Rephotographing the Chalk Monuments of Western Kansas
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
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, 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. 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. 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.

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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.

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. 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

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).
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.

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. 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.

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-southwest. 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. 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.” 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.


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

These dark 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. 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.
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 noticeably 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. 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 far-away photographs than from some close-ups. Although
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.

The Sphinx, Gove County, 1890s.

**T**HE SPHYNX. About a quarter mile north-northwest of the main body of Monument Rocks is a chalk outlier that was known variously as the Sphinx or Old Smoky. Of the photos we used, this one obviously demonstrates the most change. The large knob that formed the head of the Sphinx 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 Sphinx has been lowered and flattened somewhat by erosion. The formation on the right side of the photo has been dramatically reduced, and
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 ero-
sion. 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. 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. 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.

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.

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

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.

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.