Rocks was carved by wind and water in the thick chalk of the Smoky Hill Chalk Member of the Niobrara Chalk. Chalk is white in its pure form, but it may be colored by iron oxide or other impurities. Harder layers within the chalk protect the underlying rock from erosion, creating the distinctive buttes or monuments. Nonetheless, erosion continues to wear away pieces of these monuments, as was demonstrated by the dramatic toppling of Cobra Rock in 1998 and the collapse of Castle Rock's tallest spire following a thunderstorm in July 2001 (fig. 6).

Chalk is a kind of limestone that forms from the seafloor accumulation of tiny marine organisms that lived near the surface. As the tiny shells piled up, a

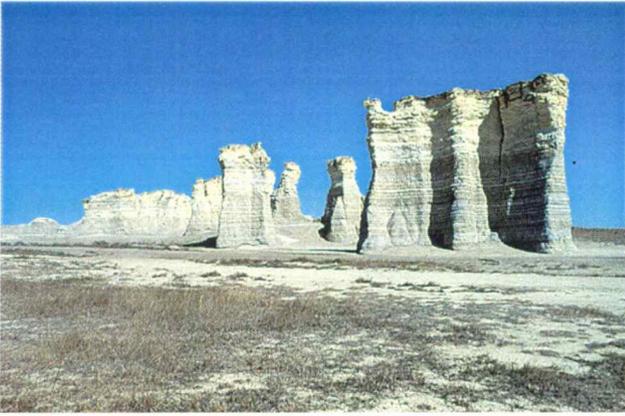


Fig. 5—Monument Rocks, Gove County.

soft limy ooze formed, perfect for engulfing and preserving the remains of other animals that fell to the bottom of the sea. The chalk here at Monument Rocks was deposited at the bottom of a great inland sea that covered most of North America during the later part of the Cretaceous Period, about 80 million years ago (figs. 3, 4).

As we will discuss in more detail at our last stop, the Niobrara Chalk in western Kansas is world famous for its fossils. Beginning in 1868, with the discovery of a large swimming reptile called a ple-

siosaur, the Smoky Hill Chalk Member produced a variety of large vertebrate fossils that attracted paleontologists from around the world.

Monument Rocks has been designated a National Natural Landmark. Although Monument Rocks is open to the public, visitors should bear in mind that it is located on private property.

### STOP 2 to STOP 3

From Monument Rocks we travel south, again crossing the Smoky Hill River. Here the bed of the river is 480 feet lower than our starting point in Oakley. We then travel east back to U.S. 83, passing numerous Niobrara outcrops before we arrive at the Keystone Gallery on the west side of the highway.

### STOP 3—Keystone Gallery

Located on U.S. Highway 83, about 7 miles west of Monument Rocks, the Keystone Gallery is a museum and gift shop operated by Chuck Bonner and Barbara Shelton. This unique gallery features a variety of fossils collected from the Niobrara Chalk, as well as original artwork by Chuck Bonner.

The gallery is housed in a former church, constructed in 1916 out of local chalk. Although offi-

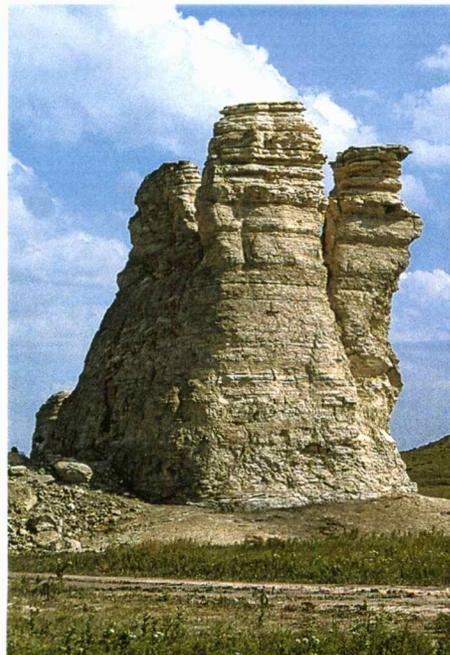


Fig. 6. Castle Rock before (1992) and after (2001) the toppling of its spire.

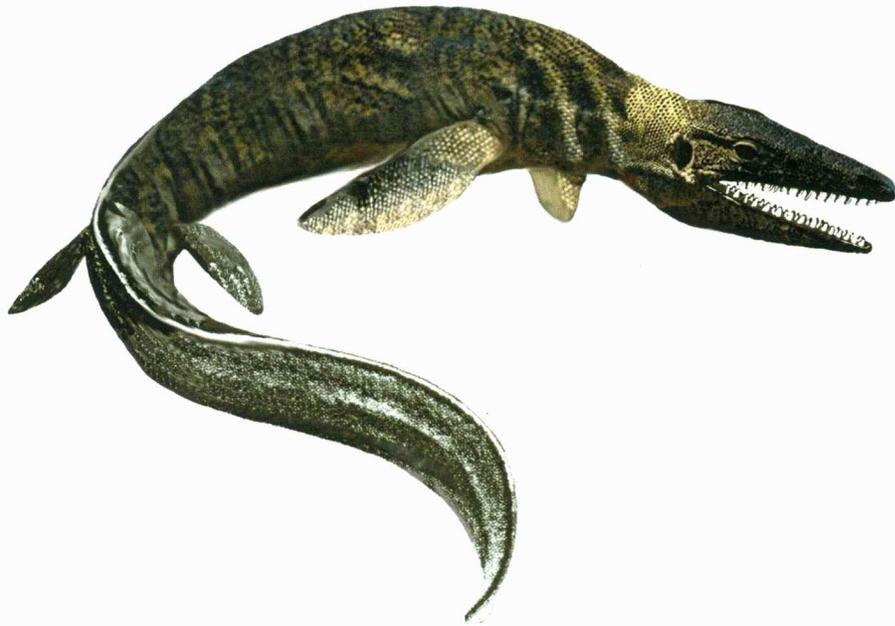


Fig. 7—Mosasaurs were large, swimming reptiles whose fossils are common in Kansas Cretaceous deposits. Kansas mosasaurs ranged in size from the 14-foot *Platecarpus* to the giant *Tylosaurus*, which grew up to 60 feet long. The largest *Tylosaurus* ever found is displayed at the KU Natural History Museum (drawing by Jennifer Sims, Kansas Geological Survey).

cially named the Pilgrim Holiness Church, the church became known as the Keystone Church, and Bonner and Shelton kept this name for their gallery (Bonner, 2002).

Among the fossils on display inside the one-room gallery is a 14-foot-long fish *Xiphactinus audux*. *Xiphactinus* was the largest bony fish that ever lived, with some reaching a length of 18 feet (Bonner, 2002). Its teeth are fairly common fossils in the Cretaceous chalk. These enormous fish had voracious appetites and often ate other fish whole. In fact, some died with their dinners inside of them, as illustrated by the famous “fish within a fish” at the Sternberg Museum of Natural History in Hays, Kansas (Bonner, 2002).

Another important predator in the Cretaceous seas was the mosasaur—a large swimming reptile that sometimes reached 60 feet in length (fig. 7). Mosasaur fossils have been found throughout the Cretaceous chalk, and the gallery has one on display.

The Bonner family has been collecting Cretaceous fossils from the Niobrara Chalk for several generations, since 1928. Some of the specimens they’ve collected over the years, including a sea

turtle and a plesiosaur (a cousin of the mosasaur), are on display in the Sternberg Museum of Natural History (Bonner, 2002).

#### **STOP 3 to STOP 4**

From the Keystone gallery we travel south, climbing back onto the High Plains surface that overlies the Ogallala Formation. We turn west on K-95 and follow it into the oasis-like Ladder Creek valley, descending through rugged outcrops of the Ogallala Formation that surround Lake Scott. We will proceed into Lake Scott State Park, our lunch stop, where we will explore El Cuartelejo, an important archeological site. Following lunch, we will head south a short distance and take a short hike to examine the Ogallala Formation up close and visit one of the large springs that have created this oasis.

#### **STOP 4—Lake Scott State Park**

Listed by National Geographic’s Traveler magazine as one of the country’s 50 must-see state parks, Lake Scott State Park is located west of U.S. 83, between Oakley and Scott City on K-95. The park’s

rugged canyons and craggy bluffs stand out from the typical shortgrass prairie of the surrounding High Plains region. The 1,200-acre park with its 100-acre lake is a popular place for boating, swimming, camping, hiking, and wildlife observation.

The park officially opened on June 12, 1930, one of the first areas set aside in the Kansas parks system. It averages about 180,000 visitors a year.

In addition to the campsites, swimming beach, playground, and concession area, the park has nature trails that accommodate hikers, horseback riders, and naturalists. Wild turkey, deer, beaver, and bobcat have been found in the park. A privately owned herd of buffalo and elk can be viewed at the south end of the park. The park is also home to the Lake Scott riffle beetle, a very small insect that lives in the well-oxygenated riffles of the park's natural springs. This is the only location on earth in which this species is known to occur.

*El Cuartelejo Indian Pueblo*—Near the west edge of the lake is the site of a pueblo built in 1664 by a group of Pueblo Indians from Taos, New Mexico, who migrated north to escape Spanish rule and settled with a band of Plains Apache about 1664. They constructed pueblos and cultivated crops using a system of irrigation ditches from a nearby spring. Their village became known as El Cuartelejo, meaning “old barracks or building.” It is the northernmost pueblo in North America. They lived here for 20 years before returning to their homes in the south. The site was occupied again in 1701 by a band of Picurie Indians, who settled there for about two years. In 1717, Juan Uribarri, who led La Salle to his fatal ambush, opened a trading post at El Cuartelejo. The site was abandoned in 1727.

The El Cuartelejo Ruins, as they are now called, have been designated as a National Historic Landmark. The lower portions of the pueblo's stone walls were excavated in 1889, along with stone and bone tools, ornaments, and pottery sherds. Since that time, erosion has destroyed all but two sections of the outer wall, portions of the stone hearths, and several post holes. In 1971, the Kansas State Historical Society reconstructed the foundation walls, which visitors can see at the site.

*Ogallala Formation*—The park is a good place to see outcrops of the Ogallala Formation, which is well known as an underground aquifer throughout the High Plains. Most of the water pumped for irri-

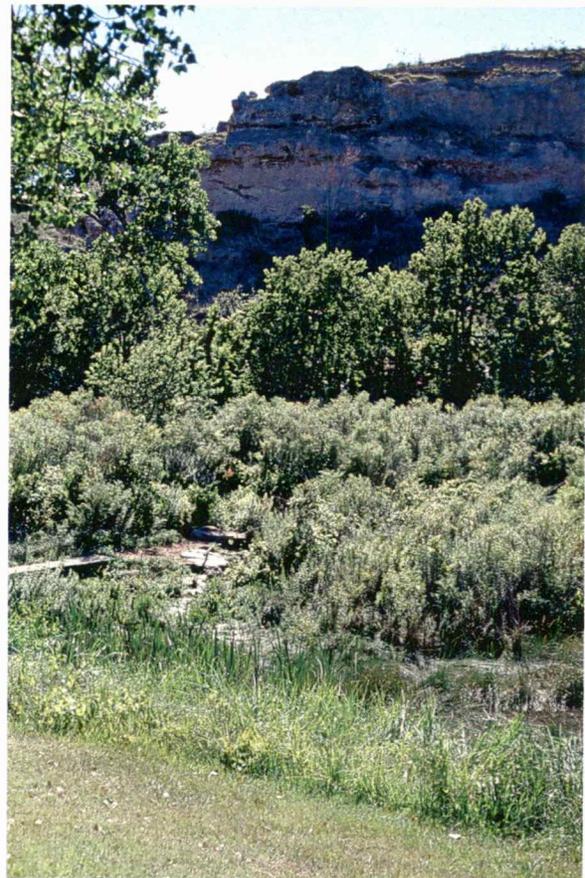


Fig. 8—Big Spring at Lake Scott, with Ogallala outcrop in background.

gation in the eight-state High Plains region is pumped from the Ogallala Formation.

The Ogallala Formation consists of unconsolidated gravel, sand, silt, and clay that eroded off the Rocky Mountains during late Tertiary times, just a few million years ago. At the park, the Ogallala crops out at the surface as hard, dense sandstones and conglomerates cemented with calcium carbonate, known locally as mortar beds (fig. 8). At the south end of the park, the Ogallala forms a long ridge called Devil's Backbone.

*Big Spring*—Springs of any sort are relatively rare on the arid landscape of western Kansas. Several historic springs have now dried up with the lowering of the water table in the Ogallala Formation, primarily because of irrigation. However, Big Spring, one of the largest springs in the Ladder Creek valley, continues to flow at about 350 gallons per minute, a rate roughly comparable to estimates made in the 1950's, making it among the most productive

springs in the western third of Kansas. Water moves through the Ogallala Formation before encountering the relatively impermeable rocks in the underlying Niobrara, then comes out here. In addition to their historic importance, the springs in the Ladder Creek valley are also important ecologically, providing habitat for a species of riffle beetle that is only found in this location.

#### **STOP 4 to STOP 5**

From Stop 4 we return to K-95 and proceed south climbing through Ogallala outcrops and rejoining U.S. 83. We continue south on U.S. 83 to the junction with K-4 and head east, travelling 27 miles across the High Plains surface to K-23, 6 miles east of Healy. Like the area around Oakley, this stretch of highway overlies thick Ogallala deposits that contain sufficient ground water to allow irrigation.

The land surface along this west to east leg of the trip is very flat, but it is not level. The High Plains surface slopes to the east. In this 27-mile stretch of K-4, we drop, imperceptibly, 170 feet or about 6.3 feet per mile.

At K-23 we head north and pass outcrops of Ogallala. Then, we again descend into the Smoky Hill River valley, where scattered outcrops of Niobrara Chalk can be seen. When we cross the Smoky Hill River, we will be at an elevation of 2,440 feet, the lowest point of the trip, more than 620 feet below our starting point in Oakley.

After several miles, we will meander east of the highway to our last stop, an outcrop that exposes a thick section of Niobrara Chalk. The highest point of this outcrop is capped by the Ogallala Formation.

#### **STOP 5—Fossils in the Niobrara Chalk**

Because of the value of large vertebrate fossils, and because of the popularity of fossil collecting in western Kansas, landowners here are particularly sensitive about fossil collecting on their property (see section on legal issues, p. 4). Out of respect for the landowners who have been considerate enough to allow us onto their property, we will not be describing this site in any detail and we ask participants to bear in mind the following:

(1) The Kansas Geological Survey has received permission from the landowner for participants to collect fossils. That permission applies only to this trip, however, and does not constitute permission to return to this location for future visits. Failure to obtain permission from landowners for any future visit would make you liable to prosecution for trespassing, and may mean that landowners will not allow future field trips to visit this site.

(2) If you find fossils that you believe are particularly unusual or valuable, we ask that you provide that information to the landowners. Then you and the landowner can determine how such fossils should be recovered and where they should eventually reside.

**Note:** Watch out for rattlesnakes. Local residents have lots of stories about the number of rattlesnakes they've seen in these canyons. While you walk through the chalk beds looking for fossils, or when you turn over rocks, keep an eye out for snakes.

*Fossils in the Niobrara Chalk*—As we've already mentioned, the Smoky Hill Chalk Member of the Niobrara Chalk is world famous for its well-preserved and scientifically significant fossils. The first vertebrate fossil collected from the chalk was found by Capt. Theophilus H. Turner, the post surgeon at Fort Wallace in the 1860's (Almy, 1987). Turner discovered the remains of a plesiosaur, a large swimming reptile related to the mosasaur. Other collectors soon uncovered additional remains of the vertebrate and invertebrate animals that lived in the vast inland sea that covered Kansas during the Cretaceous Period, some 80 million years ago. The Cretaceous Period was part of the Age of Reptiles, an era famous for its dinosaurs. Although dinosaurs were restricted to landmasses far from western Kansas, their marine cousins—mosasaurs and plesiosaurs—roamed the seas. Besides these large marine reptiles, huge turtles, sharks, flying reptiles, and toothed-birds also inhabited the area and their fossils have been found in the chalk.

Sharks' teeth and the remains of fish (teeth, vertebrae, bones, and scales) are found at almost all chalk exposures in the region. In general, however, vertebrate fossils are less common than the remains of invertebrates, creatures without backbones.



Fig. 9—This inoceramid clam shell, covered with the shells of encrusting oysters (*Ostrea*), was collected in the Niobrara Chalk of Trego County, Kansas.

Probably the most common invertebrate fossils in the chalk are clams and oysters. In fact, the largest clams known, the inoceramids, come from the chalk beds of western Kansas. These extinct clams, some of which had shells with diameters of 6 feet, lived in colonies on the sea floor of the shallow Cretaceous ocean. Great numbers are preserved in the Niobrara Chalk. Some of these huge fossils are covered with encrusting oysters (fig. 9). Others have been found with a variety of fish fossils between their shells, indicating that the fish used the giant clam as a safe feeding place.

The crinoid *Uintacrinus* is another noteworthy fossil found in the Niobrara Chalk. Crinoids are echinoderms, relatives of starfishes and sea urchins. Most crinoids have a cluster of segmented arms that sits on top of a long stem, but *Uintacrinus* is different. This spectacular and rare fossil is a stemless crinoid and entire specimens have been found in the chalk (fig. 10). Because *Uintacrinus* occurs in thin layers and weathers easily, finds are rare; one locality for this fossil is Blue Knob at the Smoky Valley Ranch Preserve.

Ammonoids, extinct squidlike creatures that lived inside an external shell, are also fairly common in the Cretaceous chalk. Ammonoids are relatives of the modern squid as well as the octopus and chambered *Nautilus*, all of which belong to the class of animals called cephalopods.

Specimens from the Kansas Cretaceous are exhibited in museums around the world. Some of these include the Smithsonian Institution in Washington, D.C., the American Museum of Natural History in New York, the Denver Natural History Museum, and, here in Kansas, the Sternberg Museum of Natural History in Hays, the KU Natural History Museum in Lawrence, and the Fick Fossil Museum in Oakley.

### Stop 5 to Oakley

Following Stop 5, we proceed north and west to the town of Gove. According to the 2000 census, Gove has a population of 105, making it the smallest county seat in Kansas. Some Gove County facilities and offices have moved to Grainfield in the northern



Fig. 10—*Uintacrinus socialis* is a stemless crinoid that lived in the Cretaceous seas that covered Kansas roughly 80 million years ago. Among the numerous segmented arms preserved in this slab, a segmented calyx is also visible. This slab was collected in the Niobrara Chalk of Gove County.

part of the county, which is larger (population 327) and located on I-70.

From Gove we head north to I-70 at Grainfield and travel west, climbing 240 feet on the High Plains surface, to our starting point in Oakley.

### Sources

Almy, K. J., ed., 1987, Thof's Dragon and the Letters of Capt. Theophilus H. Turner, M.D., U.S. Army: Kansas History, v. 10, no. 3, p. 170–200.

Blakey, 2001, Late Cretaceous Paleogeographic Globe: Regional Paleogeographic Views of Earth History: [http://jan.ucc.nau.edu/~rcb7/Late\\_Cret.jpg](http://jan.ucc.nau.edu/~rcb7/Late_Cret.jpg) (October 1, 2002).

Bonner, L., 2002, Keystone Gallery—Art, Fossils, and Curiosities in Western Kansas: <http://www.keystonegallery.com/index.html> (October 7, 2002).

Lake Scott State Park, Kansas State Parks: <http://www.kdwp.state.ks.us/parks/pages/scott.html> (May 11, 2001).

McCauley, Jim, Buchanan, Rex, and Sawin, Bob, 1997, Fossil Collecting in the Cretaceous Niobrara Chalk—Kansas Earth Science Teachers Association, Sixth Annual Field Trip: Kansas Geological Survey, Open-file Report 97-62, 14 p.

Rogers, R. A., and Martin, L. D., 1984, The 12 Mile Creek site—A reinvestigation: American Antiquity, v. 49, no. 4, p. 757–764.

Sawin, Robert, McCauley, Jim, Buchanan, Rex, and Lebsack, Wayne, 1999, Smoky Valley Ranch Preserve Geologic Reconnaissance: Kansas Geological Survey, Open-file Report 99-36, 6 p.

Wicander, R., and Monroe, J. S., 1989, Historical Geology—Evolution of the Earth and Life through Time: St. Paul, Minnesota, West Publishing Company, 578 p.

Williston, S. W., 1902, An Arrow-head Found with Bones of *Bison occidentalis* Lucas, in Western Kansas: American Geologist, v. 30, p. 313–315.

## Smoky Hills: Rocks and Minerals

The region known as the Smoky Hills occupies the north-central part of the state. It is delineated by outcrops of Cretaceous-age rocks and takes its name from the early morning haze that often gathers in the valleys.

During the Cretaceous Period (that interval of geologic time from about 144 to 66 million years ago), Kansas was once again under water. Unlike the relatively shallow seas of the Pennsylvanian and Permian, the seas that advanced and retreated during the Cretaceous were deeper and more widespread. Three principal rock outcrops characterize the Smoky Hills—the sandstones of the Dakota Formation, the limestones of the Greenhorn Limestone Formation, and the thick chinks of the Niobrara Formation.

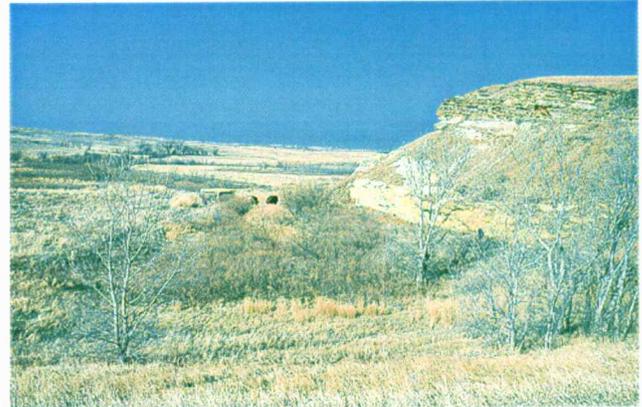
The Dakota Formation sandstones crop out in a wide belt from Rice and McPherson counties, in the south, to Washington County, in the north. They are the remains of beach sands and sediments dumped by rivers draining into the early Cretaceous seas. The hills and buttes in this part of the Smoky Hills, such as Coronado Heights in Saline County, are capped by this sandstone and rise sharply above the surrounding plains.

The next outcrop belt to the west is the Greenhorn Limestone, which is made up of thin (usually less than 6 inches) chalky limestones beds alternating with thicker beds of grayish shale. The Greenhorn Limestone was deposited in a relatively shallow part of the Cretaceous sea. Near the top of the Greenhorn is a limestone bed called Fencepost limestone. Because timber was scarce in this part of the state, limestone was used extensively by early settlers for buildings and fenceposts.

The third and westernmost range of hills in the Smoky Hills developed on the thick chinks of the Niobrara Formation. These chalk beds, which were deposited in the deeper part of the Cretaceous ocean, are exposed in bluffs of the Solomon, Saline, and Smoky Hill rivers and in an irregular belt from Smith and Jewell counties to Finney and Logan counties. The Niobrara chalk is known for the pinnacles, spires, and odd-shaped masses formed by chalk remnants, such as Castle Rock and Monument Rocks in Gove County. It is also known for fossils of swimming reptiles such as plesiosaurs and mosasaurs that lived in the ocean while dinosaurs roamed the land.

### Common Rocks and Minerals

**Sandstone.**—Sandstone is a sedimentary rock, made up largely of quartz grains held together by some natural cement (calcium carbonate, iron oxide, or silica). In the Smoky Hills, some of the sandstones in the Dakota Formation are cemented by dark-brown iron oxide and are so resistant to erosion they cap steep hills. Other sand-



*Outcrop of the Dakota Formation at Wilson Lake, Russell County.*

stones—such as the giant concretions at Rock City in Ottawa County and Mushroom Rock State Park in Ellsworth County are cemented by calcium carbonate.

**Concretions.**—Concretions are formed when minerals in water are deposited about a nucleus (such as a leaf or shell or other particle), creating a rounded mass whose composition or cement is usually different from the surrounding rock. This can occur at the time of deposition, shortly thereafter, or after the sediment has hardened.

Generally, concretions are harder than the rocks around them; therefore, over time, they can weather out of the surrounding rocks. Concretions in Kansas are formed from any of a number of minerals, including calcite, limonite, barite, pyrite, or silica. They vary widely in shape and size. The smallest are oolites, which can be smaller than the head of a pin. At the other end of the spectrum are the huge spherical concretions at Rock City in Ottawa County and Mushroom Rock State Park in Ellsworth County, the largest of which have diameters of 27 feet.

**Limestone.**—A sedimentary rock common in Kansas, limestone is composed mostly of calcite (calcium carbonate,  $\text{CaCO}_3$ ). 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 of the ocean, lake, or river.

The limestones that crop out in the Smoky Hills were deposited during the Cretaceous Period. A popular limestone for building, the Fencepost limestone, occurs near the top of the Greenhorn Limestone. This relatively thin limestone, up to one foot thick, is marked by a distinctive rust-colored band in the middle. In addition to widespread use as a building stone, Fencepost limestone is the source of the stone fenceposts that have made this part of the Smoky Hills known as post-rock country.

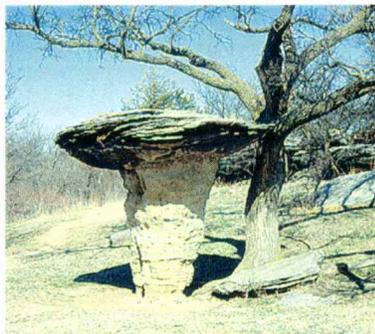
Another variety of limestone, chalk dominates the landscape in the western part of the Smoky Hills. Chalk is a soft, porous, very fine grained kind of limestone that crumbles easily. In its pure form, it is white, but it may be colored by iron oxide or other impurities. Chalk forms from the seafloor accumulation of tiny marine organisms that lived near the surface. As the tiny shells piled up, a soft limy ooze formed, perfect for engulfing and preserving the remains of other animals—such as fish, sharks, turtles, clams, pterodactyls, mosasaurs, and plesiosaurs—that fell to the bottom of the sea.

### Places to Visit

*Rock City.*—At Rock City, two hundred sandstone concretions are distributed in an area about the size of two football fields. Rock City is located 3.6 miles south of the town of Minneapolis in Ottawa County, off Kansas Highway 106. A small admission fee is charged from May to August. For more information, contact the Chamber of Commerce, 213 West Second, Minneapolis, KS 67467 (785) 392-3068.

*Mushroom Rock State Park.*—Another place to see sandstone concretions from the Dakota Formation is Mushroom Rock State Park, one mile south of Carneiro in Ellsworth County. Balanced on pedestals of softer rock, the spheres are the result of differential erosion of the Dakota Formation sandstone.

*Kanopolis State Park.*—This park is a good place to get a feel for the rugged beauty of the Dakota Sandstone country.



*Sandstone concretion at Mushroom Rock State Park.*

Gypsum crystals (selenite) weather from the shale slopes around the lake. The gypsum is a secondary product derived from the weathering of iron sulfide (mainly marcasite) in the shale. For more information, contact Kanopolis State Park, 200 Horsethief Rd., Marquette, KS 67464 (785) 546-2565.

*Sternberg Museum.*—The newly remodeled Sternberg Natural History Museum in Hays opened in March 1999. Adjacent to Interstate 70 on the northeast edge of Hays, this is a great place to learn more about what life was like

at the edge of the Cretaceous sea that covered western Kansas, roughly 80 million years ago. For more information, visit the Museum's web site at [www.fhsu.edu/sternberg/](http://www.fhsu.edu/sternberg/).

*Monument Rocks and Castle Rock.*—These chalk monoliths in western Gove County were carved by wind and water in the thick chalk of the Smoky Hill Chalk Member of the Niobrara Formation. Harder layers within the chalk protect the underlying rock from erosion, creating the distinctive buttes or “monuments.” To get to



*Chalk monuments at Castle Rock in Gove County, showing Cobra Rock before it toppled in 1998.*

Castle Rock, take the Quinter exit off Interstate-70 and head south for 14 miles on Castle Rock Road. To get to Monument Rocks, head south on U.S. Highway 83 from the intersection with U.S. 40 at Oakley. After 20 miles, head east on Jayhawk Road for 4 miles, then south for 2 miles, east for 1 mile, and south for one-half mile. Although both sites are open to the public, visitors should bear in mind that they are located on private property.

### Sources

- Buchanan, Rex C., and McCauley, James R., 1987, *Roadside Kansas—A Traveler's Guide to Its Geology and Landmarks*: Lawrence, Kansas, University Press of Kansas, 365 p.
- Buchanan, Rex, McCauley, Jim, and Sawin, Bob, 1996, *Field Trip to the Kanopolis Lake Area*: Kansas Geological Survey, Open-file Report 96-41, 17 p.
- Buchanan, Rex C., Tolsted, Laura L., and Swineford, Ada, 1986, *Kansas Rocks and Minerals*: Kansas Geological Survey, Educational Series 2, 60 p.
- Evans, Catherine S., 1988, *From Sea to Prairie—A Primer of Kansas Geology*: Kansas Geological Survey, Educational Series 6, 60 p.
- Jackson, Julia A., editor, 1997, *Glossary of Geology* (Fourth Edition): Alexandria, Virginia, American Geological Institute, 769 p.
- Landes, Kenneth K., 1935, *Scenic Kansas*: Bulletin of the University of Kansas, State Geological Survey of Kansas, v. 36, no. 18, 52 p.
- McCauley, James R., Buchanan, Rex C., and Sawin, Robert, 1997, *Fossil Collecting in the Cretaceous Niobrara Chalk*: Kansas Geological Survey, Open-file Report 97-62, 14 p.
- Wilson, Frank W., 1978, *Kansas Landscapes—A Geologic Diary*: Kansas Geological Survey, Educational Series 5, 50 p.

## High Plains: Rocks and Minerals

In Kansas, the High Plains region comprises almost all of the western one-third of the state. It is an area of vast flatlands and gently rolling hills, with topographic relief largely restricted to streams and river valleys, such as the Arikaree Breaks in Cheyenne County or along the Cimarron River in Seward County.

The High Plains developed on sediments that originated in the Rocky Mountains to the west. The Rocky Mountains were formed by deformations of the earth's crust at intervals during the last part of the Cretaceous Period and continuing into the Tertiary Period, which lasted from approximately 66 to 1.6 million years ago. By late Tertiary time, just a few million years ago, the Rockies were being eroded by wind and water. Streams flowing eastward out of the Rocky Mountains were full of sand, gravel, silt, and other rock debris. Over millions of years, this mass of eroded material filled the stream valleys and eventually covered the hills, creating a huge, gently sloping floodplain. The remnants of that region (which extends far beyond the Kansas border) is the region we call the High Plains.

The great wedge of sand and gravel that lies below the surface is the Ogallala Formation. The Ogallala is made up of the unconsolidated deposits (sands, gravels, clays, and other materials) that eroded off the face of the Rockies. Some of this material was cemented together to form porous sandstones, which are known as mortar beds. Most of the Ogallala is underground, but it crops out in many places, such as at Scott County State Lake. The Ogallala is one of the chief sources of ground water in western Kansas.

The High Plains get less precipitation than other parts of the state, averaging between 15 and 25 inches a year. The combination of low precipitation, windiness, and abundant sunshine makes for a dry, or semiarid, climate in much of the High Plains. Short, drought-tolerant grasses cover the uncultivated areas, trees are scarce, and desert-type plants (such as cactus and yucca) are common.

### Rocks and Minerals

*Loess.*—Loess covers much of the uplands in northern and western Kansas, concealing many of the rocks near the surface. Loess is a finely ground silt that is deposited by the wind. In the High Plains of Kansas, loess was deposited by the wind during the glaciations of the past million years. This finely ground silt was formed as glaciers advanced over the continent, pulverizing rocks and sediments in their path. When the glaciers melted, this silt



*Elephant Rock in northwestern Decatur County is an eroded outcrop of the Ogallala Formation.*

was deposited on the floodplains by streams coming from the melting ice sheet. Geologists think that temperature differences between the snow-covered regions to the north and the bare ground to the south may have created large differences in atmospheric pressure, which produced strong winds capable of moving large amounts of silt a considerable distance.

More than 90 percent of the soil in Thomas, Sherman, Cheyenne, Greeley, Wichita, Scott, Hamilton, and Lane counties has developed in loess deposits. In some places the loess has been eroded away by streams. The resulting draws and canyons have extremely steep sides. Loess can maintain a nearly vertical face without slumping or caving in. Along the Arikaree River in Cheyenne County, canyons carved into thick loess deposits form a rugged landscape called the Arikaree Breaks.



*Arikaree Breaks, Cheyenne County.*

**Sandstone.**—A common sedimentary rock, sandstone is made up largely of quartz grains that are held together by some natural cement such as calcium carbonate, iron oxide, or silica. In the High Plains, the most common rock in the Ogallala Formation is a porous sandstone made up of quartz and feldspar grains that are cemented by very fine-grained calcium carbonate. Because these rocks look like concrete, they are known locally as mortar beds. Sandstones in the Ogallala crop out in the bluffs around Scott County State Lake and near the town of Cedar Bluffs in Decatur County.

Another kind of sandstone—a hard, dense, gray-green rock—also occurs in some parts of the Ogallala Formation, especially in southern Phillips County, but also in Graham, Hodgeman, Ness, Norton, Rawlins, Rooks, and Smith counties. The sandstone is cemented with opal. This opaline sandstone is occasionally used as a building material.

**Opal.**—Opal is found in the Ogallala Formation in Clark, Ellis, Logan, Ness, and Rawlins counties. Opal consists of silicon dioxide (SiO<sub>2</sub>), like quartz, plus an indefinite amount of water. It never forms as crystals and cannot be scratched by a knife, though it is slightly softer than quartz.

Kansas opals are not the precious variety. The opals from the Ogallala may be colorless, white, or gray and are 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 has been found in Trego and Wallace counties.

**Jurassic Rocks.**—The Jurassic Period occurred between 208 and 144 million years ago, just before the Cretaceous Period. During the Jurassic, sandstones and shales were deposited over the western one-third of Kansas. These Jurassic formations were then covered during the Cretaceous and are found only in the subsurface, except at a few locations in the southwest corner of the state. One of these, known as Point of Rocks, overlooks the Cimarron River in west-central Morton County. This outcrop of Jurassic and Tertiary rocks is capped by the Ogallala Formation.

## Places to Visit

**Arikaree Breaks.**—The rugged landscape of the Arikaree Breaks was carved by water in the windblown loess deposits that blanket this part of the High Plains. To see the Breaks, take Kansas Highway 27 north of its junction with U.S. Highway 36 (the junction is two miles west of the town of St. Francis).

**Scott County State Lake.**—This is a good place to see outcrops of the Ogallala Formation, which is an important underground aquifer throughout the High Plains. Here at Scott Lake, the Ogallala crops out at the surface as hard, dense sandstones cemented with calcium carbonate, known locally as mortar beds. At the south end of the park, the Ogallala forms a long ridge called Devil’s

Backbone. For more information, contact Scott County State Park, 520 W. Scott Lake Drive, Scott City, KS 67871-1075 (316-872-2061) or visit the Kansas Department of Wildlife and Parks website at <http://www.kdwp.state.ks.us/parks/parks.html>.

**Point of Rocks.**—Located in Morton County, Point of Rocks is one of the few places where Jurassic rocks are exposed at the surface in Kansas. Capped by the Ogallala Formation, Point of Rocks was an important landmark on the Santa Fe Trail’s Cimarron Cut-off (known as the Dry Route). Near this landmark, Middle Spring offered a reliable source of water to thirsty travelers. Numerous wagon ruts are still visible in the vicinity. Point of Rocks is located west of Kansas Highway 27, about 10 miles north of the town of Elkhart in the Cimarron National Grasslands.



*Point of Rocks, Morton County.*

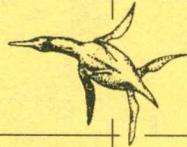
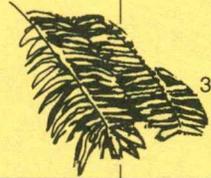
**Fick Fossil and History Museum.**—This museum features Cretaceous fossils, most of which were collected within a 50-mile radius of Oakley. Included in the fossil exhibits are sharks’ teeth, mosasaurs, and plesiosaurs, as well as other representatives of the Cretaceous seas. The museum also houses exhibits of mammalian and plant fossils, rocks and minerals, and archeological pieces. The museum is open year-round, Mondays through Saturdays, 9:00 to 5:00; from Memorial Day to Labor Day, it is also open Sundays, 2:00 to 4:00 pm (785) 672-4839.

## Sources

- Buchanan, Rex C., and McCauley, James R., 1987, *Roadside Kansas—A Traveler’s Guide to Its Geology and Landmarks*: Lawrence, Kansas, University Press of Kansas, 365 p.
- Buchanan, Rex C., Tolsted, Laura L., and Swineford, Ada, 1986, *Kansas Rocks and Minerals*: Kansas Geological Survey, Educational Series 2, 60 p.
- Evans, Catherine S., 1988, *From Sea to Prairie—A Primer of Kansas Geology*: Kansas Geological Survey, Educational Series 6, 60 p.
- Goodin, D. G., Mitchell, J. E., Knapp, M. C., and Bivens, R. E., 1995, *Climate and Weather Atlas of Kansas—An Introduction*: Kansas Geological Survey, Educational Series 12, 24 p.
- Jackson, Julia A., editor, 1997, *Glossary of Geology* (Fourth Edition): Alexandria, Virginia, American Geological Institute, 769 p.
- Wilson, Frank W., 1978, *Kansas Landscapes—A Geologic Diary*: Kansas Geological Survey, Educational Series 5, 50 p.

# KANSAS GEOLOGIC TIMETABLE

(Not scaled for geologic time or thickness of deposits)

ERAS	PERIODS	EPOCHS	EST. LENGTH (YEARS)*	DESCRIPTION		
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.	MILLION YEARS PAST	
		PLEISTOCENE	1,790,000			
	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.		1.8
		MIOCENE	 18,500,000			
		OLIGOCENE	9,900,000			
		EOCENE	21,100,000			
PALEOCENE	10,200,000					
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.	65		
	JURASSIC	63,700,000	Western one-fifth of the state; subsurface only. Terrestrial (nonmarine) deposits mainly shale and sandstone.	142		
	TRIASSIC	42,500,000	Only extreme southwestern part of state, mostly in subsurface. A few small outcrops. Red sandstones and conglomerates, terrestrial deposits (nonmarine).	205.7		
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.	248.2		
	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.	290		
	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.	323		
	DEVONIAN	 63,000,000	Seas covered Kansas during much of the period. Limestone, shale, and sandstone deposits are underground only.	354		
	SILURIAN	26,000,000	Land was uplifted and seas disappeared. Limestone deposits are found underground only.	417		
	ORDOVICIAN	 52,000,000	Seas covered parts of Kansas during much of the period. Dolomite and sandstone are underground only.	443		
	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.	495		
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.	545		
				4,600?		

Eons not shown

\* REFERENCES: A Phanerozoic Time Scale, 1996, by F. M. Gradstein and J. G. Ogg, Episodes, v. 19, nos. 1,2  
 A Revised Cenozoic Geochronology and Chronostratigraphy, 1995, by W. A. Berggren,  
 D. V. Kent, C. C. Swisher, III, and M.-P. Aubry, SEPM (Society for Sedimentary Geology),  
 Special Publication No. 54