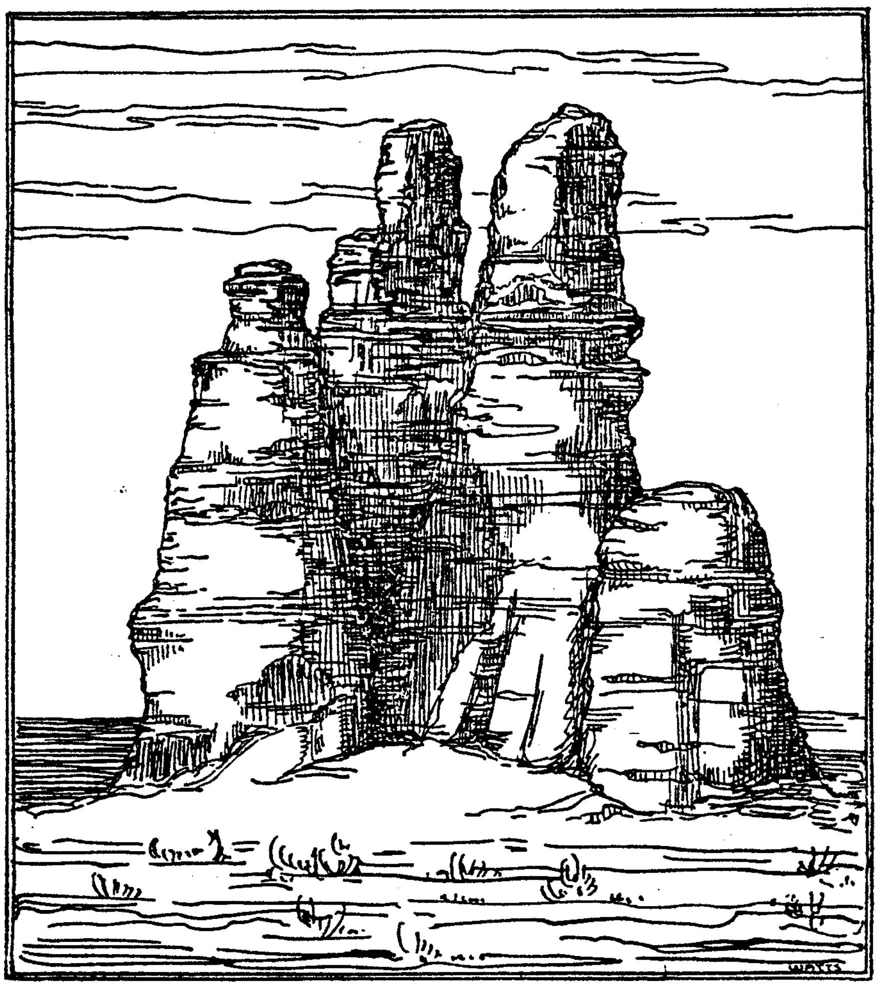
FOSSIL COLLECTING IN THE CRETACEOUS NIOBRARA CHALK



SIXTH ANNUAL FALL FIELD TRIP

Kansas Earth Science Teachers Association

October 4, 1997

KANSAS GEOLOGICAL SURVEY
Open-file Report 97-62

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FOSSIL COLLECTING IN THE CRETACEOUS NIOBRARA CHALK

KANSAS EARTH SCIENCE TEACHERS ASSOCIATION
Sixth Annual Field Trip
October 4, 1997

By

Jim McCauley
Rex Buchanan
Bob Sawin

KANSAS GEOLOGICAL SURVEY
1930 Constant Avenue
University of Kansas
Lawrence, Kansas 66047-3726

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Kansas Earth Science Teachers Association
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PAST KESTA CONFERENCES AND FIELD TRIPS

1992 First Annual	*Douglas County/Johnson County Field Trip* Field Trip Leaders - Rex Buchanan and Jim McCauley
1993 Second Annual	*Chalk Beds of Western Kansas* Field Trip Leader - Jack Walker
1994 Third Annual	*Fossil Collecting in the Upper Pennsylvanian* Field Trip Leader - Paul Johnston
1995 Fourth Annual	*Southeast Kansas: Coal Mines and Fossils* Field Trip Leader - Paul Johnston
1996 Fifth Annual	*The Kanopolis Lake Area* Field Trip Leaders - Rex Buchanan, Jim McCauley, and Bob Sawin

NOTICE

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 (the following section of the guidebook contains information about controversies surrounding fossil collecting and the laws that regulate it).

Out of respect for the landowners who have been considerate enough to allow us onto their property, this guidebook does not describe today's first two stops, or give directions from Gove to those locations. The Kansas Earth Science Teachers Association, and the trip organizers, also ask that field trip participants understand the following conditions of today's field trip.

First, KESTA and the field trip organizers have permission from landowners for participants to collect. That permission applies only to this trip, however, and does not constitute permission to return to these locations 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 these sites.

Second, if you find fossils that you believe are particularly unusual or valuable, we ask that you provide that information to the landowners, so that they are aware of finds. Then you and the landowner can determine how such fossils should be recovered and where they should eventually reside.

Finally, watch out for rattlesnakes. Local residents have lots of stories about the number of rattlers that they see 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.

If you have questions about the circumstances of today's stops, please talk to one of the field trip organizers. Remember that we will be on private property, and our ability to continue to use these sites for educational purposes depends on appropriate behavior by participants, and the cooperation of landowners.

FOSSIL COLLECTING IN THE CRETACEOUS NIOBRARA CHALK

October 4, 1997

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Cover: from *Scenic Kansas*, vol. 36, No. 18, September 1935, Kansas Geological Survey.

FOSSIL COLLECTING IN THE CRETACEOUS NIOBRARA CHALK

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

INTRODUCTION

This field trip focuses on rocks deposited during the Cretaceous Period, about 140 to 65 million years ago, in western and central Kansas (Figure 1). The Niobrara Chalk was deposited late in the Cretaceous, about 80 million years ago, when the western United States was covered by a sea (Figure 2 and 3) that was several hundred feet deep (Buchanan, et al., 1990). The bottom of that sea was warm, dark, and relatively flat. The remains of single-celled animals that lived in the oceans rained down on the ocean floor, forming a limy ooze at the rate of a fraction of an inch per year, eventually accumulating to thicknesses of as much as 750 feet. That ooze was the perfect medium to trap and preserve the animals that lived in the Cretaceous sea, including fish, sharks, pterodactyls, mosasaurs, and plesiosaurs (Figure 4).

The first large vertebrate fossil to come out of the chalk was discovered in 1867 by the post surgeon at Fort Wallace, near the Colorado border. That set off a collecting spree in the 1870s that attracted paleontologists from around the world. Among their more notable finds was the discovery of *Hesperornis*, a toothed-bird fossil that was particularly important at the time because of the debate about Darwinian evolution. Today, the area still attracts large numbers of fossil collectors, including commercial companies that take fossils from the Niobrara for sale to museums, scientists, and private collectors, both in the US and abroad. Casual collectors here are far more likely to find invertebrate remains, including clams, crinoids, oysters, and barnacles (Figure 5). Castle Rock and Monument Rocks, in far western Gove County, are probably the best known outliers of the Niobrara and have long served as collecting locations.

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 1980s. A large 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.

In response, the 1990 legislature passed a law (Kansas Statutes Annotated 21-3759) that requires 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 and not 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-Hers, or boy or girl scouts. These casual collectors, of course, must obey existing laws related to trespass, and thus 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 the sale of any fossils. Because these leases may give the leasor exclusive right to collect on a piece of property, landowners cannot allow other people, including casual collectors, to collect on their land.

VERTEBRATE FOSSIL COLLECTING IN KANSAS

The first vertebrate collected from the western Kansas chalk beds was discovered by Capt. Theophilus H. Turner, the post surgeon at Fort Wallace in the 1860s (Almy, 1987). Turner discovered the remains of a pleisiosaur,

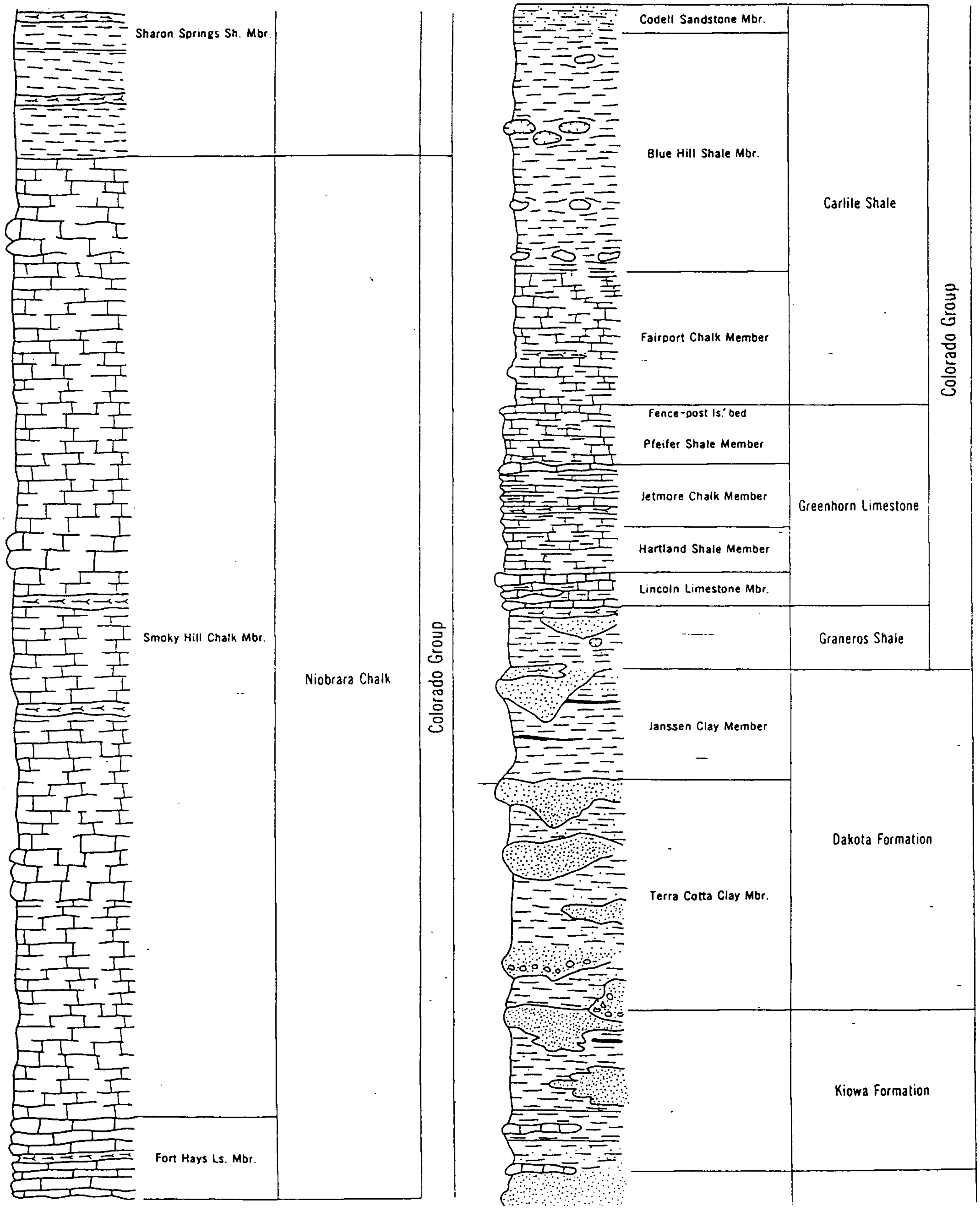

Figure 1. Stratigraphic classification of Upper Cretaceous rocks in Kansas (from Zeller, 1968).

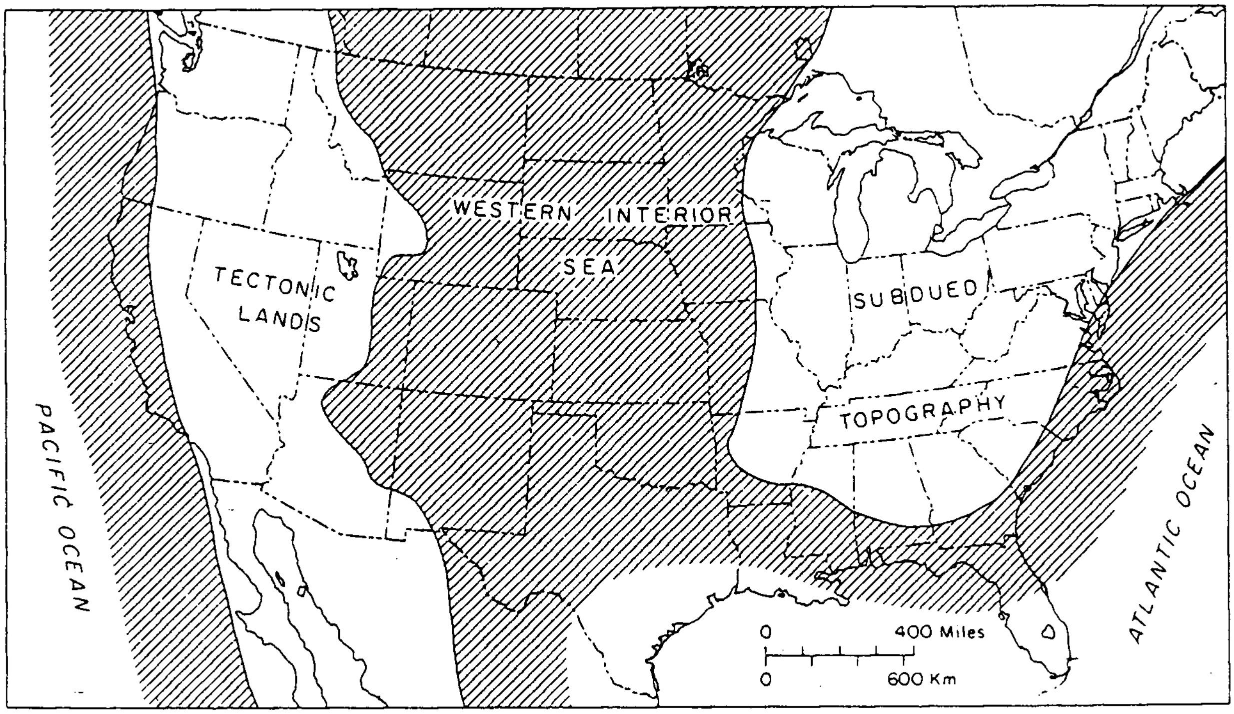

Figure 2. Paleogeographic map of the United States during deposition of the Greenhorn Limestone (from Hattin, 1978).

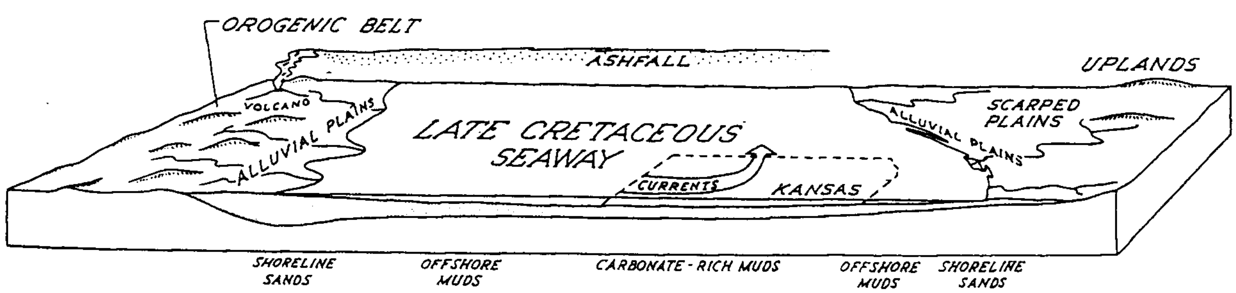

Figure 3. Block diagram showing a portion of the Western Interior Sea during deposition of the Greenhorn Limestone (from Hattin, 1978).

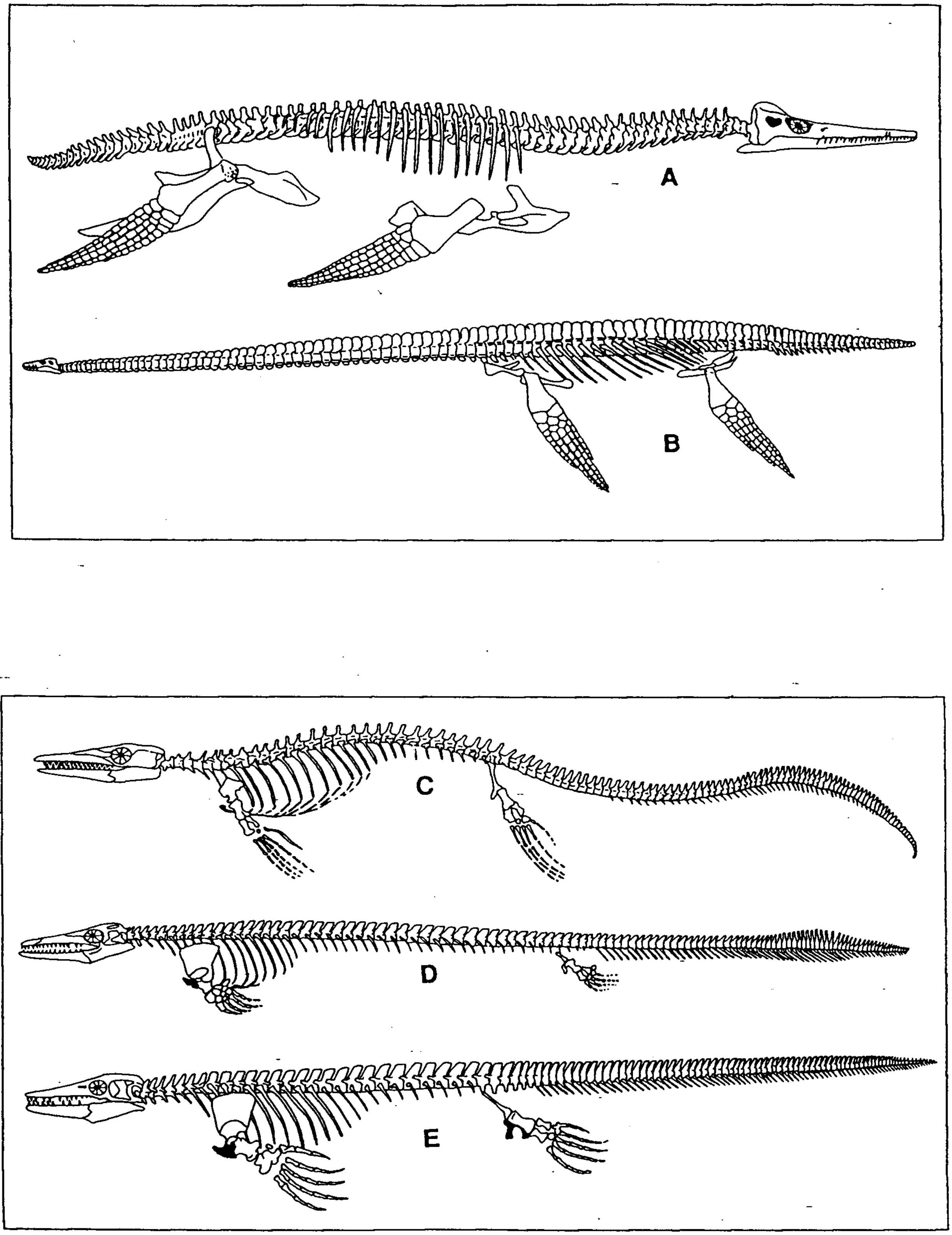

Figure 4. Plesiosaurs (A and B) and mosasaurs (C, D, and E) from the Kansas Cretaceous. A) the short-necked *Dolichorhynochops*, B) the long-necked *Styxosaurus*, C) *Tylosaurus*, D) *Clidastes*, and E) *Platecarpus*. (from Buchanan, 1984).

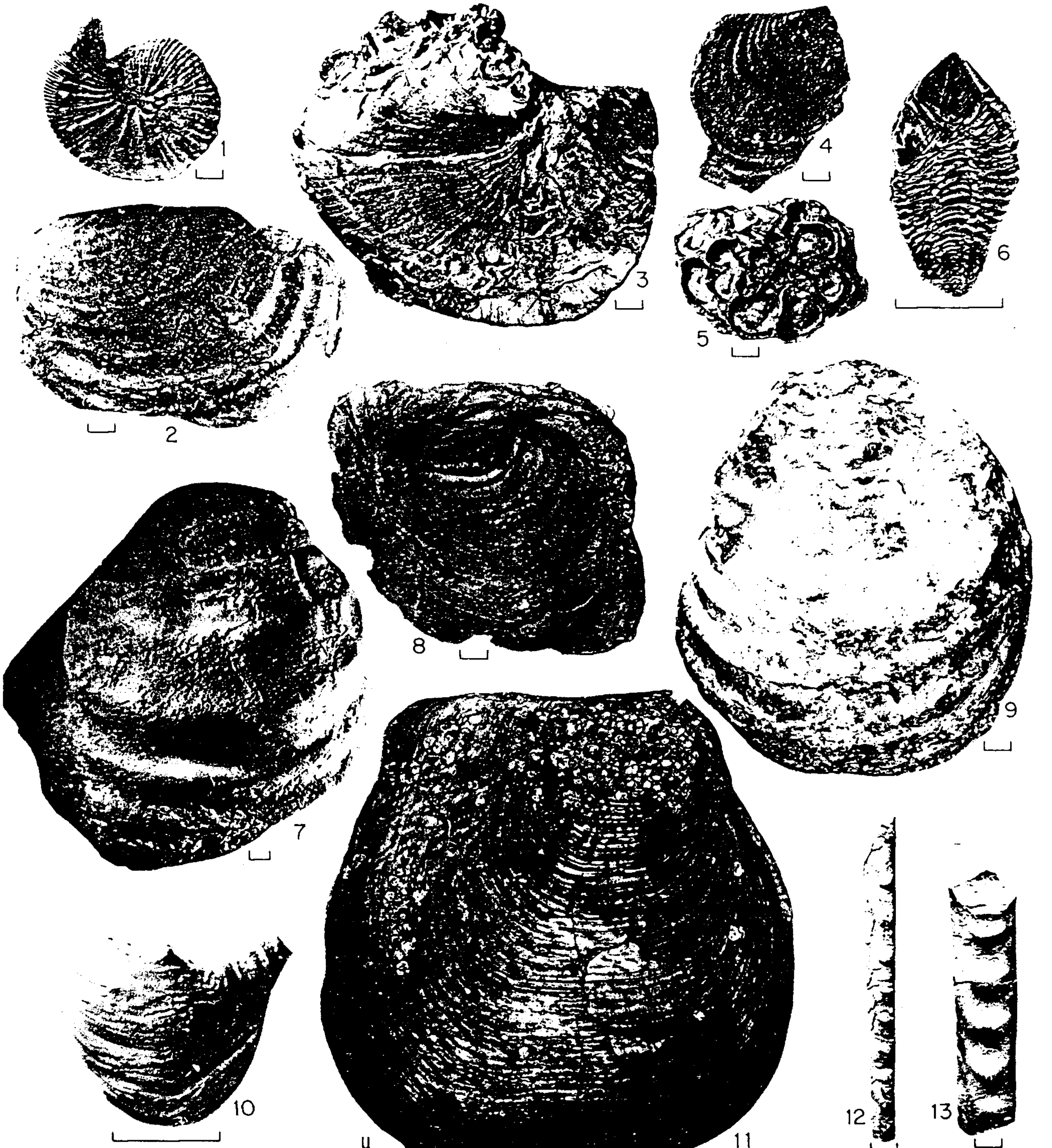

Figure 5. Representative species of macroinvertebrate fossils from the Niobrara Chalk (1-11) and Pierre Shale (12,13). Bar scales equal 1 cm. **1)** *Clioscaphites choteauensis* Cobban; **2)** *Inoceramus (Cremnoceramus) inconstans* Woods; **3)** *Inoceramus (C?) koeneni* Muller; **4)** *Inoceramus (Endocostea) balticus* Bohm; **5)** *Pseudoperna congesta* (Conrad); **6)** *Stramentum haworthi* (Williston); **7)** *Inoceramus browni* Cragin; **8)** *Volviceramus grandis* (Conrad); **9)** *Inoceramus deformis* Meek; **10)** *Pycnodonte aucella* Roemer; **11)** *Inoceramus (Platyceramus) platinus* Logan; and **12-13)** *Baculites asperiformis* Meek (from Hattin, 1978).

Elasmosaurus platyurus, in Wallace County when he was on a hunting trip. Turner excavated the fossils and shipped them east, by train, to Edward Drinker Cope, curator at the Academy of Natural Sciences in Philadelphia. The pleisiosaur was displayed in Philadelphia and was known as "Thof's dragon." Turner died of gastritis at Fort Wallace in July 1869.

Other Kansas collectors soon found additional vertebrate fossils in the Cretaceous, often working as hired collectors for scientists at eastern universities (Zakrzewski, 1984). George M. Sternberg, post surgeon at Fort Harker, worked with Othniel C. Marsh, a paleontologist at the Peabody Museum at Yale. Sternberg was the first of the famous fossil collecting family that the Sternberg Museum is named for (Rogers, 1991). Benjamin Mudge, the first state geologist of Kansas and later a professor of geology at Kansas State University, sent specimens to both Cope and Marsh. One of those finds, sent to Marsh in 1872, turned out to be the first documented find of a bird with teeth.

Both Cope and Marsh made collecting expeditions to Kansas. But their collecting episodes turned into a scientific rivalry, and they resorted to such behavior as covering up specimens to prevent their discovery by the other party and guarding locations to keep the other away (Skelton, 1984). There were even accusations that one side destroyed fossils to keep them from falling into the hands of the other side.

Collectors continued to work in Kansas in the late 1800s. One of the collectors for Marsh was S.W. Williston, who eventually became one of the early members of the Kansas Geological Survey and later moved to the University of Chicago, where he became famous both as a paleontologist and an entomologist (Shor, 1971). Other, more recent paleontologists who worked in Kansas include C.H. Sternberg, H.T. Martin, George F. Sternberg, Marion C. Bonner, and his son, Orville Bonner (who continues as a vertebrate paleontologist at the University of Kansas).

Because fossils from here are so well-preserved, the chalk beds of western Kansas are among the world's most famous locations for collecting large vertebrate fossils. Specimens from Kansas are exhibited in museums around the world, including the Smithsonian Institution in Washington, D.C., the American Museum of Natural History in New York, and the Denver Natural History Museum. World-class collections are also on display in Kansas museums (see the enclosed brochure about fossil collecting in Kansas for more information).

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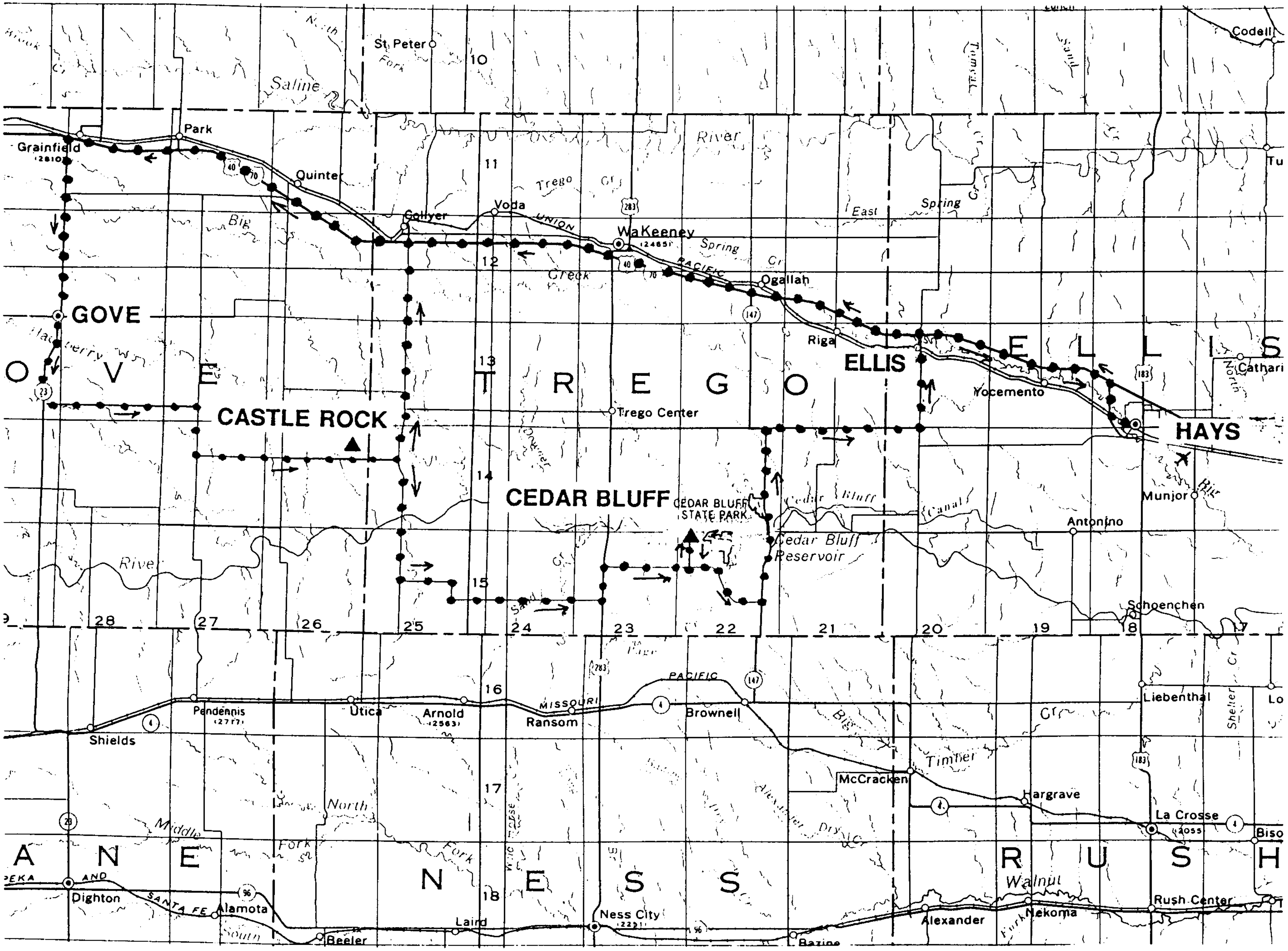


Figure 7. Field trip route map.

ROAD LOG
See Figure 7, Field Trip Route Map

0.0 From the parking lot at **Tomanek Hall**, proceed northeast a short distance on South Campus Drive and make a small jog to the east.

0.15 Park Street. Turn left (northeast).

0.3 8th Street. Jog one block to the right (southeast) then turn left (northeast) on Elm Street.

0.5 Cross Union Pacific railroad tracks. The elevation here is 2,000 feet. About one-half mile down the tracks to the west is the railroad trestle over Big Creek. In the early days of Hays this was known as "Hangman's Bridge," the site of several executions, frontier-style.

0.6 12th Street. At this five-cornered intersection proceed due north on Hall Street. This is about a 30-degree course correction to the left.

0.9 Thomas Moore Prep School is to the west. Just southwest of this school is the site of the failed town of Rome, which lost out to Hays as a railroad stop despite being promoted by Buffalo Bill Cody. Unlike the city in Italy, this Rome was built in a day.

1.2 27th Street. Turn left (west).

2.0 The road bends around a meander in Big Creek, just to the south. This stream and its alluvial aquifer are an important water resource for Hays. But despite its name, Big Creek does not carry major amounts of water, at least in comparison to the Arkansas River or even the Smoky Hill River, 13 miles to the south. In addition, Hays sits in a valley carved into the Carlile Shale, with the Fort Hays Limestone Member of the Niobrara Chalk capping the surrounding hills. These Cretaceous rocks are not aquifers, or water-yielding formations. In fact, they are what geohydrologists call aquitards or aquicludes. Aquitards allow only very slight movement of groundwater while aquicludes do not allow movement of groundwater at all.

This geologic setting results in limited water resources for the city of Hays, the largest city in northwest Kansas. The city has taken a variety of measures to meet its needs, including conservation, restricting private wells in town, drilling wells in the Smoky Hill alluvial aquifer south of town and piping the water north, and drilling deeper wells into the Dakota aquifer, which underlies the city. The water from the Dakota in this area is of marginal quality because of high salt content and must be blended with fresh water before it can be used.

2.2 Junction with U.S. 183 Bypass. Turn right (north).

4.0 Junction with **Interstate 70**. Turn west onto I-70.

The following portion of this road log is keyed to milepost markers along I-70. The description is from *Roadside Kansas: A Traveler's Guide to Its Geology and Landmarks*, reproduced here by permission of the University Press of Kansas.

157.0 Hays, named for the fort that was established here, is today a regional trade center for much of western Kansas. It is the home of Fort Hays State University; many of the school's buildings are constructed out of native limestones, particularly the Fort Hays limestone seen at milepost 149.5. Fort Hays was established here in 1865, one of a string of forts designed to protect the trail to Denver across western Kansas.

The fort was originally known as Fort Fletcher and was located about five miles south of the town of Walker (which is about 11 miles east of Hays), where the North Fork of Big Creek flows into Big Creek. In June, 1867, a flood roared through many of the buildings. Elizabeth Custer, whose husband George Armstrong Custer was stationed at Fort Hays with the Seventh Cavalry, described the flood in her book *Tenting on the Plains*: "Between the bluffs that rose gradually from the stream, and the place where we were on its banks, a wide newly made river spread over land that had been perfectly dry, and as far as any one knew, had never been inundated before. The water had overflowed the banks of the stream between our ground and the hills. We were left on that narrow neck of land, and the water on either side of us, seen in the lightning's glare, appeared like two boundless seas. The creek had broken over its banks and divided us from the post below, while the garrison found themselves on an island also, as the water took a new course down there, and cut them off from the bluffs." Later that summer, Elizabeth Custer returned to Fort Riley and George Custer headed north and west in search of Indians. During this campaign Custer became concerned about reports of cholera in Kansas and, without permission, left his troops to see his wife at Fort Riley. He was subsequently court marshaled and suspended from duty for a year.

After the 1867 flood, the government relocated the fort upstream, on the southwest edge of today's city of Hays. The fort was abandoned in 1889.

156.0 Wells here are in the Gatschet Southeast field.

155.3 Gatschet oil field. The Toronto Limestone Member of the Oread Limestone is one of the producing horizons for this field. The Toronto crops out along I-70 around Lawrence.

154.0 The wells here are in the I-70 oil field, producing from the Topeka Limestone and rocks in the Lansing and Kansas City groups.

153.0 Yocemento Road. The U.S. Portland Cement Company, owned by I. M. Yost, once operated here, and the town's name may have come from the combination of Yost and cement. The geological expertise for the plant was provided by Erasmus Haworth, a director of the Kansas Geological Survey around the turn of the century.

150.0 South of the highway are wells in the Pfeifer North oil field, discovered in 1982. Nearby is the Pfeifer Northwest oil field, discovered in 1983. During the late 1970s and the early 1980s, rising oil prices led to a drilling boom in Kansas, which resulted in new oil fields such as these.

A mile south of the highway is a railroad siding named Hogback, which probably got its name from a sharp bluff formed by an outcrop of the Fort Hays limestone along the Big Creek valley. In geological terms, a hogback is a sharp ridge formed by a resistant rock unit that dips steeply. A less sharp ridge formed by rocks that dip more gently is called a cuesta. Although the Fort Hays limestone dips very gently here, the ridge was still called a hogback. Mount Oread, the hill that is the site of the University of Kansas in Lawrence, was originally called Hogback Ridge.

149.5 Fort Hays limestone.

149.2 Fort Hays limestone. This massive limestone bed often contains fossilized clamshells. It marks the base of the Niobrara Chalk.

148.4 Oil wells to the south of the highway are in the Werth Southeast oil field.

147.7 Wells north of the highway are in the Werth field. Because of its location astride the Central Kansas Uplift, Ellis County has long been the top oil-producing county in Kansas.

145.6 K-247 exits south to Ellis, the boyhood home of Walter Chrysler, of automobile fame. Although Chrysler grew up in Ellis, he was born in Wamego, in northeast Kansas.

143.7 Ellis/Trego county line. Ellis County was named for George Ellis, a Civil War lieutenant who was killed in the Battle of Jenkins' Ferry in Arkansas. Lieutenant Ellis happened to be in the Eldridge House in Lawrence when it was burned by Quantrill's raiders in 1863. To the north of Ellis County is Rooks County, named for a Civil War private, John C. Rooks. Forty-seven Kansas counties are named for soldiers, but only Rooks County is named for a private.

143.0-145.0 Numerous wells in the Ellis oil field are visible along both sides of the highway in this area. These wells produce oil from four different horizons, or layers, of Paleozoic rocks.

141.0 About 3.5 miles south of I-70 is a hill called Round Mound (elevation 2,323 feet). Oil wells in the Ridgeway South oil field are also visible from here. These wells produce from formations deposited in the Cambrian and Ordovician periods of geologic history.

140.5 Riga Road. This town was settled by Volga-Germans who moved westward from Ellis County to Trego County. Now just a railroad siding, Riga is a mile south of I-70.

139.8 Spring Creek. According to the U.S. Geological Survey, Spring Creek is the most popular name for rivers and creeks in Kansas.

139.5 The well south of the highway is in the Spring Creek oil field. Wells in this field are up to 3,800 feet deep.

138.0 This is the approximate boundary between Tertiary rocks, to the west and older Cretaceous rocks to the east. Chalks and chalky shales are common to the east, while the Ogallala Formation is more common to the west. The Cretaceous Period was named from the Latin word *creta*, which means chalk. Limestones and chalks were common deposits in the seas of this age; they are found over large parts of the world, including the island of Crete in the Mediterranean. The famous white cliffs of Dover, England, are thick Cretaceous chalk deposits, similar to the Niobrara Chalk that is widespread in western Kansas. The Niobrara Chalk contains famous fossil beds that have yielded skeletons of fish, marine reptiles, and even flying reptiles from the age of dinosaurs.

136.0 Just south of Ogallah is the Ogallah oil field. Since oil was discovered here in 1951, this field has produced more than 14 million barrels from wells that penetrate the same Pennsylvanian rocks that are visible on the surface in eastern Kansas. From here east to the area around Russell, I-70 passes through numerous oil fields that are located on the Central Kansas Uplift, a broad, northwest-southeast trending upwarp of the earth's crust. This uplift occurred in the early Pennsylvanian Period and has several smaller folds and faults superimposed upon it, which have localized many of the oil accumulations. Oil was first discovered in the Central Kansas Uplift in 1923, northwest of Russell. Since then, the area has been the site of continued oil exploration. Today it is the most densely drilled geologic feature in the United States.

135.4 K-147 exit. To the north this highway goes to Ogallah. Ogallah was once the home of the Kansas State Forestry Station, started in 1887. In 1897 it produced 2,000,000 trees for homesteaders and timber claims. It closed in 1913. To the south, Highway 147 goes about 13 miles to Cedar Bluff Reservoir, a lake built in 1951 on the Smoky Hill River by the Bureau of Reclamation. Chalk bluffs and outcrops are visible along many of the banks of Cedar Bluff.

134.6 The wells here are part of the Ogallah Northwest oil field, discovered in 1957.

132.5 Oil well in the FCS field.

131.8-133.0 Rest area.

127.2 U.S. 283 interchange. North of the highway is the town of WaKeeney, a place-name that was created from combining two names: Albert Warren and James Keeney, owners of a Chicago business firm that bought land here in the 1870s. According to the United States Postal Service, WaKeeney is still the only town in the country by that name. This is also about the halfway point between Kansas City and Denver.

121.7 The elevation here is 2,500 feet.

120.1 Voda Road exit. The town of Voda is 2 miles to the north of the highway.

118.5 To the north are wells in the Hladek oil field. These wells produce oil from the Lansing and Kansas City groups of formations at a depth of about 4,000 feet. These rocks, deposited in the Pennsylvanian Period when a shallow sea left limestones and shales across the state, crop out at the eastern end of I-70 in Kansas.

115.1 K-198 leads a short distance north to Collyer. The county road that runs south from here winds near Castle Rock. Visitors to Castle Rock should keep in mind that they are on private property.

About a mile north of Collyer is Coyote Creek. Coyotes, the largest member of the dog family still found in Kansas, live throughout the state and are often seen in fields and along creeks. Coyotes are generally solitary, nocturnal animals whose howls and yips can be heard at night. Resembling underfed German shepherds, coyotes live on a variety of plants and animals, eating everything from mice to birds and berries. In his book *Roughing It,* Mark Twain described a prairie encounter with a coyote: "The coyote is a long, slim, sick and sorry-looking skeleton, with a gray wolf-skin stretched over it, a tolerably bushy tail that forever sags down with a despairing expression of forsakenness and misery, a furtive and evil eye, and a long, sharp face, with slightly lifted lip and exposed teeth. He has a general slinking expression all over. The coyote is a living, breathing allegory of Want. He is *always* hungry.... When he sees you he lifts his lip and lets a flash of his teeth out, and then turns a little out of the course he was pursuing, depresses his head a bit, and strikes a long, soft-footed trot through the sage-brush, glancing over his shoulder at you, from time to time, till he is about out of easy pistol range, and then he stops and takes a deliberate survey of you; he will trot fifty yards and stop again—another fifty and stop again; and finally the gray of his gliding body blends with the gray of the sage-brush, and he disappears."

113.1 Gove/Trego county line. These counties are named for two captains in the Civil War, Grenville Gove and Edgar P. Trego.

107.5 K-212 leads north to Quinter. This is also the exit for Castle Rock Road, a county road that runs about 14 miles south to Castle Rock. Castle Rock overlooks the valley of Hackberry Creek; near Castle Rock is a heavily eroded outcrop of the Niobrara Formation, the same formation that makes up both Castle Rock and Monument Rocks in western Gove County. The old Butterfield stage line ran past Castle Rock. The ruts are still visible in the grass just north of the formation.

99.8 K-211 leads north one mile to Park. This town was originally named Buffalo, then Buffalo Park, and finally simply Park. During the late 1800s, fossil collectors often used this town as a supply base as they moved into the Cretaceous chalk to look for fossils. At the time, western Kansas was a paleontologist's paradise, offering numerous samples of previously unknown species. Swimming reptiles called mosasaurs; flying reptiles called pterosaurs; shark's teeth; toothed birds; and other fantastic fossils that came out of the Cretaceous—all lured paleontologists to western Kansas.

The scientists weren't always at home on the western Kansas range. Prof. O. C. Marsh of Yale University came to Kansas in 1870 and began to dig for fossils in Wallace County the day before Thanksgiving. That night the coyotes scared away the party's mules, which returned to nearby Fort Wallace. When the mounts straggled into the fort, the commander surmised that "the Indians have jumped the professor. We must save the party if possible." He sent soldiers to Marsh's dig; they found the scientists safe, although "somewhat short of mules."

With the episode settled, Marsh invited the soldiers to supper and provided the following description of that Thanksgiving night on the plains. "Our bill of fare for the game courses included buffalo tongue, steak, and roast rib; antelope meat in various forms, and stewed jack rabbit; with pork and beans, canned fruit, and vegetables as side dishes. Our beverages were limited but good army coffee and the wine of Kentucky were in abundance. As the feast progressed, the fun became fast and furious. I was requested to make a speech, thanking the lieutenant and his comrades for our rescue, and he replied in feeling terms. Yale songs were sung by our party and western stories were told by the army officers. The November wind howled through our camp and the coyotes, sniffing the feast, serenaded us from the orchestra bluff above, but we heeded them not for we were safe and happy, and that Thanksgiving dinner on the plains of Kansas will, I am sure, not be forgotten by any one present." Marsh's visit may mark the first time that the strains of a nineteenth-century version of "Boola Boola" were heard in western Kansas.

The competition among paleontologists to find and record new fossils became so intense that it was later known as the Fossil War. Collectors resorted to bribery and to covering up new finds to keep their rivals from discovering them. And they lived in fear of attack by Indians. Geologist F. V. Hayden, who explored Kansas during the 1850s and 1860s, was given the Indian name of "The-man-who-picks-up-rocks-running." According to one report, Hayden was once stopped by the Indians, but "finding him armed only with a hammer and carrying a bag of rocks and fossils, they concluded he was insane and let him alone."

Yale's Marsh wrote that he was worried about Indians during his trip to Kansas in 1870. "We kept a sentinel posted on the high part of the bluffs, so that our enemies, the Cheyennes, could not steal upon us unawares." But other geologists took issue with Marsh's concern about Indians. Samuel Wendell Williston, a noted paleontologist and early member of the Kansas Geological Survey, later wrote that "his (Marsh's) reference to the personal dangers encountered from hostile Indians is amusing in the extreme to all those who know the facts. I think that I can say without fear of dispute . . . Prof. Marsh never ran any greater danger from Indians than when he entertained Red Cloud at his home in New Haven."

96.6-97.0 Rest area.

94.0 **K-23 interchange.** Just to the north is the town of Grainfield. Here it is easy to see why this area is called the High Plains. The ground is flat and seemingly featureless, although the Saline River cuts through the earth just a few miles to the north. Exit here and take K-23 south.

Reset your trip odometers, because the following portion of the guidebook begins with mileages at 0.0. We apologize for any inconvenience this may cause.

0.0 Junction with I-70 and K-23. The elevation here is 2,820 feet, the highest point on the trip. Go south on K-23.

0.2 Wheatland High School, home of the Wheatland Shockers.

1.4 North Fork Big Creek.

3.8 Big Creek. This creek, which flows through Hays and joins the Smoky Hill southwest of Russell, has its sources 17 miles to the west, just east of Oakley. Its drainage basin is nowhere more than 10 miles wide.

6.6 East Spring Creek.

8.7 Niobrara Chalk is exposed in the shallow roadcuts along the highway.

10.0 North edge of Gove, officially called Gove City, the county seat of Gove County. Gove is named for Grenville L. Gove, who enlisted in the Union Army as a private but attained the rank of Captain in the 11th Kansas Cavalry. He died from brain fever in Olathe in 1864. The town of Gove was laid out by settlers from Davenport, Iowa. With a population of 109, Gove is the smallest county seat in Kansas. Although Gove is centrally located in Gove County, it's the smallest town in the county, having been bypassed by first the railroad, then U.S. Highway 40, then I-70, all of which pass through the only other towns in the county: Quinter, Park, Grainfield, and Grinnell.

From Gove we will travel to our first collecting site, then return to the county office building and former school house on the southeast edge of town for lunch. After lunch we will proceed to another site, then to Castle Rock. This guide once again begins at 0.0 at Castle Rock.

TABLE 1. OUTCROP DESCRIPTION AT COLLECTING SITES: Smoky Hill Chalk Member, Niobrara Chalk, Gove County, Kansas.

Unit	Description	Thickness (cm)
39	Massive yellow chalk to the top of the outcrop	668
38	Bentonite unit—1.4 cm of gray clay, expanded by gypsum and iron oxide, crops out as two selenitic seams in a reentrant	5.1
37	Yellow chalk	41
36	Gypsiferous seam	2
35	Yellow chalk	26
34	Bentonite	3.5
33	Yellow chalk	27
32	Bentonite unit—1.4 cm of brownish-tan clay, expanded by gypsum and iron oxide	2.5
31	Yellow chalk	30
30	Bentonite	6
29	Yellow chalk—the top 6 cm are silty and soft	28
28	Ferruginous/gypsiferous seam	2.5
27	Yellow chalk—the bottom half is granular, paler, and forms a rounded resistant ledge	53
26	Bentonite unit—2.6 cm of pale-gray clay, expanded by iron oxide and gypsum	3.5
25	Gray and yellow chalk	66
24	Bentonite	3.8
23	Gray chalk	100
22	Ferruginous/gypsiferous seam	2
21	Gray chalk	20
20	Ferruginous/gypsiferous seam	2
19	Gray chalk	38
18	Bentonite	2.5
17	Gray chalk	296
16	Ferruginous/gypsiferous seam	2
15	Chalk	24
14	Gypsiferous seam—crops out as a selenite ledge	1.5
13	Yellow chalk	41
12	Ferruginous/gypsiferous seam	3.5
11	Tan chalk	23
10	Bentonite	2.5
9	Chalk	7
8	Bentonite unit—1 cm of gray-green clay, expanded by iron oxide and gypsum	5.1
7	Gray chalk	83
6	Gypsiferous seam	2
5	Gray chalk	57
4	Bentonite	4.4
3	Gray chalk	23
2	Gypsiferous seam	2
1	Gray chalk	122
Total thickness of measured section		1,831.4 cm

0.0 Castle Rock. The elevation at this scenic overlook is 2,577 feet, about 100 feet higher than the top of Castle Rock, which stands about 50 feet above the surrounding prairie. The bluff at the scenic overlook is capped by the Ogallala Formation, which is composed mostly of sand and gravels that eroded off the face of the Rocky Mountains and were washed out onto the Kansas plains about five to 10 million years ago. Here the Ogallala is in contact with the Smoky Hill Chalk Member of the Niobrara Chalk. The road continues south and east, to the bottom of the bluff, then east past the base of the bluff to Castle Rock. This east face is a maze of narrow canyons, hoodoos, and other erosional features, including a small cave near Cobra Rock. Features such as Cobra Rock look fragile, but they have not changed dramatically over the past 100 years (see the attached article about rephotography of these features).

Castle Rock was an important landmark on the Butterfield Overland Despatch stage route, marking the approximate halfway point between the Missouri River and Denver. Traces of the old stage route are still visible a short distance north of Castle Rock, and there was a Castle Rock station about two miles northeast of the rock itself. From Castle Rock, return south to the east-west section road, and head east (**reset your trip odometers to 0.0**).

2.7 T-intersection. Those who wish to return directly to Hays should turn left (north) and go 12.5 miles to I-70, then head east. Those wishing to visit Cedar Bluff should turn right (south) and follow the road log.

3.2 A short distance to the east is **Wildcat Canyon**, a maze of badlands in the Niobrara Chalk. From here, go south 6.5 miles.

5.9 Smoky Hill River and exposures of Fort Hays limestone. The elevation here is 2,240 feet.

9.7 Turn east on County Road 478.

10.8 Wild Horse Creek and exposures of Smoky Hill chalk.

12.7 Turn right (south).

13.7 Turn left (east).

14.2 Abandoned farm house built of Fort Hays limestone.

18.9 Sand Creek and exposures of Fort Hays limestone.

20.0 East Branch Sand Creek.

22.5 Stop sign. Junction with U.S. Highway 283, which runs south to Ness City and Dodge City, and north to Trego Center, WaKenney, Hill City, and Norton. Turn left (north).

24.5 Turn right (east) on County Road 474 for 4.2 miles

24.7 Fort Hays limestone in creek banks.

26.9 Fort Hays limestone in creek banks.

28.7 Turn (left) north on dirt road leading to Public Wildlife area. Look for the small sign showing the way to Cedar Bluff.

29.8 Turn right (east), go up steep hill. Make sure your vehicle has sufficient clearance to handle this steep, rocky road.

30.3 Turn left (north).

30.7 Cedar Bluff. This sheer cliff has been carved from the Fort Hays Limestone Member of the Niobrara Chalk and is the source of the name for the lake below. Cedar Bluff Reservoir was built in 1951 to provide water for irrigation downstream in the Smoky Hill River valley, for flood control, and to provide water for a fish hatchery below the dam. Shortly after the dam was completed, heavy spring rains in 1951 and 1957 filled the reservoir. In the mid 1960s, lessened streamflow--caused by pumping in alluvial wells and the increased use of conservation practices such as terracing and farm ponds--caused the lake to drop and releases to entities with water rights, such as irrigators, stopped in 1979.

The lowering of the lake level had consequences beyond the reservoir. When discharges from Cedar Bluff ended, considerably less water was available in the Smoky Hill River downstream from the lake. That, along with other factors, had an impact on wells pumping out of the alluvial aquifer along the river, including wells belonging to the city of Hays. Eventually Hays was forced to take aggressive water-conservation measures and began to develop other water sources, including purchasing a ranch in Edwards County, with the plan to build a pipeline and bring water some 85 miles from the ranch to Hays.

Heavy rains in the summer of 1993, and several years of above-average precipitation, have served to bring the lake level back up, drowning out the cottonwoods and other vegetation that established themselves during low-water times. The tops of that vegetation are now apparent in the water below this bluff. Backtrack from Cedar Bluff to the east-west section road and then turn east. **Again, the roadlog starts at 0.0, so reset your odometers.**

0.0 Entrance to Cedar Bluff. Head east on gravel section road.

1.0 Cedar Gorge, with exposures of the Fort Hays limestone.

3.0 Carlile Shale, the formation immediately below the Niobrara, is exposed in a roadcut west of the road. The Carlile consists of a chalky shale, bentonites, chalk, and fine-grained sandstones. Its maximum thickness is about 300 feet. This uppermost portion of the Carlile is the Blue Hill shale member.

3.4 Page Creek.

4.5 Curve east and climb out of Goat Canyon through an exposure of the Fort Hays limestone.

6.1 Stop sign at Kansas Highway 147. Turn left (north) across Cedar Bluff dam. Ogallala Formation is exposed at this intersection, elevation 2,409 feet.

7.2 Road curves around exposures of the Ogallala Formation.

10.0 Outlet for Cedar Bluff Reservoir. Fort Hays limestone is exposed at the south abutment of the dam. Carlile Shale is exposed in the outlet below the dam to the east. The elevation here is 2,200 feet.

10.6 To the east are the remnants of the Cedar Bluff National Fish Hatchery and irrigation canals that once carried water from Cedar Bluff Reservoir eastward to fields in the Smoky Hill River valley. Unlike reservoirs in eastern Kansas that were built by the Corps of Engineers, Cedar Bluff was built by the Bureau of Reclamation, which operates numerous irrigation projects throughout the west.

11.8 This historical marker is located on the approximate path of the Butterfield Overland Despatch Stage route that followed the Smoky Hill Trail. This trail was used from 1859 to 1867 when the railroad came to this part of Kansas. Three miles to the west is Threshing Machine Canyon, named for machinery being carried west to Brigham Young and fellow Mormons in Utah. The freighters were attacked by Indians and killed and the three threshing machines were burned.

16.2 K-147 curves to the west. Turn right (east) on the gravel road.

27.3 Turn left (north) on the black-top road.

31.8 The town of **Ellis**. Turn left on old U.S. 40 and go one block, then turn right on Main Street. Ellis is an important railroad town, being the division point on the line from Kansas City to Denver, the place where crews change. The high school's nickname is the "Railroaders."

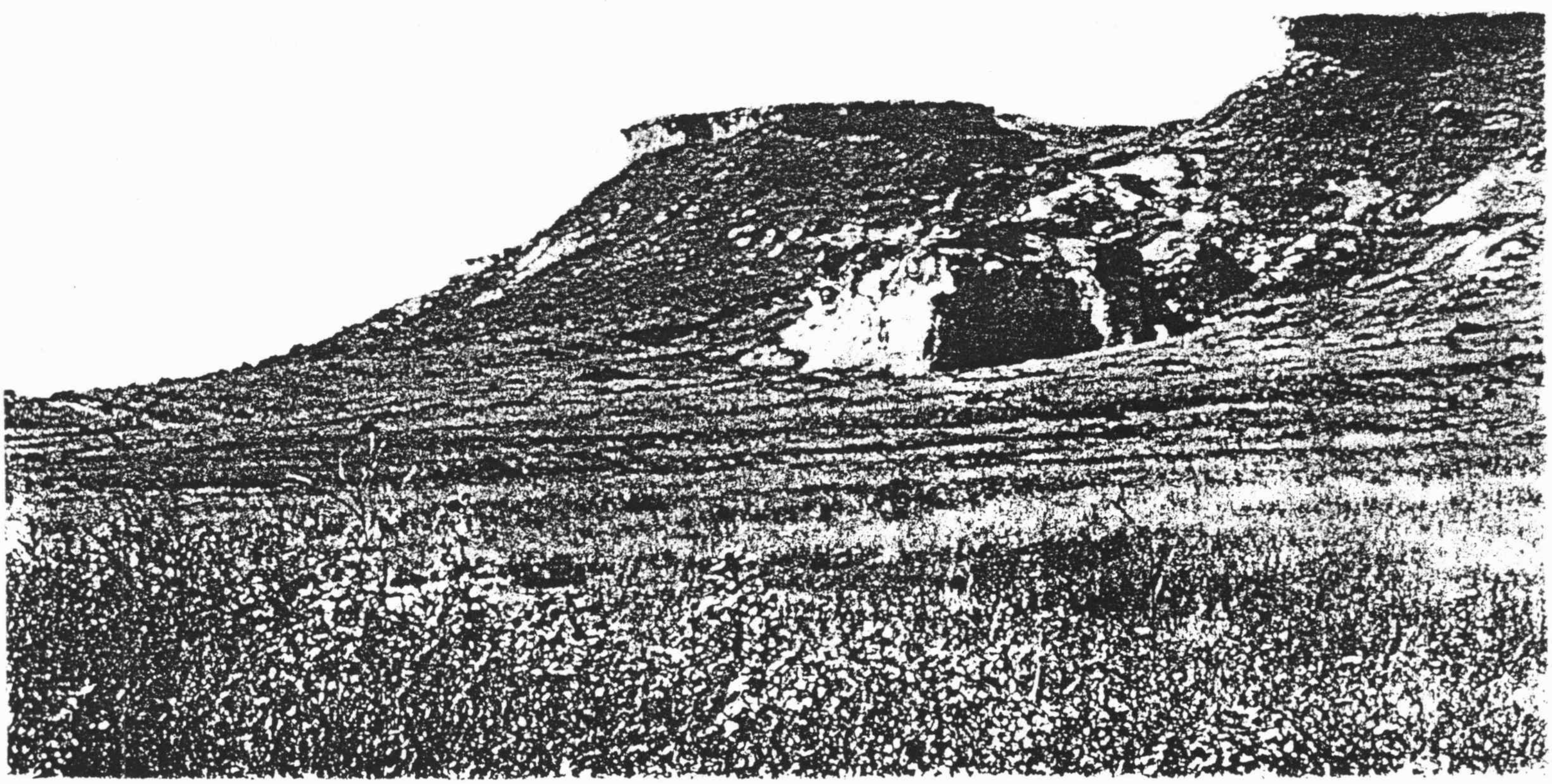
32.6 Kansas Highway 247, the shortest highway in the state, leads 417 feet to I-70. Take I-70 east to Hays and the **Sternberg Museum**. To reach the Sternberg, take exit 159 (U.S. Highway 183) south into Hays. Travel 0.8 miles to 27th Street, then turn left (east) for one mile, then turn left (north) a short distance to the museum.

Portraits of Change

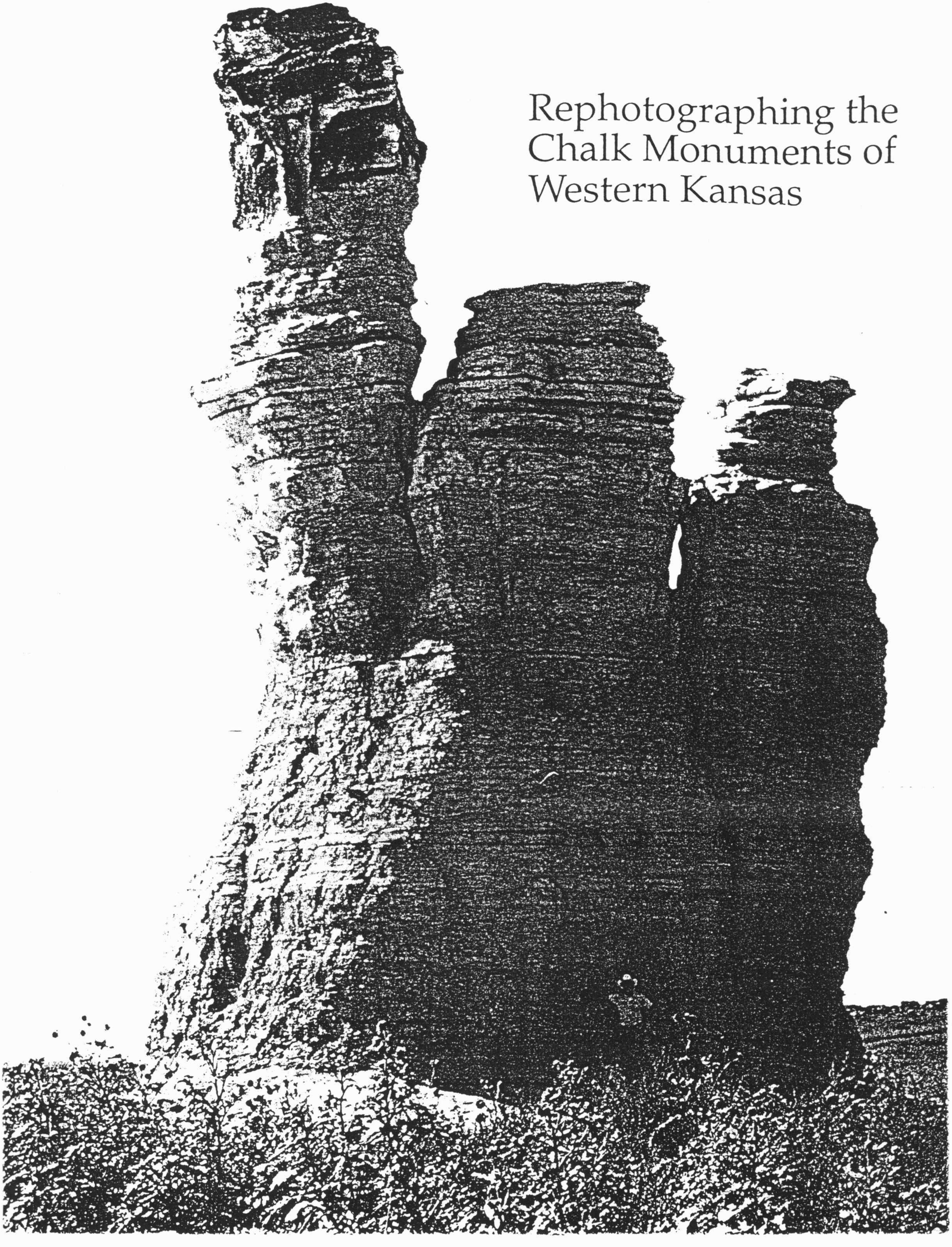
by James R. McCauley, John R. Charlton, and Rex C. Buchanan

My first knowledge of the Rock [Castle Rock] dates from October 1874, and since that time I have seen but little evidence of erosion. In various places throughout the chalk beds of the Smoky Hill river I have observed marks scratched by myself eighteen years previously that appeared as clear almost as when they were made. The erosion in general is not nearly so rapid as one would think.

—S. W. Williston, 1897[1]



Rephotographing the Chalk Monuments of Western Kansas



Few geologic landmarks in Kansas are as distinctive and well known as the chalk monoliths of the western part of the state. Monument Rocks and Castle Rock, in particular, served as landmarks for early travelers and pioneers, and are still popular tourist sites in the Smoky Hill River valley. Although these features may have the semblance of permanence, they change, sometimes dramatically, over time. Erosion, mostly from precipitation but sometimes also from the wind, constantly chips away at the shales, limestones, and chalks that form these monuments. The vegetation changes, in terms of both the species and the profusion of plants. Cultural changes, those induced by people, are also apparent.

Change is constant and certain. Most change occurs slowly, over the course of several decades or centuries, and not at a rate that is familiar to most humans.

Change is constant and certain, but discerning change in a landscape is not easy. Most change occurs slowly, over the course of several decades or centuries, and not at a rate that is familiar to most humans. Yet the documentation of that change reveals a great deal about not only the impact of natural forces on the environment, but also the impact of human activities, even on seemingly impregnable landscape features such as rock outcrops.

In recent years, geologists have increasingly employed photography to measure changes in geologic landscapes. Using an original photograph of a field location, geologists return to the exact location where the original photo was taken and re-shoot the photo at the same angle. The result is a new photograph that, when compared with the older photo, reveals changes—or in some cases the lack of change—in the landscape. This technique (variously called duplicate photography, repeat photography, or comparative photography) has been applied to document changes in such places as the Grand Canyon and other locations in the Southwest.[2]

The use of photography to record geologic change is limited to the past 150 years after this technology was invented. This is a small portion of the geologic record, but an eventful period of human history, corresponding to European movement into the American West. The original government surveys of the western territories, such as those by Clarence King and George M. Wheeler in the 1860s and 1870s, provide some of the most familiar images of the West now in the national park system. The Rephotographic Survey Project of the late 1970s revealed little natural change in these areas.[3] Repeat images from outside the parks, however, often show dramatic change, much of it from human activity. Sometimes this change is controversial, such as changes in river flow, vegetation, and erosion along the Colorado River in the Grand Canyon, nearly all related, one way or another, to human activities.[4]

A geologist at the Kansas Geological Survey, James R. McCauley *received his master's and Ph.D. degrees from the University of Kansas.* John R. Charlton *is staff photographer for the Kansas Geological Survey, and holds a master's degree from the University of Kansas.* Rex C. Buchanan *received master's degrees in history and in journalism from the University of Wisconsin-Madison, and is the assistant director of publications at the Kansas Geological Survey. The three authors previously collaborated on* Roadside Kansas: A Traveler's Guide to Its Geology and Landmarks, *published in 1987 by the University Press of Kansas. They currently are working on a rephotographic project involving Alexander Gardner's 1867 photographs of Kansas.*

The authors would like to express appreciation to Dr. Robert Lichtwardt, Dr. Larry Martin, the staff at the University of Kansas Archives, and owners of the land where the chalk monuments are located.

1. S. W. Williston, "The Kansas Niobrara Cretaceous," in Erasmus Haworth, *University Geological Survey of Kansas* 2 (1897): 240.

2. Garry F. Rogers, Harold E. Malde, and Raymond M. Turner, *Bibliography of Repeat Photography for Evaluating Landscape Change* (Salt Lake City: University of Utah Press, 1984); Harold E. Malde, "Geologic Bench Marks by Terrestrial Photography," *Journal of Research*, U.S. Geological Survey, 1 (1973): 193-206.

3. Mark Klett, Ellen Manchester, JoAnn Verburg, Gordon Bushaw, and Rick Dingus, *Second View: The Rephotographic Survey Project* (Albuquerque: University of New Mexico Press, 1984).

4. Hal G. Stephens and Eugene M. Shoemaker, *In the Footsteps of John Wesley Powell: An Album of Comparative Photographs of the Green and Colorado Rivers, 1871-72 and 1968* (Denver: The Powell Society, 1987); Raymond M. Turner and Martin M. Karpiscak, *Recent Vegetation Changes Along the Colorado River Between Glen Canyon Dam and Lake Mead, Arizona*, Professional Paper 1132 (Washington, D.C.: U.S. Geological Survey, 1980).

Repeat photography has also been used, in a less technical way, to document purely societal and cultural change. Portraits taken during the Depression by Works Progress Administration photographers Walker Evans and Dorthea Lange have provided a basis for repeated portraits years or even generations later.[5] These portraits display direct social, economic, and cultural changes made on individual lives. These repeated photographs are also controversial, but in a much different way from geologic and environmental photographs.

Castle Rock, Monument Rocks, and other outcrops that are part of the Smoky Hill Chalk Member of the Niobrara Chalk, provided obvious and scenic subjects for photography.

In Kansas, extensive use of landscape photography in geologic publications dates only to the 1890s when geologists from the Kansas Geological Survey began regularly using photographic plates to accompany their reports. Some of the early heavily photographed locations in Kansas were in the chalk beds in the west-central part of the state. There, Castle Rock, Monument Rocks, and other chalk outcrops provided obvious and scenic subjects for photography. These monuments are part of a rock layer that geologists have labeled the Smoky Hill Chalk Member of the Niobrara Chalk, one of the most paleontologically important rock formations in Kansas and in much of North America in the latter part of the nineteenth century. Beginning in 1868, the Smoky Hill produced a variety of large vertebrate fossils that brought paleontologists from around the world to western Kansas.[6] There they found skeletal remains of sharks, turtles, pterodactyls, swimming reptiles, bony fish, and a variety of other animals.

Those fossils had been deposited at the bottom of the Cretaceous sea, a large inland waterway that covered much of North America about eighty million years ago. The bottom of the Cretaceous sea was dark, level, and covered with a mucky ooze—perfect for holding and preserving parts of the animals that drifted to the ocean floor.[7] After that sea receded, erosion exposed the remains of those animals, and paleontologists trooped to western Kansas to find, name, and take home a variety of fossils.

Among the best-known of those paleontologists was Samuel Wendell Williston, who came to the University of Kansas and the Kansas Geological Survey in 1890. Williston was a native of Massachusetts who had studied at the Kansas State Agricultural College in Manhattan with Benjamin Franklin Mudge, the first state geologist of Kansas and later a teacher at the Agricultural College. Williston left Manhattan and went to Yale University, where he studied paleontology with O. C. Marsh (who worked with large vertebrate fossils from the Kansas chalk beds in the 1870s) and earned an M.D. When he came back to Kansas, Williston undertook extensive field work in the chalk beds and published his results widely, including two major Geological Survey bulletins that were devoted to paleontology and remain standard references.[8] Although he later moved to the University of Chicago, Williston is certainly among the most important scientists to have worked in nineteenth-century Kansas.

The photographs that accompany Williston's work provide convenient, approximately one-hundred-year-old starting points for rephotography of Kansas geology. These photos are highly useful for comparative purposes for several reasons. First, they are among the early geologic

5. Bill Ganzel, *Dust Bowl Descent* (Lincoln: University of Nebraska Press, 1984).

6. Kenneth J. Almy, ed., "Thof's Dragon and the Letters of Capt. Theophilus H. Turner, M.D., U.S. Army," *Kansas History* 10 (Autumn 1987): 170-200; Lawrence H. Skelton, "Kansas Skirmishes in the Cope/Marsh War," *Earth Sciences History* 3 (1984): 117-22; Charles Sternberg, *The Life of a Fossil Hunter* (Bloomington: Indiana University Press, 1990); Katherine Rogers, *A Dinosaur Dynasty: The Sternberg Fossil Hunters* (Missoula, Mont.: Mountain Press, 1991).

7. Donald E. Hattin, *Stratigraphy and Depositional Environment of Smoky Hill Chalk Member, Niobrara Chalk (Upper Cretaceous) of the Type Area, Western Kansas)*, Kansas Geological Survey, Bulletin 225 (1982).

8. Samuel W. Williston, *University Geological Survey of Kansas, Paleontology, Part 1* 4 (1898); Samuel W. Williston, *University Geological Survey of Kansas, Paleontology, Part 2* 6 (1900); Elizabeth Noble Shor, *Fossils and Flies: The Life of a Compleat Scientist: Samuel Wendell Williston (1851-1918)* (Norman: University of Oklahoma Press, 1971).

photographs of the state. Second, many of Williston's photos are of specific, easily identifiable locations, such as Monument Rocks and Castle Rock. Third, identifying change in the geology of the High Plains of west-central Kansas is much easier than in locations in central or eastern Kansas where increased vegetation has obscured many locations that served as landscape sites one hundred years ago. Erosion in chalk beds monuments is relatively easy to spot without increased vegetation growth or extensive erosion of vantage points where the early photographs were taken.

The purpose was to match the location where Williston took his original photograph, and to stand in his footprints as nearly as we could.

We began the process of duplicating Williston's photographs by locating photographs taken during Williston expeditions in the 1890s. While a number of such photographs are extant at the University of Kansas Archives and the University of Kansas Museum of Natural History, most are close-ups of field locations with no identifiable background features and thus would be very difficult to relocate. We eventually selected six photographs from three locations (Castle Rock, Monument Rocks, and Cedar Bluffs) that we could positively identify and could rephotograph. It is unclear whether Williston himself took these photographs; he generally worked with several field assistants who may have taken some of the photos. Either way, the photographs appear in Williston publications and are closely associated with his work, and for the remainder of this article we will refer to them as Williston's photos.

In 1941, H. T. U. Smith of the University of Kansas repeated two of Williston's photographs in a paper that was published in the *University of Kansas Science Bulletin*.[9] In the case of Castle Rock and one photo at Monument Rocks, Smith's photographs provide an approximate halfway point between Williston's 1890s photographs and views of the chalk monuments today.

During August 1991, we visited the three locations. In each spot, we used several variables from Williston's old photographs to locate the vantage point. In particular, we searched for the point at which the far horizon intersected a rock formation in the foreground. By attempting to match that location, we could usually approximate the distance between Williston and the site he was photographing. We also attempted to find objects in the foreground, such as boulders and other rock debris, that were still in place. Next, we moved by trial and error to match up the angular relationships of other features in the scene until parallax between the two photos was reduced as nearly as possible to zero. The purpose was to match, as exactly as we could, the location where Williston took his original photograph, and to stand in his footprints as nearly as we could.

We do not know the type of camera that Williston used to take his original photographs. We used a view camera with normal and wide-angle lenses. We shot Polaroids at each location, developing them on the spot to test how well they matched up with the original. We then made adjustments to the angle, the height of the camera, and its location, eventually arriving at the precise location.

The result is a series of six duplicate photographs. Each duplicate set of photographs was compared using a Bausch and Lomb Zoom Transfer Scope, an optical device that allows the simultaneous viewing of two different photos of the same or different scales. By superimposing the new photo on the old and flicking back and forth between them, the extent of the obvious changes can be quantified and subtle changes, those not apparent in normal viewing, can be detected. In general, the photographs show considerable geologic change over the past one hundred years. While erosion is an active ingredient of nearly every photograph, other factors are also visible. The following is a detailed discussion of each of those photographs.

9. H. T. U. Smith, "Erosional Modification of Landmarks in Western Kansas During Historic Time," *University of Kansas Science Bulletin* 30 (May 1944): 3-13.

CASTLE ROCK: Of the chalk monuments in the Smoky Hill River valley, probably the best known is Castle Rock, an outlier of Smoky Hill chalk in eastern Gove County, and a landmark along the old Butterfield Overland Despatch stagecoach route. Castle Rock is about sixty feet high and stands north of an outcrop of extensively eroded Smoky Hill chalk overlain by much younger Ogallala Formation deposits.

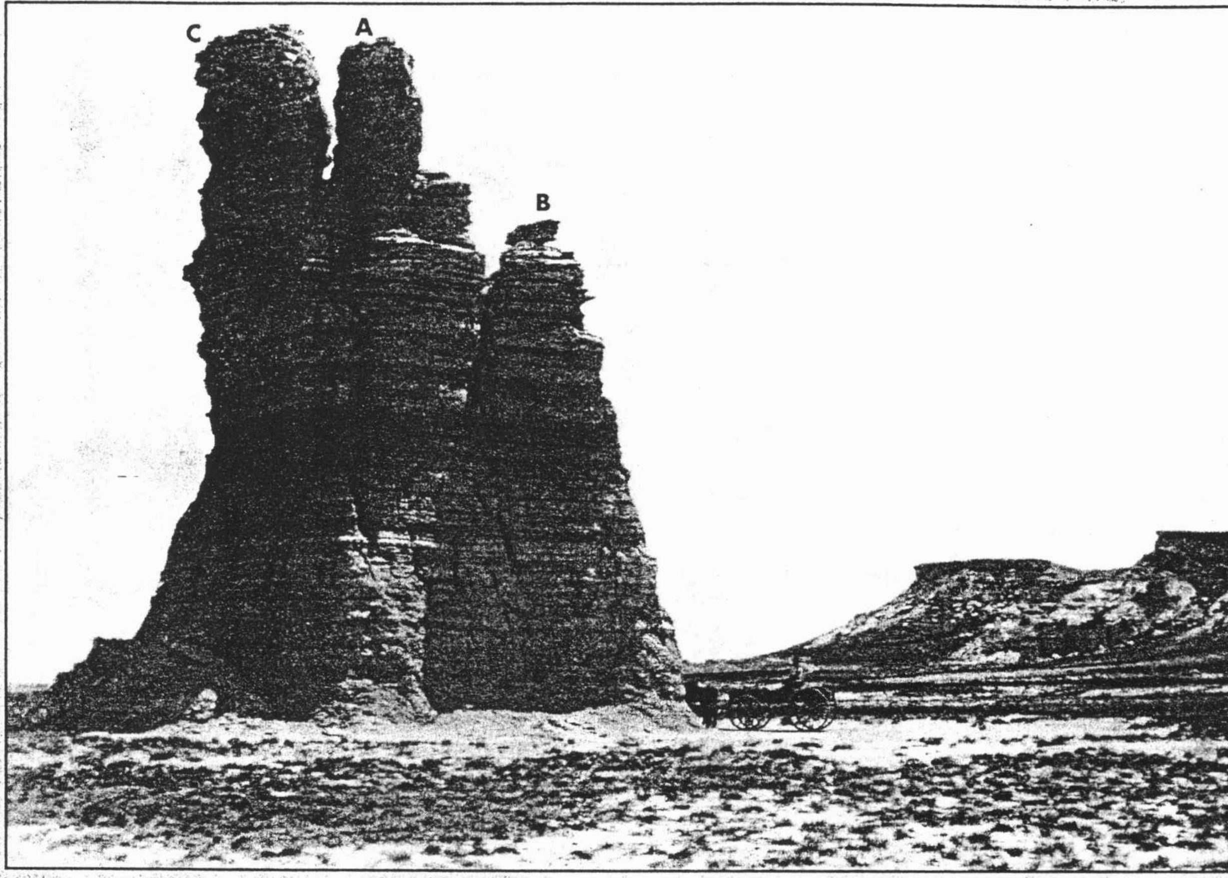
The photographs (on the following two pages) were taken about one hundred feet north of Castle Rock, with a view south-southeast. Note that the horizon to the right of Castle Rock, immediately above the horse in the older photograph, intersects Castle Rock at almost precisely the same point in both photographs. The backgrounds in the photographs do not show considerable change. The vegetation, however, is substantially different, with both additional growth—mostly sunflowers in the disturbed ground adjacent to Castle Rock—and a fuller growth of prairie grasses appearing in the newer photograph. United States Weather Bureau records for the town of Gove, eighteen miles to the northwest, begin in 1889 and show that precipitation was below average that year and even less in 1890, when slightly more than half of the average of 19.42 inches of precipitation was recorded.[10] Thus, the sparse vegetation in the older photo may be drought-related.

Our rephotograph of the rock formation itself shows substantial change from erosion. The middle spire (labeled A in the older photograph and A' in the newer one), which was nearly as high as the spire on the left, has collapsed. H. T. U. Smith's 1941 photo shows this middle spire still standing, so the rock fall took place in the intervening fifty years. By placing the newer photograph over the Williston photograph, it is apparent that the far right-hand spire (B and B') has also undergone substantial erosion. That spire is thinner and approximately five to six feet lower than in 1892.

In addition, considerable rock has spalled off immediately below the top of the left spire (C and C') and between it and the middle spire, exposing a deep crack. The tallest spire may be the next to fall. Even more rock has spalled off on the right edge of the right spire, so that the spire appears to be nearly undercut, instead of gently angling away from the top as in the older photograph. The undercutting of the right side of Castle Rock makes visible more of the chalk outcrop on the horizon behind Castle Rock. Most of that undercutting had not taken place when Smith's 1941 photo was taken, so it too must be fairly recent. Because the surrounding area is treeless grazing land, it is possible that cattle could have contributed to this undercutting by their habit of rubbing against vertical structures, such as gates, trees, and buildings. The absence of such features could mean that Castle Rock has been a popular scratching post for some years. Writing in 1897, Williston commented on "smooth, worn surfaces made on the projecting angles of many low cliffs by the buffaloes."[11] Human activity, including the search for fossils and the carving of graffiti, could also be a factor. In addition, the crack between the right spire and the middle spire is considerably larger, to the point that sky is visible between the two spires in the new photograph. The left spire (C and C') appears to have undergone some undercutting, although not nearly so much as the right side.

10. Warren G. Hodson and Kenneth D. Wahl, *Geology and Ground-Water Resources of Gove County, Kansas*, State Geological Survey of Kansas, Bulletin 145 (1960): 17.

11. Williston, "The Kansas Niobrara Cretaceous," 240.

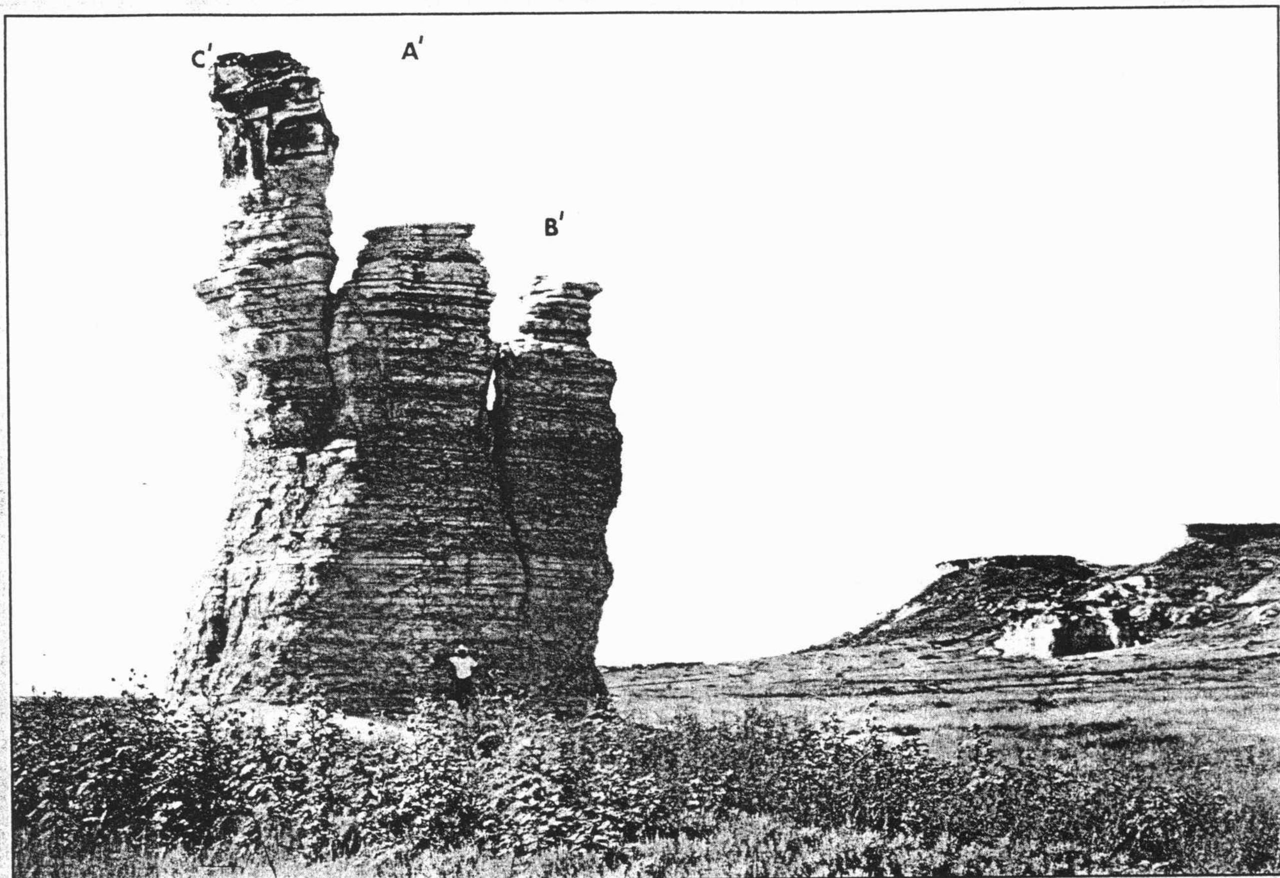


Castle Rock, Gove County, 1890s.

The pile of rock debris at the base of the left side of Castle Rock in the older photo is now gone. The angular nature of this debris suggests a rock fall that occurred shortly before Williston took his picture. Much of the Smoky Hill chalk is actually a chalky shale. Large chunks that fall from Castle Rock and other monuments tend to disintegrate fairly rapidly into low, rounded mounds of chalky clay. Shale has a laminate structure like a deck of cards. When shale is horizontal, this structure is intact. However, when it is no longer horizontal, as in a rock fall, shale tends to separate along the many laminae that compose it, much like a deck of cards that has been dropped. These shale fragments are quickly dispersed by runoff, wind, and animal action. This helps explain the lack of large piles of rocks in the recent photos despite the rock falls that have obviously occurred.

One notable change between these two photographs, and a difference that shows up in several rephotographs, is the darkening at the top of the left-hand pillar that appears to be present only slightly, if at all, in the older photograph. The source of this darkening is apparently related to green algae, which commonly grow on the chalk monuments and limestones throughout Kansas.[12]

12. Robert Lichtwardt, University of Kansas mycologist, communication to author, December 3, 1991.



Castle Rock, 1991.

These darks spots are colonies of dead green algae, with more living cells near the edges. The darkening appears at the top of the monuments in the harder chalk that forms a caprock and is more resistant to weathering.

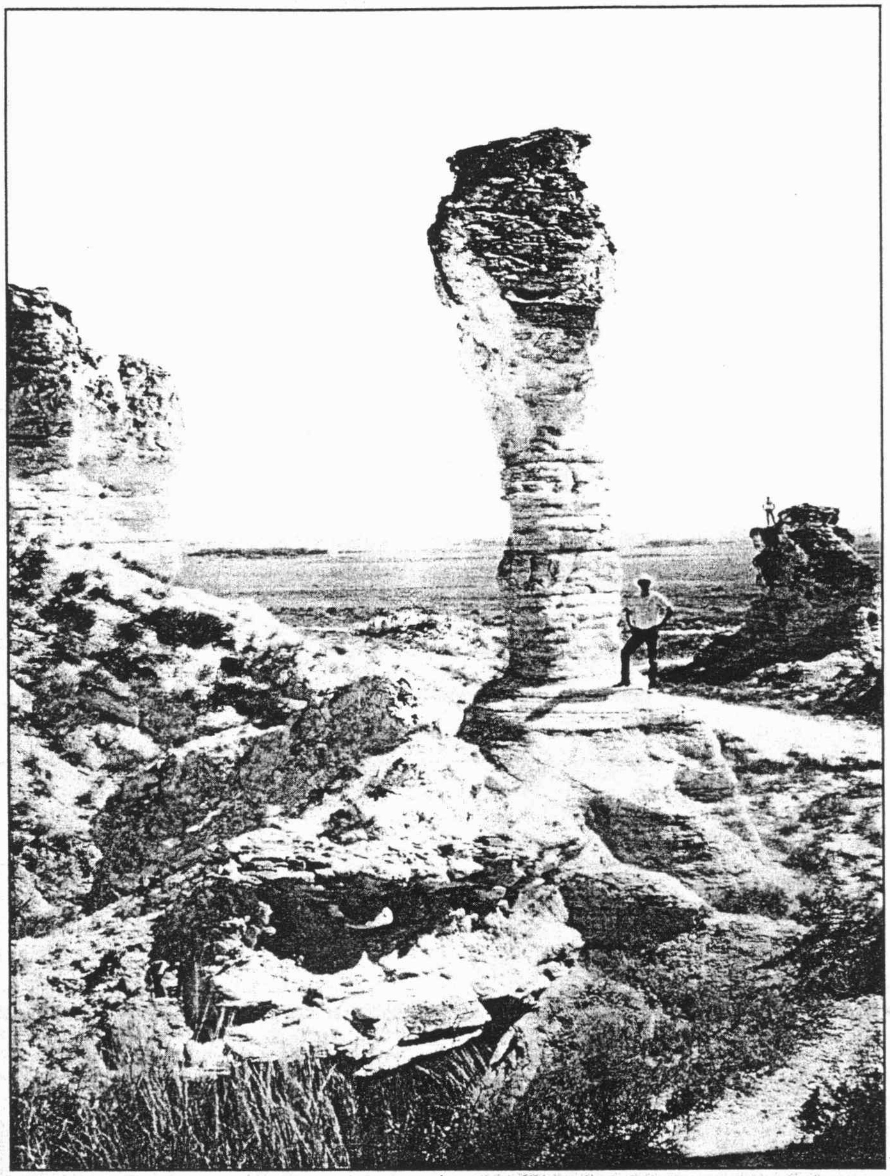
This resistant chalk is a more stable substrate for algal growth than the softer, shaley sections below, which are constantly sloughing off. The staining appears to be most prominent in locations that have not undergone recent rock fall; that is, where rock recently spalled off the chalk outcrops, the color is a creamy white or gray, the rock's unweathered color. Only in those locations where the rock has remained for some time is it stained black. The increase in alga-related staining over the past one hundred years may be because the surfaces at Castle Rock had recently undergone spalling before the 1892 photograph, and the surfaces were too fresh to show the darkening. The increase may also have been caused by changes in climate, which may have encouraged recent algae growth.

Cobra Rock, Gove County, 1890s.

COBRA ROCK. In one of the many box canyons in the chalk badlands immediately south of Castle Rock is a chalk monolith called Cobra Rock. This slender chalk spire, a feature that geologists refer to as a "hoodoo," is one that appears in imminent danger of collapse, with an oversized "head" being supported by a slender neck below. However, comparison of the two photographs shows that the Cobra has apparently perched precariously, with roughly the same amount of support, since at least the 1890s.

Again, a comparison of the horizon line between the two photographs shows how well the two match. The horizon strikes one of the far pillars on the right-hand side just at the feet of the person standing on the rock. The horizon crosses the neck of the Cobra Rock at the same bedding plane in the chalky shale. Because of the indistinct background in the older photo, vegetational changes are difficult to discern. However, the dark patterns just below the horizon on the new photo appear to be riparian woodlands along Hackberry Creek that are not detectable on the old photo.

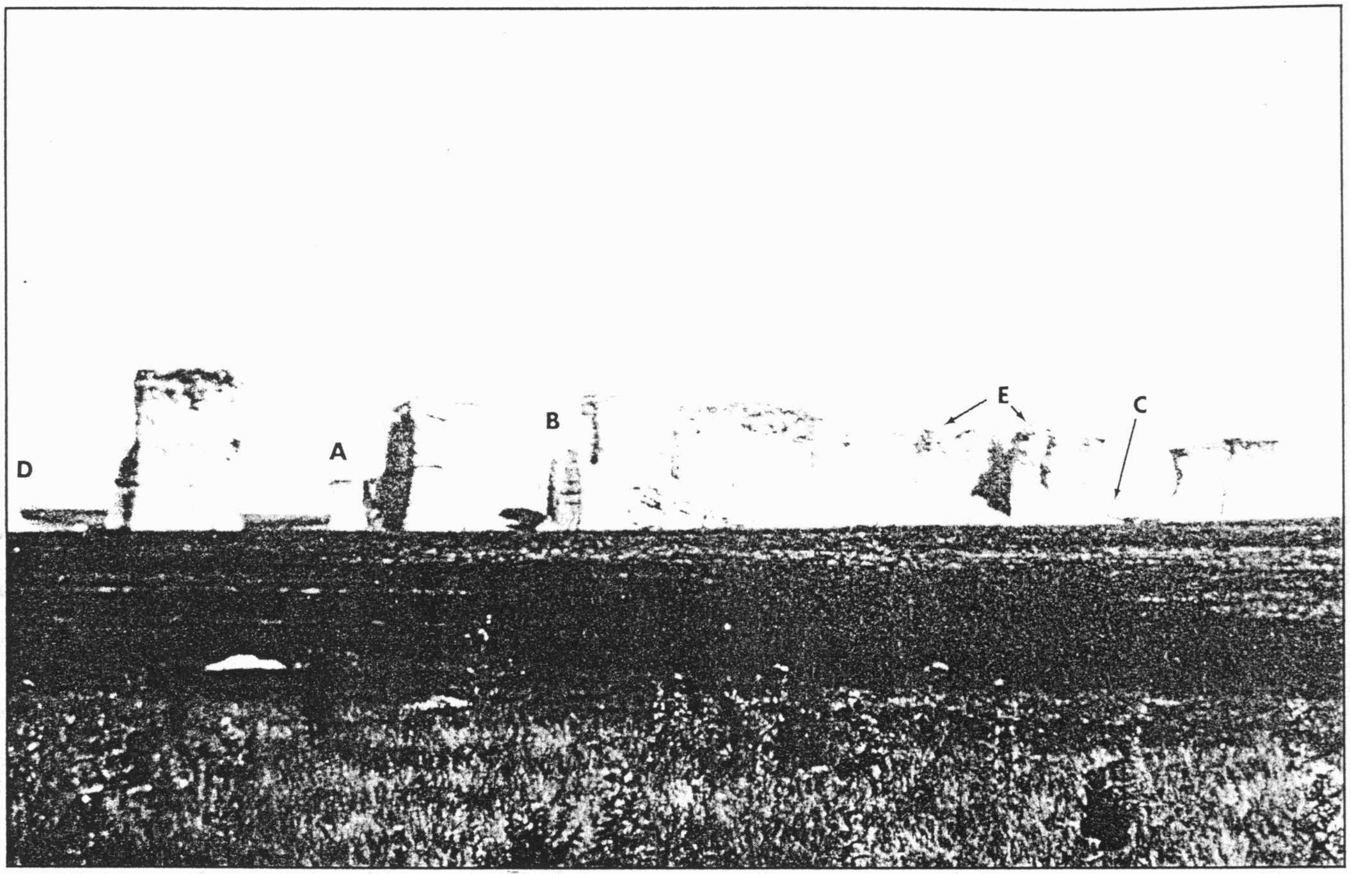
The geologic change in this photograph lies largely in the foreground. The large boulder in the left-center foreground of the older photograph has been reduced



Cobra Rock, 1991.

somewhat in the new picture with softer strata having been weathered away, leaving more resistant rock standing out in relief. The small gully between the photograph and the boulder, which leads to the base of the Cobra, has oticeably deepened over the years as well. More noticeably, the outcrop on the right hand foreground of the photo is no longer present in the newer photograph.

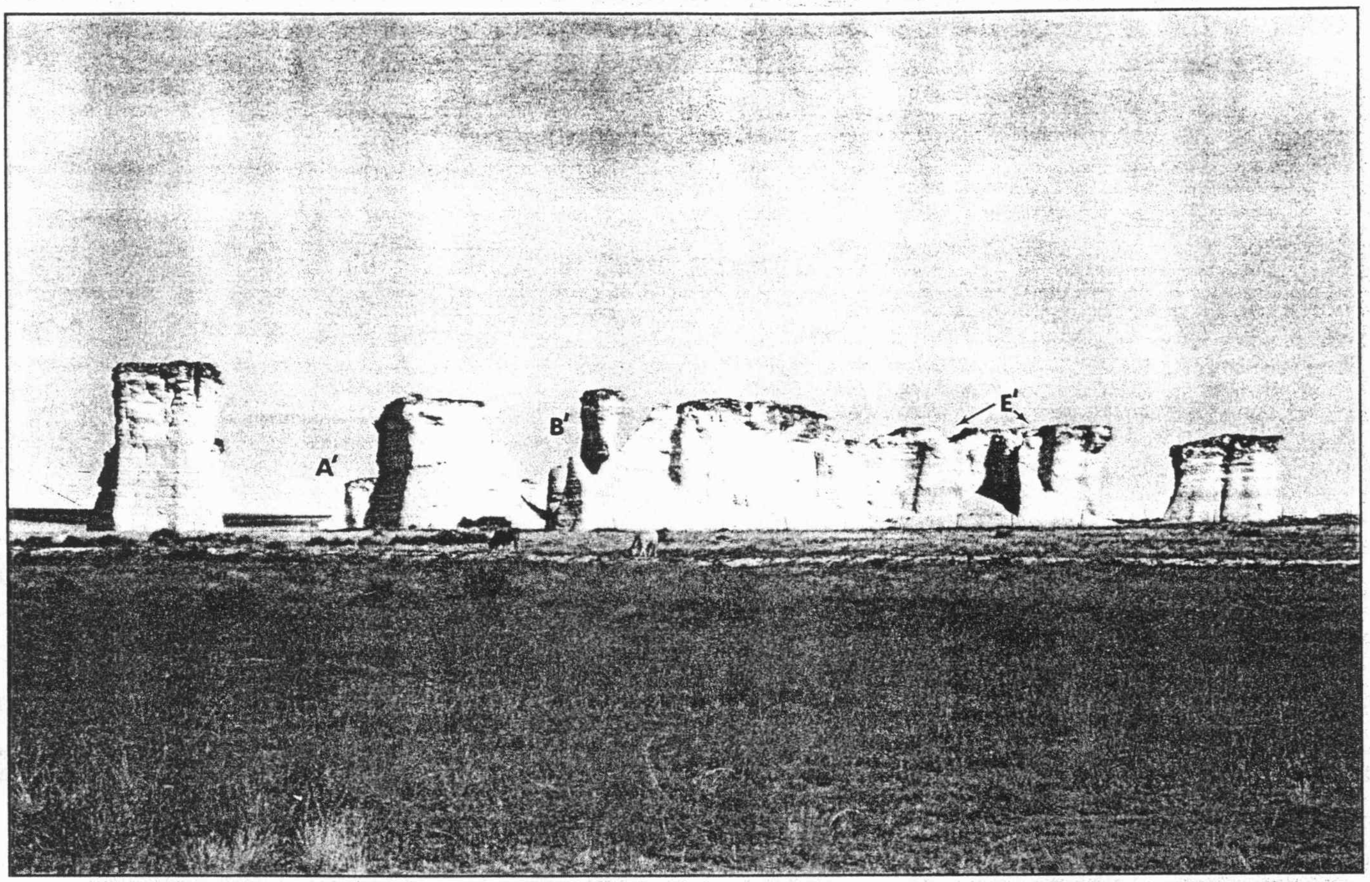
Overlaying the photographs shows that the chalk bluff on the left has been reduced somewhat near the top, but Cobra Rock is largely the same now as in the older photograph. The base of Cobra Rock itself has been reduced somewhat. However, since it sits on a broader pedestal, it is protected from undercutting runoff and rubbing livestock. The darkening at the top of the rock is considerably more pronounced in the new photograph, and it may have increased in the bluffs on the left side and in the rock at the far right side of the photograph, although the quality of the older photo makes that difficult to determine.



Monument Rocks, Gove County, 1890s.

MONUMENT ROCKS. On the western edge of Gove County is a series of chalk monoliths called Monument Rocks. This photograph was taken on the southeast side of Monument Rocks, looking to the north-northwest. The vantage point is about a quarter mile south of the rocks and about one hundred yards east of the dirt road that runs south from the rocks. Again, the locations where the far horizon intersects the sides of the rocks provides a sense of the correctness of the vantage point. Also, the angle of the new photo is indicated by the portions of rocks that appear behind other rocks. The vegetational changes do not appear dramatic; the plant in the foreground of the older photograph is catclaw briar, which is found in the area today. Many of the other changes are cultural, such as the addition of the fence in front of the rocks and the small terrace that runs across the photograph.

While these two photographs appear similar at first glance, the changes are fairly substantial, an indication that change is often more difficult to detect from faraway photographs than from some close-ups. Although

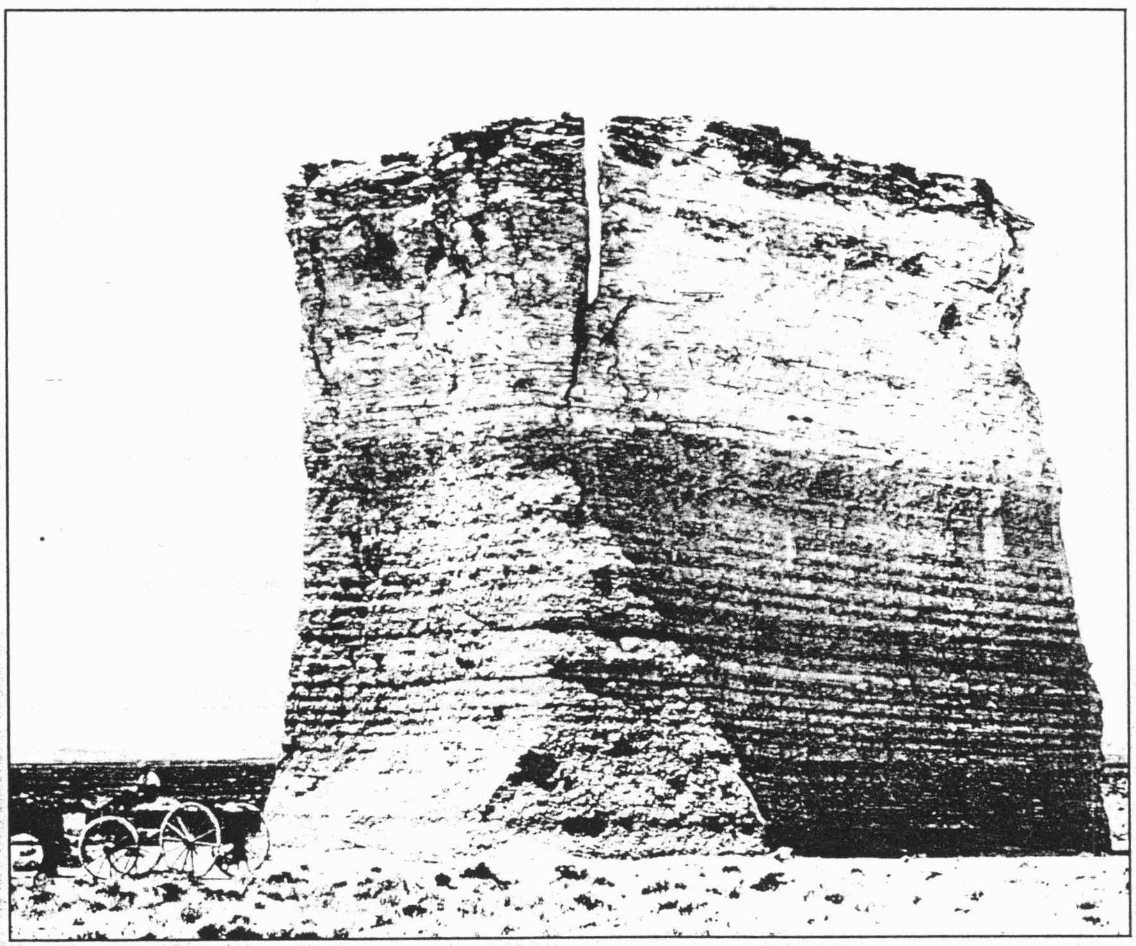


Monument Rocks, 1991.

the first rock on the left appears largely the same, the rock to its right (A and A′), in the background, has lost an entire corner, leaving only a buttress-like structure behind. Perhaps the biggest change is in the large spire just left of the center of the older photograph (B and B′). That spire, present in the older photograph and blocking the view of much of the spire behind it, is gone in the newer photo. The concave slope at the front of the rocks in the photograph's center is partially vegetated in the older photo, as are some of the other gentle slopes. This vegetation is virtually absent on the newer photo. At the right side of the photo, in the space between the main part of the rocks and one outlier, is a knob (C) above the landscape that represents a rock pile that is no longer visible at all. Similarly, at the far left side of the older photo is the edge of a stone pillar (D) that is also no longer present. Two turret-like features on the right side of the scene (E and E′) also appear to have fallen off in the intervening years.

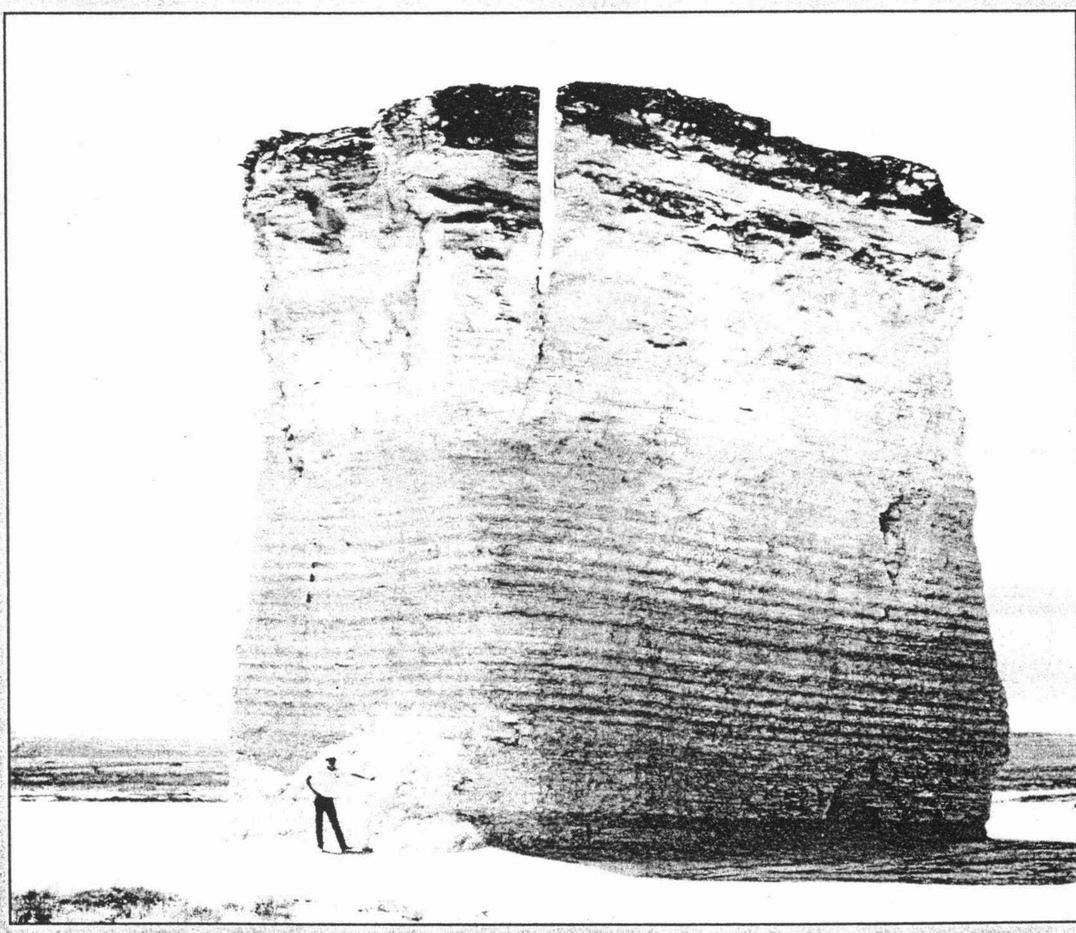
The alga-related darkening at the tops of the rocks is visible in the older photograph as well as the new one.

MONUMENT ROCKS. *This is a photograph taken about sixty feet from one of the formations at the south end of Monument Rocks, the second photograph that Smith repeated in 1941. The vantage point looks west-northwest. The changes at this location are somewhat more subtle than at other locations. The crack at the top of the rock appears to be about two feet deeper. The base of the formation appears to be slightly more undercut in the newer photograph, up to a*

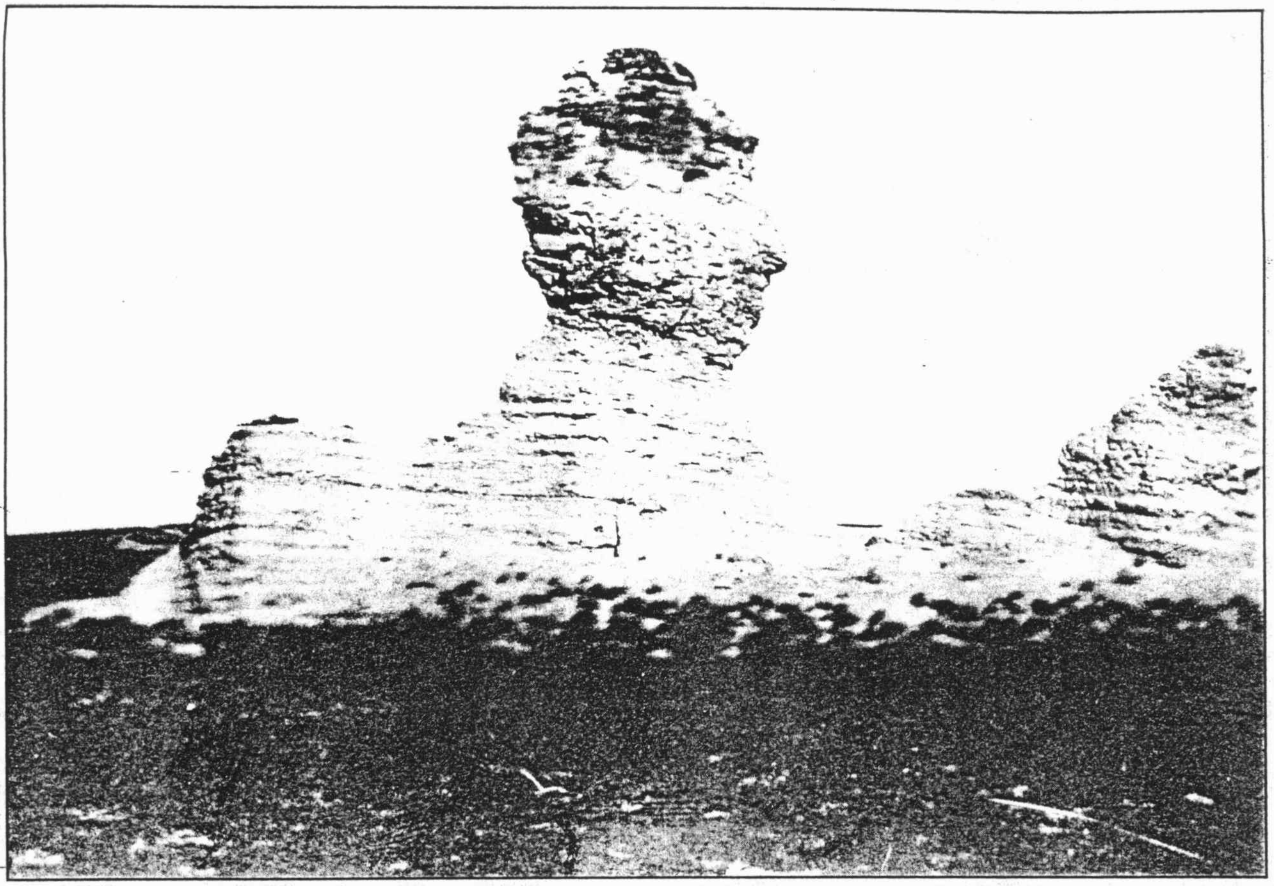


Monument Rocks, Gove County, 1890s.

height of about six feet. Near the right-hand base of the newer photograph is an arched hole that may be the result of human activity, digging or possibly vandalism. That hole is not visible in Smith's 1941 photo. Above that hole, about midway up the side of the formation, is an elongated hole that appears to be new, although the beginnings are visible in the older photo. Again, the darkening at the top of the stone is visible in both photographs, although perhaps more pronounced in the newer one.

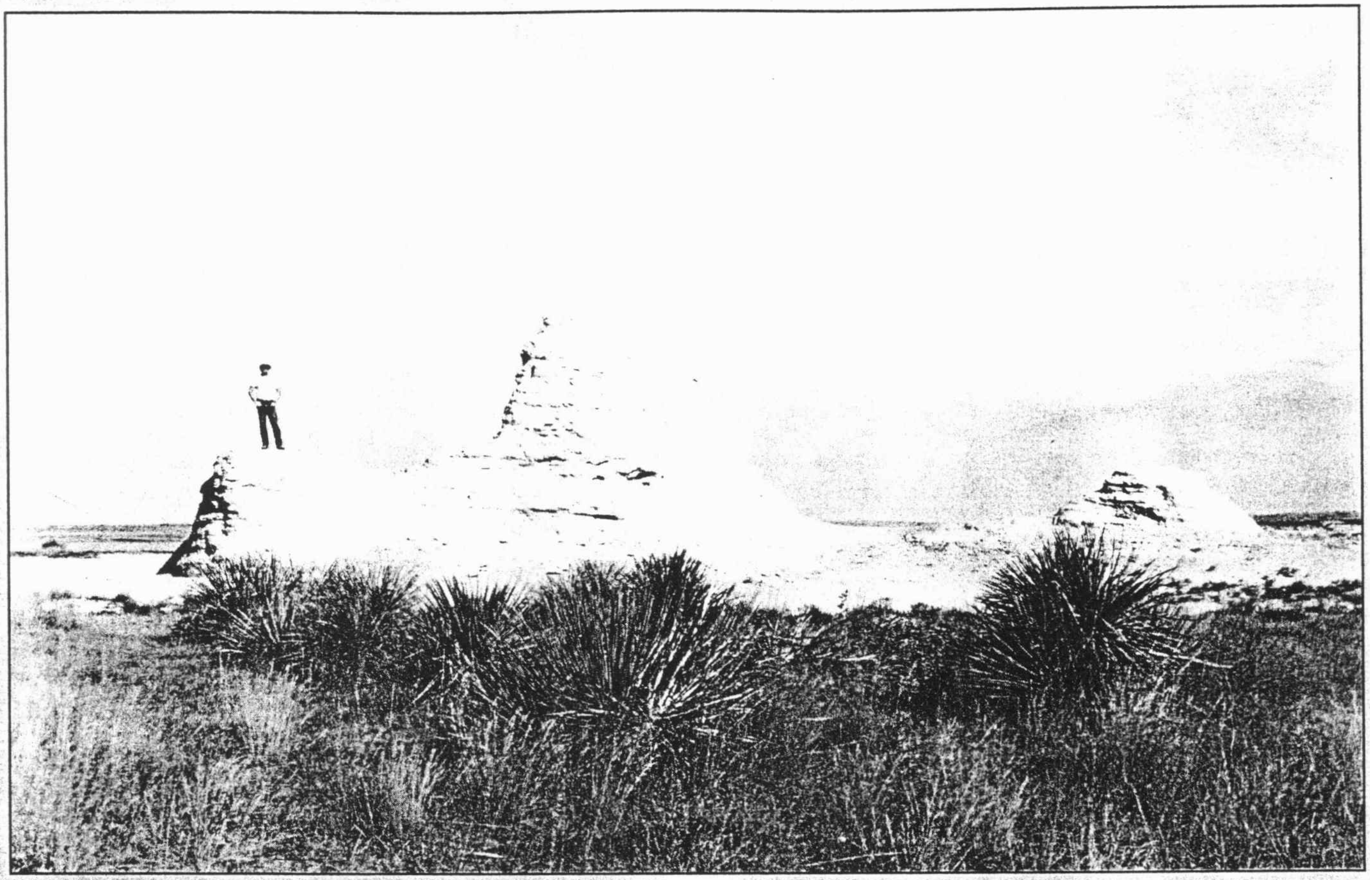


Monument Rocks, 1991.



The Sphynx, Gove County, 1890s.

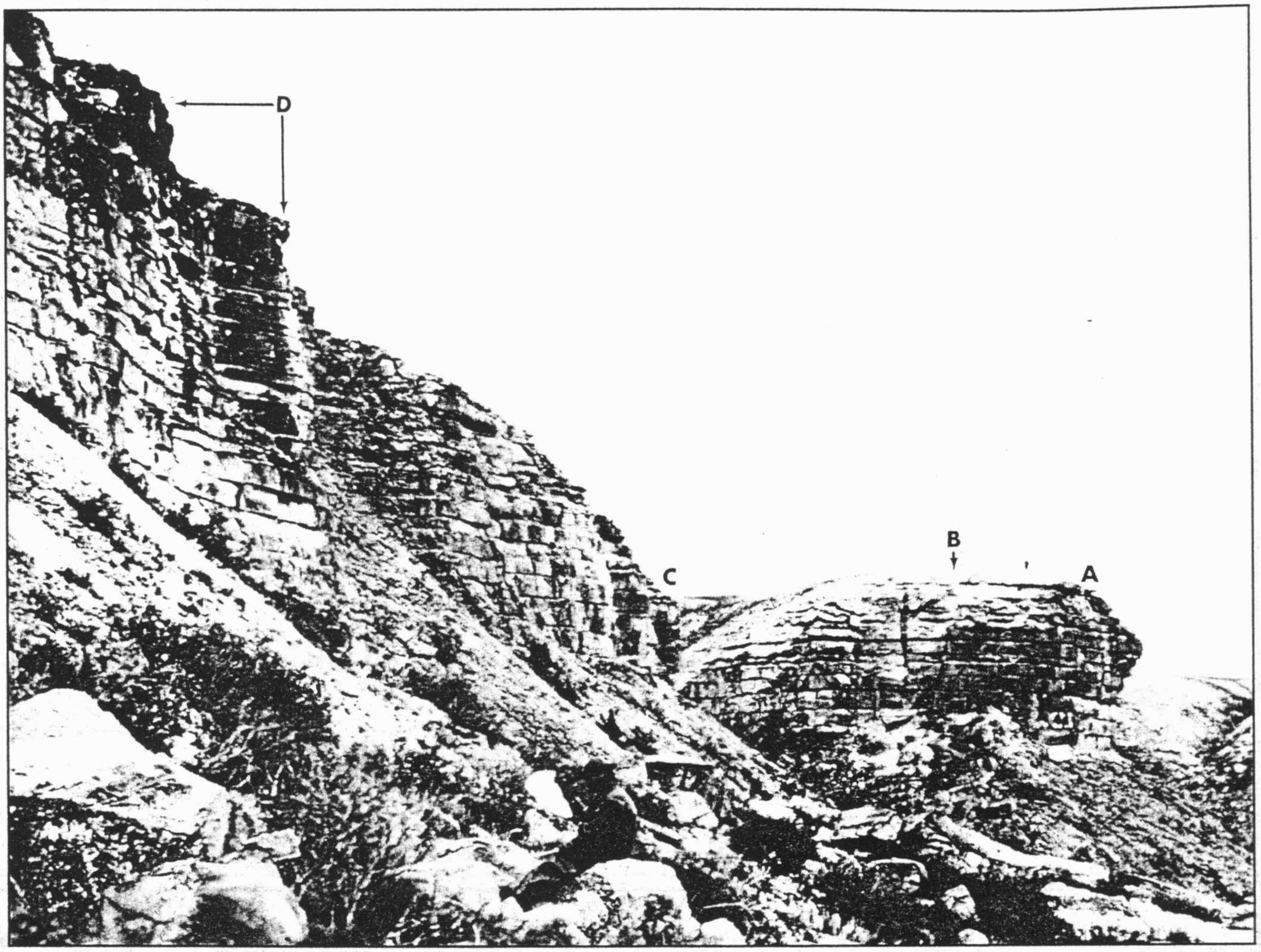
THE SPHYNX. About a quarter mile north-northwest of the main body of Monument Rocks is a chalk outlier that was known variously as the Sphynx or Old Smoky. Of the photos we used, this one obviously demonstrates the most change. The large knob that formed the head of the Sphynx toppled over in 1986. Most of the debris from that rock fall lies immediately north of the now-broken neck, and is thus out of view in the newer photograph. The falling of the neck is not the only noticeable change shown in the photos. The knob at the left side of the Sphnyx has been lowered and flattened somewhat by erosion. The formation on the right side of the photo has been dramatically reduced, and



The Sphynx, 1991.

the chalk between it and the neck has been so reduced that much more of the horizon is visible in the newer photograph. The rapid deterioration of the Sphynx may be because it lacks the more resistant massive chalk beds that cap most of Monument Rocks. This exposes the softer, more shaley sections below to direct attack by the elements, with resulting rapid erosion. This may also explain the apparent disappearance of features C *and* D *in the photographs of Monument Rocks on pages 230-231.*

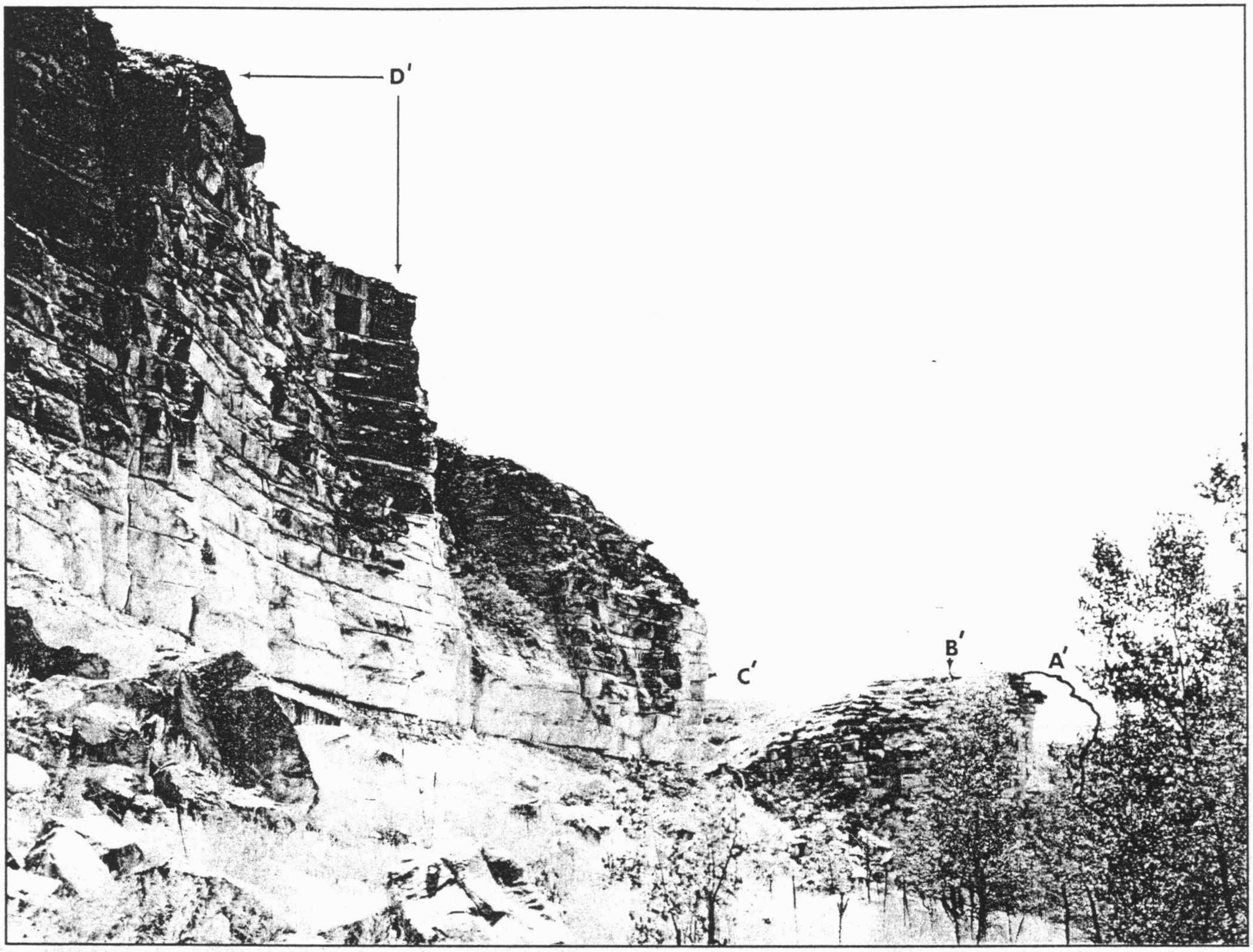
The foreground shows substantial vegetative change, with a heavy growth of yucca that does not appear in the older photograph. This may be related to grazing pressure.



Cedar Bluffs, Trego County, 1890s.

CEDAR BLUFFS. Of the locations we rephotographed, this is the only one not taken in the Smoky Hill Chalk Member of the Niobrara Chalk. Instead, it is at Cedar Bluffs, in western Trego County, and is a photograph of the Fort Hays Limestone, a slightly older rock unit that is also part of the Niobrara Chalk. Williston identified this location on the original photograph as "Near White Rock Creek." In one of his books on paleontology, he identified it as in Gove County, near the Smoky Hill River.[13] *However, the location is quite clearly Cedar Bluffs on the south side of present-day Cedar Bluffs Reservoir. Of all the locations rephotographed, this one presented the most problems. The vantage point was difficult to locate. This photo was taken from below the bluffs at the east end of the bluffs looking almost due west. The greater problem was the considerable growth of vegetation north of the base of the bluffs, which made it impossible to take the photograph in the exact same vantage point.*

13. Williston, *Paleontology, Part 1*, 39.



Cedar Bluffs, 1991.

Many of the changes in the photograph are related to the construction of Cedar Bluff Reservoir by the U.S. Bureau of Reclamation in 1951. This reservoir was designed to have a conservation pool level of 2,144 feet above sea level, that is, the level at which the reservoir was meant to be maintained when storing water. The 2,144-foot contour line runs very close to the base of the chalk in the photos. In times of flood, the reservoir was designed to hold back water to a level of 2,166 or twenty-two feet higher than the conservation pool.[14] *In the early life of the reservoir, the water level was at times maintained at the conservation pool level, or possibly higher. In recent years, streamflows in western Kansas are much reduced, mostly due to water use and conservation and tillage practices. Today, Cedar Bluff and other reservoirs in western Kansas seldom reach levels close to their conservation pools.*

14. Kansas Water Resources Board, *A Kansas Water Atlas*, Kansas Planning for Development "701" Project Number P-43—Report Number 16-a (Topeka: Kansas Water Resources Board, 1967), 52-53.

When the reservoir was at or near conservation pool levels, the water level was near the level at which the photos were taken. This level is below the base of the cliff-forming Fort Hays Limestone and is in the much softer Carlile Shale. The contact between the two formations is not apparent on the older photo, being buried beneath a talus slope at the base of the cliffs, which in places extends up into the small gulches carved in their cliffs. Wave action is a powerful erosive force even on a relatively small body of water such as Cedar Bluff Reservoir. When the reservoir was at higher levels, wave action removed much of the unconsolidated rubble making up the talus slope, exposing the sharp limestone-shale contact that is visible in the later photo. Wave action also appears to have carved a wave-cut bench that is visible as a level strip of ground in the right foreground of the later photo. This bench does not appear in the old photo, which shows a continuous slope to the right toward the Smoky Hill River, less than two hundred feet north of the camera's location. Of the six photo pairs analyzed, the Cedar Bluffs photos are the ones in which the original camera location has changed the most over the years. Wave erosion has removed so much material from the base of the cliffs that the original camera location is now in mid-air several feet above the present terrain, and might only be reoccupied by means of some sort of elevated platform.

*With wave action working on soft rocks underlying more resistant rocks, undercutting would be expected and can be seen by careful matching and comparison of the two photos. This is most apparent in the bluff in the distance upon which the individuals are standing (the "Y" shape in the middle of the bluff on the older photo is a photographic artifact). The person in the older photo is standing about eight feet to the right of the one in the newer photo. The edge of this bluff has receded considerably. The line drawn (*A′*) in the new photo shows the outline of the bluff as it appeared in Williston's photo. Using the human figure in the new photo as scale, we estimate that the bluff face has receded a maximum of thirty feet. The erosion of the soft shale base of the cliff has considerably undercut the limestone face, creating instability. Visible only in the newer photo at* B′ *is a deep crevice that has developed in the interim. This crevice is two to three feet wide at the surface, extends across the bluff to the opposite side, and is roughly parallel to the viewing direction of the photo.*

The overall effect of beach erosion at Cedar Bluffs has been the steepening of the limestone cliffs by undercutting and removal of rock, especially from the base of the cliffs. This is apparent not only at A *and* A′ *but also in the cliff face that dominates the left half of the photos. The limestone nose at* C *and* C′ *has been sheared off to near verticality. The remaining bases of the cliffs to the left have been exhumed, undercut, and sheared off as well. Although large-scale features such as the prominences at* D *and* D′ *can be matched up by casual viewing of the photos, optical analysis fails to match up many of the details of the cliff, showing that considerable change has occurred. The fresh rock surfaces where the most recent rock falls have occurred have not yet developed the dark-colored algae growth of older surfaces and appear white in the new photo.*

Conclusion

Repeat photography is a useful method of documenting change in the geologic and cultural landscape of Kansas. When undertaken with care, the technique can reveal changes that are seldom visible in the field. Substantial change has taken place in some of the better-known locations of the chalk beds of west-central Kansas since the time of Samuel Williston. For example, the last fifty years have seen considerable shrinkage of the base of Castle Rock, making it appear much more unstable than in the early photos. If, in fact, non-natural agents are responsible for this erosion, protective steps may need to be taken to prevent the pre-natural collapse of this landmark.

Repeat photography shows the subtle but certain change in the geologic landscape that may escape the notice of field observers or local residents.

Like the erosion of Castle Rock, many of the other changes in the chalk beds may be the result of interaction between natural and human activities. The increased algae growth at the tops of the rocks, for example, is probably natural, although it may be influenced by human activities. Changes in vegetation may be related to climatic fluctuations and human activities—the introduction of grazing cattle or the disturbance of the soil through cultivation, for example. Regardless of the rate or nature of change, repeat photography shows changes in the landscape that may escape the notice and recollection of field observers or local residents. It provides reminders of the subtle but certain change that takes place in the geologic landscape. Repeat photography is a valuable tool to record, document, and understand the dynamic of humans and the environment.

KH

Battle

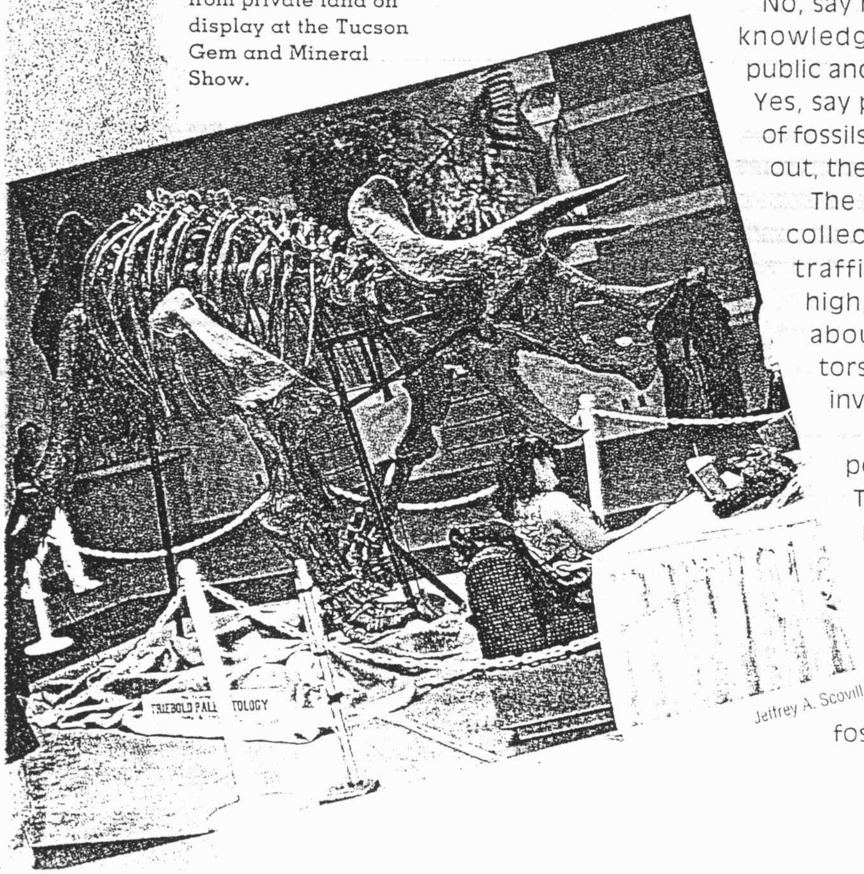
It's an issue that splits the world of fossil hunting down the middle.

Every year, on hundreds of millions of acres of public land in the western United States, the forces of wind and water uncover a fresh crop of fossilized bones. Under federal government regulations, all of those bones, as well as footprints and other remnants of the creatures that bore them, are reserved for scientists. But many fossils are worth a lot of money, too, and business people who buy and sell fossils would like to take a crack at them. Should they get the chance?

No, say many researchers: these fossils, and the knowledge we glean from them, belong to the public and shouldn't disappear into private hands. Yes, say professional collectors: there are plenty of fossils for everyone — and if we don't dig them out, they will erode into nothing.

The stakes are high. The FBI even raided one collector and arrested him on suspicion of trafficking in stolen bones. Emotions run high, too, and grievances and horror stories abound — from scientists, amateur collectors, dealers, museum curators, and others involved in the dispute.

Earth has invited a broad range of these people to air their opinions in these pages. They include the head of the major organization of vertebrate paleontologists; a well-known commercial collector; a volunteer field worker; a fossil broker; and a Canadian museum director with a radically different take on fossil regulation. All of them care deeply about fossils. And they think you should, too.



Triceratops skeleton from private land on display at the Tucson Gem and Mineral Show.

Jeffrey A. Scovill

Bones

Fossil lovers clash over the right to own the past.

Don't sell our fossil heritage

What should become of fossils found on federal public land? Should every effort be made to collect, preserve, study, and display — in effect, to use the fossils for all the people of the United States? Or should federal public lands be opened to commercial collecting — to selling our paleontological heritage?

I think all vertebrate fossils from federal public lands should go to the public good and not be sold off. This view of the public value of fossils is shared by most Americans and put into practice by many private landowners. For example, earlier this year, *Lone Star Dinosaurs*, a museum exhibit I helped develop, was on display in the rotunda of the Texas state capitol in Austin. Texas legislators lauded the exhibit in official speeches. Politicians know that people like dinosaurs, and they know that Texans take pride in seeing this part of the story of their state brought to light for the first time.

Most of the fossils displayed in *Lone Star Dinosaurs* came from private land. The landowners gave their fossils to the public good. Selling fossils from federal public lands does just the opposite — it removes fossils from the public good. And landowners see this. For instance:

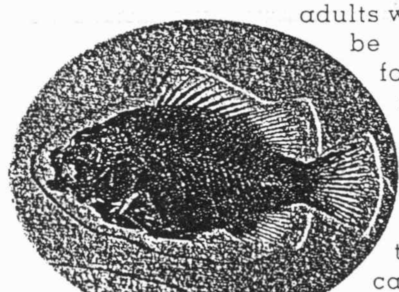
As a grandfather, Billy Jones had one desire for the *Pleurocoelus* bones on his land: "I want my grandkids to be able to see these bones in the museum and say, 'These came from my grandpa's place.'"

Seven-year-old Thad Williams was out with his father, a high school biology teacher from Millsap, and found three individuals of a new species of *Tenontosaurus*. The owners of the land where Thad made his find wanted to see these fossils studied and displayed. Now a skeleton is on display in Fort Worth, seen by over a million visitors a year, and the name of Thad's dinosaur is being published in the *Journal of Vertebrate Paleontology*.

These Texans aren't unusual. A recent survey shows that most Americans agree. In 1995, the Dinosaur Society asked three hundred adults what should be done with fossils found in the American West in various hypothetical situations. In most cases, more than three quarters of the respondents

EARTH Illustrations: Terri Metzger

Louis L. Jacobs, paleontologist, Southern Methodist University; president, Society of Vertebrate Paleontology



Government policies give special protection to fossils of vertebrates — including fish.

Courtesy University of Wyoming Geological Museum

Courtesy Chris Weege

"You can go to the Denver or Tucson rock shows and see appalling things. But you can go to museums and see appalling things, too: large museums where fossils disappear, specimens unprepared after fifty or a hundred years, bad preparation. Nobody is so righteous to be able to point a finger at somebody else — to say 'you can't do it.'"

Chris Weege, petroleum engineer and amateur fossil hunter, Littleton, Colorado

opposed commercial collecting and thought fossils should go to museums and universities for scientific study.

Private landowners like those of Texas own their place on Earth. But even those of us who are not private landowners possess vast areas of land. We — together — own the federal public lands of the American West, millions of acres from Montana to the Mexican border, in most adjacent states and westward. And we own what comes from them, including some of the most amazing and important fossils in the world.

Public land in the West is controlled by several public agencies, most notably the Bureau of Land Management (BLM), the Forest Service, and the National Park Service. On land managed by the BLM, people may collect invertebrate fossils (that is, fossils of animals without backbones, such as clams and starfish) and small amounts of petrified wood for personal use, but they need a permit to collect vertebrate fossils. Other agencies have more restrictive regulations, but the upshot is that vertebrate fossils cannot be commercially collected and sold from federal public lands.

That is as it should be. Vertebrate fossils of a given species are usually rare. They can also be spectacular — even awe-inspiring — and since private landowners are free to sell fossils from their own lands, a commercial market has developed. Vertebrate fossils are sold at curio shops, at auctions, through catalogs, and on the World Wide Web, sometimes at posted prices of tens of thousands of dollars. Each sale represents educational and scientific value lost from the public domain.

Federal public lands are our legacy and one source of our national pride. As a paleontologist and researcher, I value fossils for what they tell us about how Earth works, about time and place, who was where when. The knowledge gained from studying Earth can and should be put to use to make a better world for people. Education and pleasurable fossil experiences are two of those ways, and both depend heavily on our federal public lands as their source. We, as responsible citizens, should manage for our grandchildren, and all grandchildren, what is rightfully as much theirs as ours.

We don't want a free-for-all

Mike Triebold president, Triebold Paleontology

Critics of commercial fossil collectors say that businesses such as mine should not be allowed on public lands because fossils there must be protected "for the children." Anyone I have ever heard invoking "the children" had a hidden motive, and this case is no exception. Public land is the academics' exclusive domain, and they want to keep it that way.

At present, almost all permits for collecting fossils on public land are held by academic paleontologists affiliated with universities or museums; independent collectors are not invited. The academics' idea of benefit to the public is very narrow: when one of them finds a fossil, it goes to that person's institution. It probably will never be displayed (museums used to brag that fewer than one percent of their fossils were on display). A new or unusual find might be studied and written up in a scientific journal, but whatever its fate, at least it will be saved from being *sold* (oh, the horror!).

The real enemy of fossils, however, is not commercial collecting

> **"In the past, people would cut corners — and cut barbed wire. *Everybody* has been guilty of violating that one. Now there's pressure for people to clean up their act."**
>
> **Sally Shelton, paleontologist, San Diego Museum of Natural History**

but nature itself. Every year, on ranchland in western Kansas, I find new specimens weathering out of the same rocks. Without a trained eye to find them, they would simply erode away unnoticed. The federal public land in the United States — 470 million acres of it west of the Mississippi — is so vast that all the academic paleontologists in the country, working full time, couldn't cover it effectively. Yet even though they know they can save only a tiny fraction of the eroding fossils, they would rather sacrifice the rest than let any of them be saved by private companies.

What commercial collectors are seeking is not a free-for-all on public lands but an opportunity to collect there responsibly. The more workers there are, at all levels, the more fossils will be saved. The National Academy of Sciences reached the same conclusion in 1987, when a panel studying this issue wrote: "The science of paleontology is best served by unimpeded access to fossils and fossil-bearing rocks in the field."

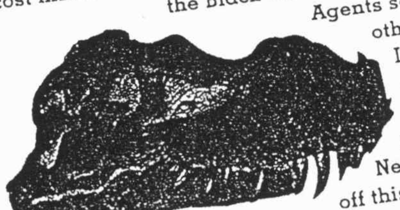
To show how that could be done, I have proposed what I consider a moderate plan that would benefit everybody. Under my proposal, commercial companies must comply with all the provisions of a permit (completing a paleontology course would be one way for collectors to meet the requirements). In the field, they must collect the same data as any academic paleontologist. Any one-of-a-kind "type specimen" they find automatically goes to a fossil repository, and the collector receives a standard fee. That way, discoverers get a reasonable return for their efforts, while the most scientifically valuable specimens are preserved for the good of all.

As for other specimens, collectors may dispose of them as they see fit. That's only fair: they have paid their permit fees (to the public) and have taken the risk of possibly finding nothing. Whenever a collector sells a fossil, however, he must pay a royalty to the state for the privilege of collecting — and the more work he puts into cleaning and preparing that fossil, the higher the royalty will be. For example, suppose the royalty is eight percent. If a "raw" fossil specimen in its plaster jacket sells for $500, then the collector must pay $40 in royalties. But the same specimen, properly prepared, might bring $10,000 — and $800 in tax. Since most collectors prepare their finds, the value-added factor of their skills as preparators could bring the public a significant bonus.

Nothing is lost, more is preserved, more fossils are available for display and study, and taxpayers benefit. Everyone wins, and the arguments against commercial fossil collecting on public lands dissolve.

> "Science has benefited over and over from the finds of commercial and amateur collectors, and we feel that they should be allowed on public lands. Some of the most prolific fossil strata are on public land, and almost all of the fossils that are exposed get destroyed. Nobody is gaining anything — not science, not the marketplace.
>
> What damage might be done — and certainly there would be some, by somebody who is not knowledgeable or, God help us, somebody who is greedy — is going to be so minute in proportion to what's going on right now. And the net gain to science would be so large that we can't even imagine it."
>
> **Marion Zenker, legislative coordinator, American Lands Access Association; administrative assistant and marketing coordinator, Black Hills Institute, Hill City, South Dakota**

Pete Larson knew almost at a glance that Sue was the best *Tyrannosaurus* rex skeleton ever discovered. What he didn't know was that the ranch where she lay had been deeded to the government — and thus was, temporarily, federal land. The mistake cost him dearly. On May 14, 1992, the FBI raided Larson's fossil business, the Black Hills Institute, in Hill City, South Dakota. Agents seized the dinosaur, along with other fossils and business records. Larson was later convicted on charges unrelated to Sue and was sentenced to two years in prison. Sue went to New York to be auctioned off this fall at Sotheby's.



Ed Gerken/Black Hills Institute

How dare someone do this to the fossils!

hen someone wants to damage a place you care about, your first impulse is to try to stop him — unless he has a pistol on his hip and a bad attitude.

The place was the Garden Park Fossil Area, a world-class Jurassic fossil site on public land in Colorado. In 1990, I was out with a group surveying the area for fossils. He was doing the same thing for a different reason. I am a "para-paleontologist," an amateur trained to work with professional paleontologists, a qualification I got through two years of study at the Denver Museum of Natural History. He was a commercial fossil collector. Legally, I belonged there; he didn't.

Patricia E. Monaco, paleontological volunteer, Garden Park Fossil Area, Colorado

But the man didn't see it that way. He had as much right to be there as I did, he said. What's more, he could do whatever he wanted because, as he put it, "There is no law."

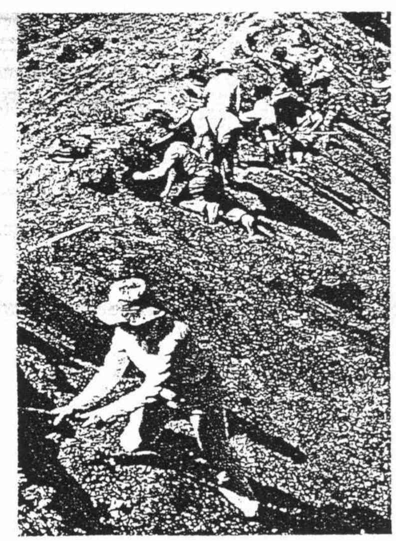
No law? I hear that a lot from commercial collectors I encounter in the field, though never from the scientists I work with or the agencies that issue our collecting permits. The only reason my gun-toting friend was at Garden Park was that there was no one around to throw him out. With only one ranger patrolling the whole eastern half of Colorado, access to public land has to be based largely on trust. In my experience, scientists have proven themselves trustworthy; commercial collectors have not.

Having worked with professional paleontologists for more than a decade, I know how much painstaking work is involved in prospecting, mapping, excavating, and restoring sites; in preparing fossils; in researching and publishing scientific papers. Not many commercial fossil collectors make that effort, and consequently, valuable scientific information is lost forever. When I am out in the field, it fills me with outrage to see a large gouge in the countryside, made by a backhoe and left open and exposed with plaster and trash strewn around and any remaining "unsaleable" fossils destroyed with hand tools. How dare someone do this to the fossils — and to a landscape that may not recover for centuries?

Fossils cannot be mass-produced like dinner plates or blue jeans; they are finite and limited. To buy or sell them without regard for scientific understanding is something I cannot fathom. What benefit would I get from owning a scientifically valuable fossil? A decoration for my living room? How could I enjoy it, knowing how much the fossil might add to our knowledge of the past? As it happens, I do have a small collection of fossils. They are replicas, given to me by the scientists I work with — mementos of unique or significant finds I have contributed to their research. They give me more satisfaction than owning the "real thing" ever could.

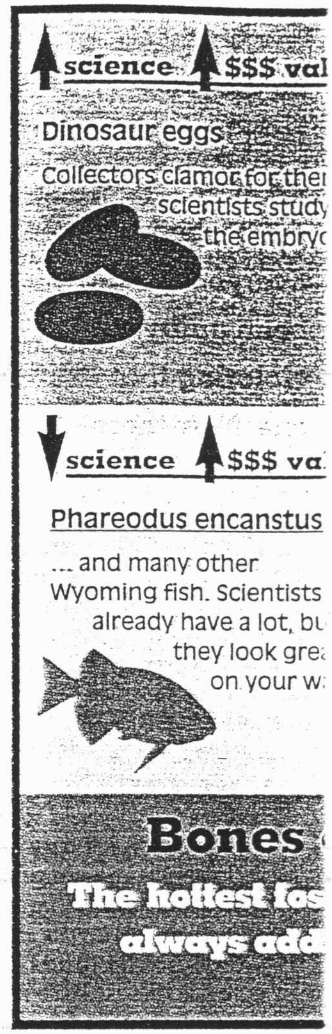
Not long ago, I was out in the field teaching a group of amateurs what they must do before they take a fossil out of the ground. I told them about mapping and gathering information about the locality and its geology. About letting other scientists working this area know about our finds. About the grueling work involved in excavating a fossil. About the ranger who (if he is around) can arrest any of them who breaks the law.

As I was winding up my lecture, we came across a commercial collector who dared me to stop him. All my talk about methods and ethics meant nothing to him. If he felt like it, he could have done what I did: earned a federal permit, and the freedom to collect fossils side by side with scientists, by choosing to work conscientiously



Students in the Denver Museum of Natural Hist Certificatio Program in Paleontolog take to the field in wes ern Colorad

Courtesy Rick Wicker/Denver Museum of Natural History



↑ **science** ↓ **$$$ value**

Multituberculates

Short on glamour, these extinct near-mammals are long on evolutionary importance.

↓ **science** ↓ **$$$ value**

Shark teeth

Abundant supply, low demand.

Contention

science don't

cold cash.

and non-exploitatively within the law. But that's not what he wanted. *He* claimed a different kind of "freedom": the freedom to do whatever he likes on public lands, whenever he likes, with no regard for any laws.

People like him are the reason public land should remain off-limits to commercial fossil collectors.

Henry Galiano, proprietor, Maxilla & Mandible, Ltd., New York, New York

There are dealers, and then there are dealers

Being a commercial fossil dealer with a background in paleontology is like straddling a barbed-wire fence: I have a foot in each camp and a lot of grief in the middle. But it is a privileged position, too, and it has led me to an unusual conclusion. I think a few dealers are professional enough to be allowed onto public lands. But the rest should be kept far away.

Right now, academic paleontologists in North America feel outnumbered. They see themselves as surrounded by barbarian hordes who have more hands and fewer scruples than the scientists do. Unfortunately, some commercial fossil collectors live up to that reputation. Many dealers — even well-equipped, well-intentioned ones — simply don't know what they are doing when they collect in the field. Many of them will collect only part of a skeleton, such as the skull, and leave the rest behind. Or, ignorant of vertebrate anatomy, they will restore fossils inaccurately, ruining specimens with irreversible epoxy glues.

Meanwhile, conscientious commercial collectors feel aggrieved, too. Some of them contribute to scientific research already, or would like to. Yet (as they see it) arrogant paleontologists treat them as second-class citizens. By alienating responsible commercial collectors, paleontologists are cutting themselves off from a valuable source of important specimens. They are also eliminating a big incentive for the bad apples to change their ways: the desire for respect.

Both sides need to change some of their attitudes before they will be ready to share the same turf. Let me start with some words of wisdom for the academics:

"I think commercial paleontologists should be kept off public land. But it's important that we move beyond this controversy. The community of fossil people — academic, museum, amateur, and commercial paleontologists — is small, and we could all use one another's help. Yet we are polarized by mistrust and lack of a common goal.

A few changes in attitudes and behavior would make life easier for everybody. Commercial collectors could gain credibility by acknowledging that certain fossils are too important to be subjected to the whims of the marketplace. By donating important fossils — creatures that might be new species, for instance — found on private land to museums, they can show that they understand the real significance of rare fossils.

At the same time, the professional community should acknowledge that many fossils — including some vertebrates, such as fish from the Green River Formation in western Wyoming — are so common that commerce in them causes no major loss to science."

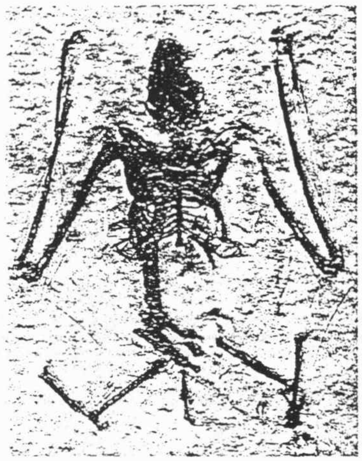
Kirk Johnson,
paleontologist, Denver Museum of Natural History, Denver, Colorado

"I've run my own fossil-collecting business for forty-two years. We cooperate with the scientists. Every time we get something that looks halfway decent or possibly new, we've turned it over to them. I think that's true of most commercial fossil collectors.

If you checked with members of the Society of Vertebrate Paleontology, I think you'd find that only a few of them are against commercial collecting. The rest of them see that it's good for science — that if it weren't for commercial collectors, about half the specimens they study would never have got out of the ground. It's just that about half a dozen people who run the SVP are radical.

People forget that all the early dinosaurs in the United States were collected from public lands. If you put back all the ones from public lands, there wouldn't be many of them left on display."

Allen Graffham, president, Geological Enterprise, Ardmore, Oklahoma



Rarest of the rare, fossils such as this fifty-million-year-old bat from Wyoming are coveted by scientists and commercial collectors alike.
Courtesy University of Wyoming Geological Museum

Commercial fossil collecting is here to stay. The business of buying and selling fossils is as old as paleontology itself and, if anything, is likely to get bigger and more efficient in the future. And why shouldn't it? People have the right to collect and enjoy fossils as much as those who collect stamps and seashells. The real issue is how to protect scientifically important, rare, and unique specimens.

Most commercial dealers aren't after your fossils. Many paleontologists think commercial collectors make their living from rare, expensive vertebrate fossils. Actually, most of the fossils offered to the public are common ones — amber, ammonites, trilobites, fish, petrified wood, and sharks' teeth — ranging in value from a few dollars to, at most, several hundred dollars. At major trade shows and in retail businesses like mine, virtually all of the fossils sold are nonvertebrate fossils. Why? Because people can afford them.

Vertebrate fossils are not created equal. Not every bone eroding out in the badlands will advance paleontological knowledge. Consider the hundreds of thousands of fossil fish that have been collected from the Green River Formation, a rock unit that stretches across vast areas of Wyoming, Colorado and Utah. The fossils from those localities are well represented in most institutional collections; their scientific value has long since passed the point of near-zero marginal returns. In cases like this, commercial collecting, under professional supervision, poses no threat to paleontology.

Some places do need special protection from unauthorized amateur and commercial collecting. Commercial collectors in Florida have already destroyed sinkhole deposits containing species unique to this part of North America. Another shameful example is the frequent illegal collection of fossil mammals on federal lands in the Bridger Basin of Wyoming. Preserving vulnerable areas, in their entirety, is just as important as protecting scientifically important specimens — and it should be a great deal easier to achieve.

The "other side" values your approval. Most commercial collectors share a deep devotion to fossils, and the professionals among them dislike the rascals as much as you do. I think recognition from professional paleontologists would go a long way toward bridging the gap between the two camps. Maybe what we need is a program aimed at teaching commercial dealers what to do and how to do it. The Society of Vertebrate Paleontology might offer classes as a requirement before applying for some kind of collecting permit on federal lands.

Perhaps someday paleontologists and fossil dealers will coexist the way archaeologists and art dealers do now. Art dealers, like fossil dealers, see the aesthetic beauty and value in the objects they sell, and archaeologists occasionally tap them for information about artifacts and localities. If similar links could be forged in the fossil community, both sides would flourish.

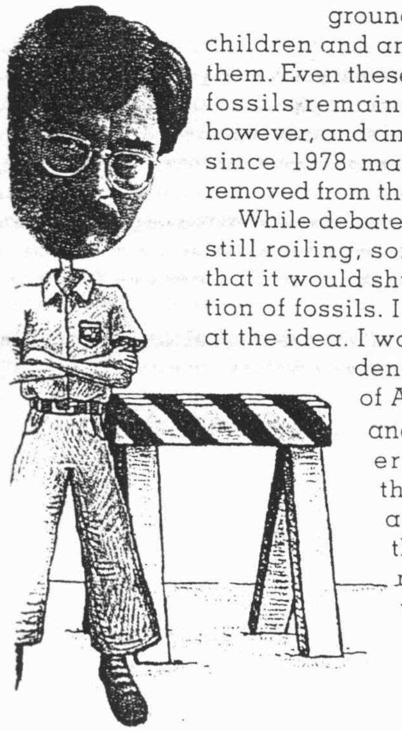
Before that can happen, though, commercial collectors must become better educated and must do their own part to establish constructive, mutually beneficial relationships with paleontologists. Only then will they be ready for prime time — and for prime collecting spots on public lands.

For Canada, regulation works

This furor over fossil collecting is old news to those of us in Alberta, Canada. We went through a similar debate in the 1970s, when the government was preparing to pass our Historical Resources Act, which restricts fossil collecting much more severely than anyone has proposed to do in the United States. But pass it did, and for two decades Albertans have been living the reality of what some in the United States fear and for which others hope. For us, I believe, regulation works. But I didn't always think so.

Before the act became law, Albertans were free to collect fossils as long as they were outside provincial parks. After passage, at one stroke, all fossils on public *and private* land became public property. They belong to us all. A few types of fossils — oyster shells, fossil wood, and the remains of ancient marine mollusks known as ammonites — may be collected and sold commercially under permit. Vertebrate fossils, however, may be excavated only by qualified scientists operating under a permit, and they must be cared for in a public collection run by a museum, university, or government agency. If fossils are found on the ground, rather than in it, children and amateurs may keep them. Even these surface-collected fossils remain public property, however, and any of them collected since 1978 may not be sold or removed from the province.

Bruce Naylor, director, Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, Canada



While debate over this law was still roiling, some people feared that it would shut down all collection of fossils. I too was appalled at the idea. I was a graduate student at the University of Alberta at the time, and I saw it as a government intrusion that might limit my access to fossils that I needed for my research. How dare the hand of the state mess with my profession?

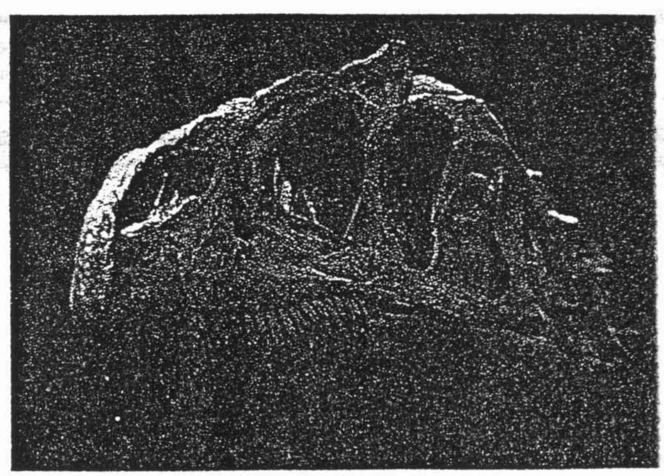
Today I find myself helping to administer the very law that worried me so much. I'm both the director of a public museum and the Provincial Palaeontologist, and our museum processes applications to excavate fossil resources.

Frankly, I believe that the overall impact of the law has been very good. Scientists and museums have been able to continue to collect freely, under permits reviewed by a panel of our peers. Unique specimens — collected by professionals and properly studied and protected — are available for study and enjoyment by Albertans and non-Albertans alike. Commercial collectors were affected, of course, but most of them shifted their interests to non-vertebrate fossils. Others moved their collecting south of the border.

I believe strongly that there is a role for commercial and amateur collectors but that it is the proper role for government to regulate these activities. For my province, Alberta, the loss of unique specimens to private collections is, in my opinion, wrong, and government has both the right and the responsibility to limit this loss to science and to future generations.

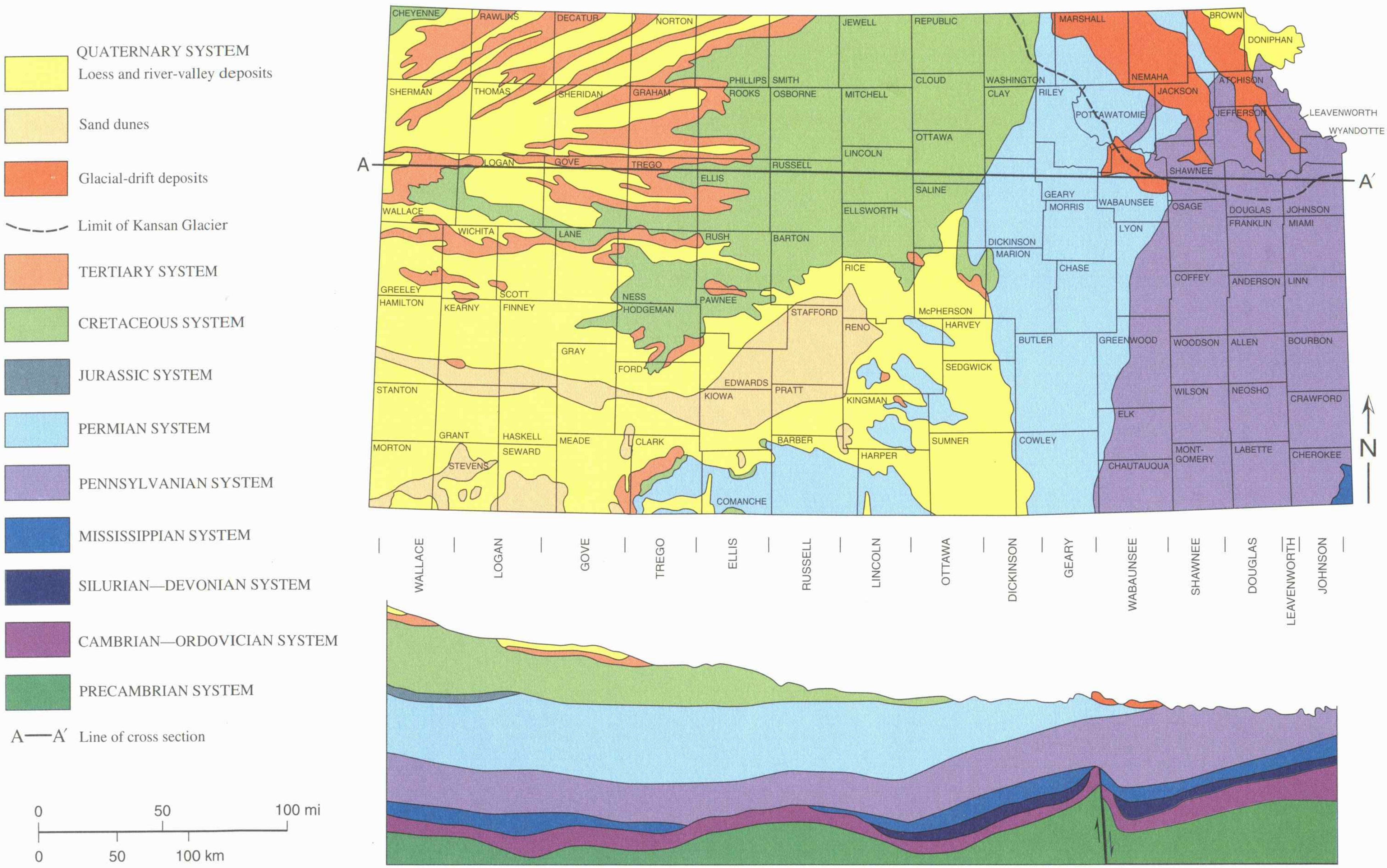
Would I recommend similar laws for the United States? Not necessarily. We have different histories and different fossils to protect. National and regional characteristics must be taken into account, as well. One of our countries became a nation during a revolution, giving its citizens "life, liberty, and the pursuit of happiness"; the other evolved from a colony, providing its citizens with "peace, order, and good government." I can't say which is the proper route, but I can say that for Alberta, if there had been serious problems with the law, we would have changed it. ⊕

In 1991, firespotters in northern Wyoming noticed commercial fossil collectors unearthing the near-perfect skeleton of an adolescent *Allosaurus* on federal land. Paleontologists finished digging up the dinosaur. Today casts of "Big Al" are on display in two museums, and scientists are studying his bones. During his short life, Al racked up more than a dozen bone injuries. He lived fast and died young. But he didn't escape the feds.



Courtesy University of Wyoming Geological Museum

Generalized Geologic Map of Kansas

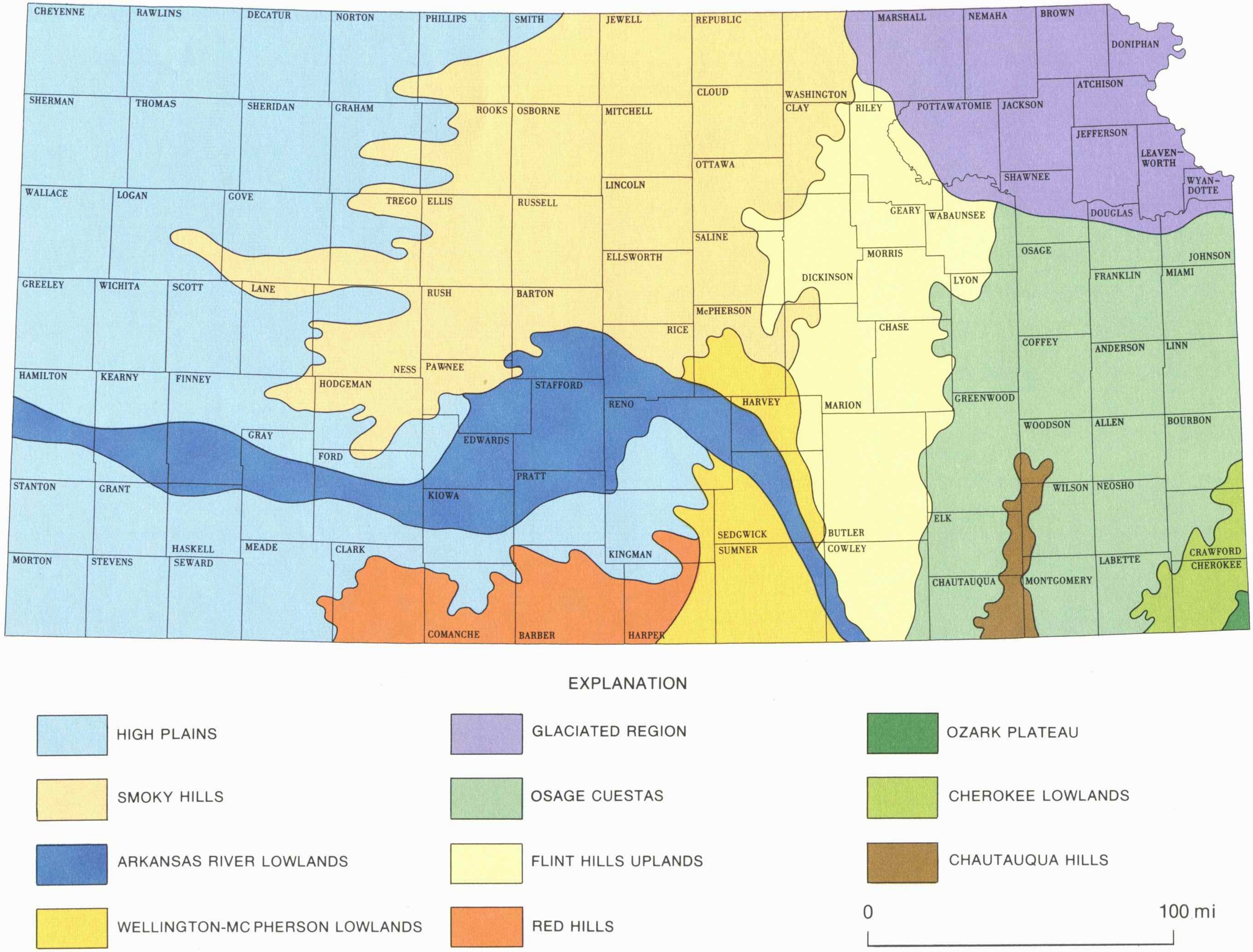


Geologic cross section below I—70

Kansas Geological Survey
The University of Kansas
1930 Constant Avenue
Lawrence, Kansas 66047
www.kgs.ukans.edu

January 2000

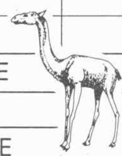
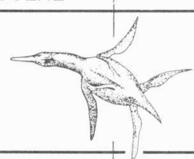
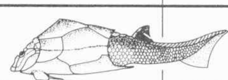
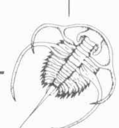
Generalized Physiographic Map of Kansas



Kansas Geological Survey
The University of Kansas
1930 Constant Avenue
Lawrence, Kansas 66047

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

Eons not shown

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

Kansas Geological Survey Lawrence, Kansas 1988