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Stephen A. Hall, William Penner, and Moira Ellis

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ARROYO CUTTING AND VEGETATION CHANGE IN ABO CANYON, NEW MEXICO: EVIDENCE FROM REPEAT PHOTOGRAPHY ALONG THE SANTA FE RAILWAY

STEPHEN A. HALL[1], WILLIAM PENNER[2], AND MOIRA ELLIS[3]
[1]Red Rock Geological Enterprises, 3 Cagua Road, Santa Fe, New Mexico 87508-8116, steve@redrockgeological.com
[2]Parametrix, 8901 Adams St. NE, Suite D, Albuquerque New Mexico 87113
[3]Moira Ellis Photography, 4500 1/2 Jupiter NW, Albuquerque, New Mexico 87107

Abstract — A series of photographs was taken before 1903 and in the period 1903 to 1907 during the construction of the Santa Fe Railway through the Abo Canyon section of the Belen Cutoff. Repeat photographs of the same views were taken in 2008. The pre-1903 and 1903-1907 photographs show the presence of a channel in Abo Arroyo in the early stage of erosion, consistent with other regional records of arroyo cutting initiated in the 1880s. The 2008 photographs show the development of a wider, deeper channel with channel and meander bars during the twentieth and twenty-first centuries. The repeat photographs of the canyon escarpments also show significant changes in local vegetation. One limestone escarpment shows a three-fold increase in one-seed juniper (*Juniperus monosperma*) from 10 to 32 individuals per hectare from 1903-1907 to 2008. In addition, the 2008 channel has dense stands of salt cedar (*Tamarix* sp.) that were not present in 1903-1907. Based on aerial photographs, salt cedar became established in the canyon between 1935 and 1954 and has expanded and increased in abundance since then.

INTRODUCTION

Many early monographs on the geology of the western states include photographs of outcrops and grand scenes. The photographs show the condition of rivers, gullies, glaciers, dune fields, hillsides, escarpments, and shorelines as well as local vegetation at the time the photographs were taken (Malde, 1973). These photographs are a treasure of information on the nature of early historic landscapes. Modern photographs of the same views show how conditions have changed, or not changed, from earlier times. Allen et al. (1995) observe, "Repeat photography is a simple and inexpensive tool for reconstructing past environmental changes and monitoring future ones...differences between then and now provide a basis for identifying and even quantifying changes, while the new photograph establishes a benchmark for future evaluation." Repeat photography is also applied to urban settings where then-and-now photographs document changes in streets, buildings, and land use (Morand, 1998). Many applications of repeat photography have been published, and an early bibliography was assembled by Rogers et al. (1984). The *Repeat Photography Newsletter* was established in 1984 by geologist-photographer Wayne Lambert who also contributed many fine landscape photographs to New Mexico Geological Society guidebooks from 1985 to 1994.

BACKGROUND

Abo Canyon (the proper spelling is Abó although generally printed without the accent) forms a pass between the Manzano Mountains to the north and Los Pinos Mountains to the south in central New Mexico. The area was known to the Spanish as *Las Bocas de Abo*. In 1598 Don Juan de Oñate visited Abo Pueblo near the east end of the canyon, and the Mission of San Gregorio was founded at the pueblo by Fray Francisco de Acevedo in 1629. The pueblo and mission were abandoned before the Pueblo Revolt of 1680 due to continuing raids by Apache (Julyan, 1996; Toulouse, 1949; Stanley, 1966).

Soon after the American take-over of New Mexico in 1846, a search for a direct rail line to California was authorized by the U.S. Congress. In 1853, Lt. A. W. Whipple examined a 35th-parallel route across Oklahoma and the Texas Panhandle, to Anton Chico, through Tijeras Canyon to Isleta, and westward (Foreman, 1968). Later the same year, Major James Henry Carleton led a small military expedition from Albuquerque to the area around the ruins of Gran Quivira, taking a route through Abo Canyon. He had with him a company of dragoons consisting of officers, 100 men, wagons, and a 12-pound mountain howitzer. He wrote a diary of the expedition (Smith and Reitz, 2001). [Carleton had a long military career. During the Civil War, he commanded the California Column volunteers on their march to the Rio Grande of southern New Mexico and Texas; he was promoted to Brigadier General along the way. He later commanded the Department of New Mexico, securing the territory against renewed Confederate incursions. He is perhaps best remembered in New Mexico for his infamous role in forcing the Navajo and Mescalero Apache into exile at Bosque Redondo (Hunt, 1958).]

Carleton was a careful observer and wrote several diaries of his military travels and experiences. His 1853 diary through Abo Canyon is titled "Diary of an excursion to the ruins of Abó, Quarrá, and Gran Quivira, in New Mexico under the command of Major James Henry Carleton, U.S.A., made in December 1853." The significance of this particular expedition is that Carleton recognized Abo Canyon as an ideal route for a rail line. While camped at the ruins of Abo Pueblo on Saturday evening, December 17, 1853, after marching all day from Casa Colorada on the west side of the mountains, he wrote in his diary. "At this time, when so many surveys are making from different points along the Mississippi toward the Pacific [he was aware of Lt. Whipple's survey earlier the same year], with a view of ascertaining the best route for a railroad track, perhaps the suggestion may be of

value that the Pass of Abó offers advantages in this respect which may not be found in any of the other passes through these mountains. They are certainly of sufficient consideration to make it an object to have this pass thoroughly explored before others shall be adopted" (Smith and Reitz, 2001, p. 25-26). It was not until half a century later that Carleton's recommendation of a railway route through Abo Pass was followed.

THE SANTA FE RAILWAY

The Atchison, Topeka & Santa Fe Railroad (AT&SF) started construction in 1868 of a line from Topeka across central Kansas, reaching Dodge City in 1872 and facilitating the shipment of buffalo hides and then cattle to eastern markets. From there the railroad pushed to Pueblo, Colorado, and, following the Mountain branch of the Santa Fe Trail, south to Raton Pass, the highest point on the line, and over Glorieta Pass towards Santa Fe. The AT&SF reached Santa Fe (actually Lamy, bypassing the steep hilly topography into town) and Albuquerque in 1880, marking the end of the wagon caravans and the Santa Fe Trail (Duffus, 1972). By 1886, the line was completed to California. In the early 1890s, the AT&SF claimed 9000 miles of track from Chicago to Los Angeles, the largest railway system in the world at that time (Bryant, 1974).

The Belen Cutoff

The steep line over Raton Pass and Glorieta Pass, following the old Santa Fe Trail, proved to be an impediment to shipping freight, and another route with lower grades was sought. The survey of the Belen Cutoff began in 1902 and construction began in January 1903 from Texico to Belen through Abo Canyon. The Wall Street panic of November 1903, however, resulted in a postponement of the project until August 1905. Abo Canyon posed construction problems, requiring the building of high bridges and blasting cuts through steep limestone escarpments. The first train went through Abo Canyon on December 18, 1907, and the line was formally opened on July 1, 1908 (Glischinski, 1997, p. 26-28). The Belen Cutoff through Abo Canyon has a 1.25 % grade of only 66 feet per mile compared with the steeper 3-3.5 % grade of Raton Pass at 7587 feet elevation. Even though the overall route from Belen to Chicago is only six miles shorter with the Belen Cutoff, the lower grade allows trains to transport more cargo without the need of helper engines, reducing transit time and operating costs (Fig. 1). Today, all transcontinental freight (Los Angeles-to-Chicago) is sent through the Belen Cutoff, although passenger trains are still routed over Raton Pass (Bryant, 1974; Glischinski, 1997; Solomon, 2003; Myrick, 1990).

On September 22, 1995, the AT&SF merged with Burlington Northern, the new company called the BNSF Railway with 24,000 miles of main-line track (Solomon, 2003). Most of the BNSF main lines are double-tracked, except at Abo Canyon itself where 80 to 110 freight trains pass daily on the single line, causing backups and delays along the transcontinental route. New construction of a double track that promises to expedite rail traffic across the continent began in 2008 through Abo Canyon.

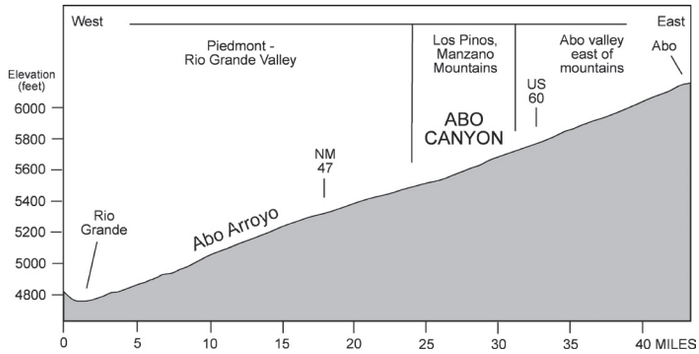

FIGURE 1. Longitudinal profile along Abo Arroyo from the community of Abo to the Rio Grande; from Abo, Scholle, Becker, Black Butte, Turn, and Veguita 7.5 minute quadrangles; note absence of knickpoints from local bedrock outcrops and faults; vertical exaggeration is 56x.

REPEAT PHOTOGRAPHS IN ABO CANYON

Photographs were taken in the canyon during railroad construction before 1903 and during the period 1903-1907 and are preserved by the Kansas Historical Society, Topeka, Kansas. Matched, repeat photographs were taken in February and March 2008, and four of these matched pairs are included here (Figs. 3 and 4, 5 and 6, 8 and 9, 10 and 11). The field locations of the photographic stations are shown in Figure 2. Some of the original photographic views were difficult to duplicate owing to disturbance by the construction of the rail line and by the presence of dense stands of salt cedar in Abo Arroyo. The repeat photographs were taken with a Nikon D200 digital SLR camera with 10.2 MP and with a Sigma 17-70 mm lens using a circular polarizing filter. The TIFF image files are presently stored at Parametrix in Albuquerque.

The Moon-Keleher Studio in Albuquerque, New Mexico, produced the 1905 photograph of the western-most railroad bridge over Abo Arroyo (Fig. 3), according to an inscription on a similar photograph published in Myrick (1990, p. 21). Carl Moon and Thomas Keleher, Jr., ran a photographic studio out of Albuquerque from 1905 through 1907. Carl E. Moon (1879-1948) became widely recognized for his portrait photography of Southwest and Plains Indians. Upon leaving Albuquerque, he moved to the Grand Canyon where he worked for the Fred Harvey organization acquiring Southwestern art. Moon's photographs were exhibited in 1907 at the White House upon request by President Theodore Roosevelt (Mautz, 1996, p. 334; Driebe, 1997; Moon, 1982). It is not known if the other early photographs of the construction of the Santa Fe line through Abo Canyon are by the Moon-Keleher Studio or other photographers; the camera used in the early photographs reproduced here is unknown.

ARROYO CUTTING IN ABO CANYON

The photographs taken in Abo Canyon during the construction of the Belen Cutoff before 1903 and during the period 1903-1907 show clearly that the Abo Arroyo channel was already incised by the turn of the century. Based on fieldwork in the canyon and

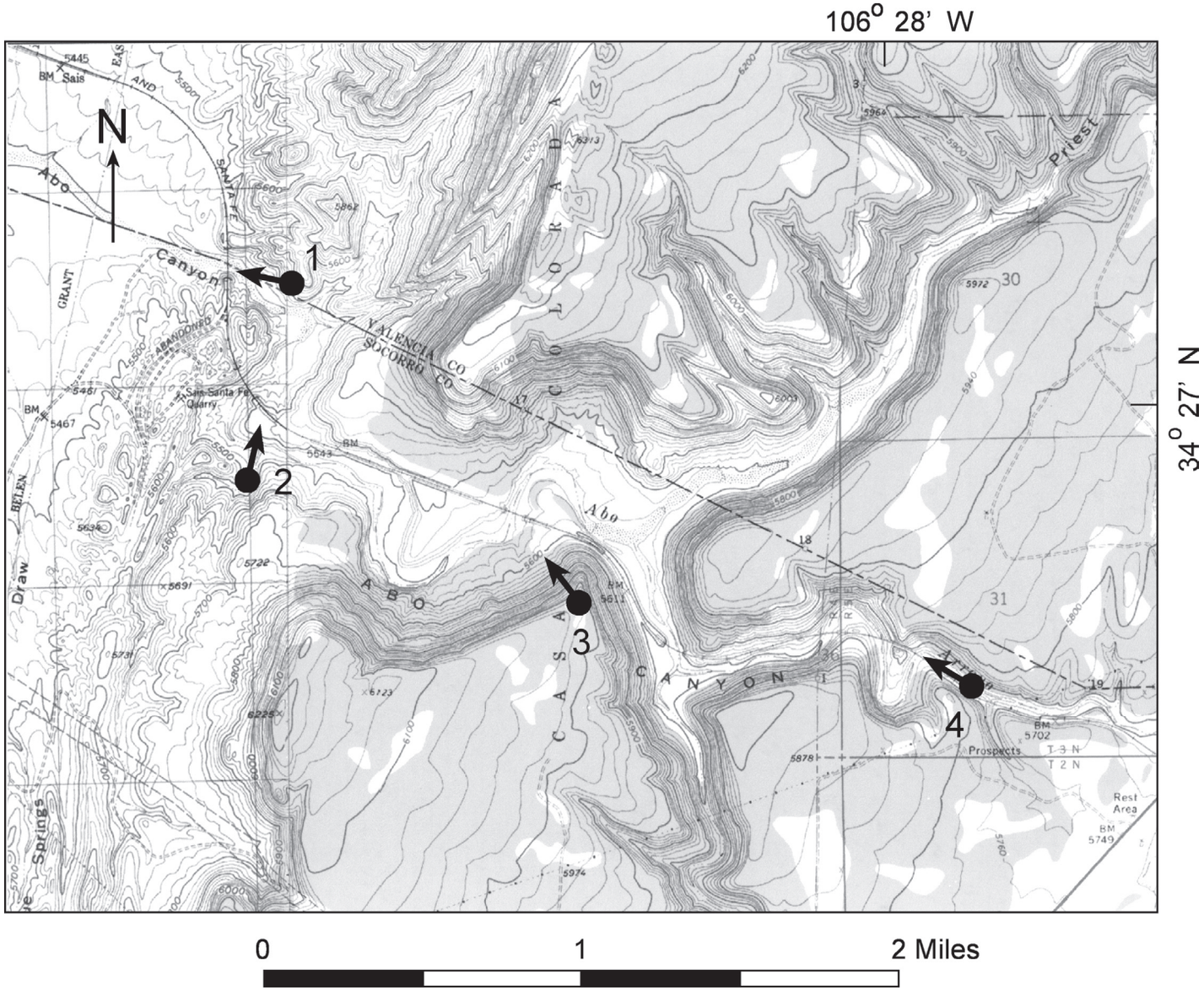

FIGURE 2. Topographic map of Abo Canyon with locations of photographs taken pre-1903 and in 1903-07 and repeat photographs in 2008; arrows show the direction that the camera was pointing; map from Becker and Scholle 7.5-minute quadrangles.

comparison of the photographs with the field conditions discussed below, we conclude that the arroyo cutting at Abo Canyon occurred during the period 1880-1890, coinciding with the same late nineteenth century period of arroyo cutting documented in New Mexico and elsewhere in the Southwest.

Abo Arroyo has a modest size drainage basin (600-700 km^2 to mouth of canyon), heading at the community of Mountainair that was established on the drainage divide about 7 miles east of the town of Abo (Fig. 1). The basin also includes streams from the southern Manzano Mountains. The present-day channel of Abo Arroyo is incised through late Holocene alluvium to a depth of 6 to 8 meters (Hall, unpublished report, 2009). Bedrock is exposed in several places in the base of the channel. A longitudinal profile of Abo Arroyo channel does not indicate that the exposed bedrock forms knickpoints or local breaks in the channel, suggesting that the bedrock outcrops were eroded to grade long ago and are now exhumed by historic incision (Fig. 1). The uniform gradient of Abo Canyon was observed by Major Carleton in 1853 and is the reason that AT&SF chose this route for its transcontinental line.

Inspection of the pre-1903 and 1903-1907 photographs and comparison of them with the 2008 photographs and field conditions show consistent trends. Most noticeably, the 2008 channel is wider, deeper, and has channel and meander bars that were not yet present in 1903-1907. Although not easy to see in the photographs, the area of the channel shown in Figs. 3 and 4 (locality 1), as well as downstream, has experienced channel widening and the development of channel bars during the twentieth century. At locality 2 (Figs. 5 and 6), the channel bends through the canyon and has visibly cut back approximately 45-55 meters along with deposition of a broad meander bar.

FIGURE 3. Photograph of bridge 874.2 milepost, Kansas Historical Society (ATSF Series 5-Photo 2.28), taken in 1905 at the western end of Abo Canyon; water flows away from the viewer. Fine alluvium is exposed in the right cut bank between the two middle concrete abutments. Note the absence of salt cedar. A photograph similar to the one above is published in Myrick (1990, p. 21) and in Stone (2003, p. 104) and has an inscription on the print "Moon & Keleher, Albuquerque, N.M., '05." A third Moon & Keleher photograph in this series with a date of 1905 is cataloged in the Palace of the Governors Photo Archives digital collection, Negative No. HP.2006.21 with an accompanying note "shows construction of railroad bridge over Abo river at the foot of Abo Canyon, bridge completed in 1907 as part of Belen cut-off project." The photograph reproduced above and the two others of this series at bridge 874.2, including the one in Myrick (1990) and Stone (2003), were evidently taken minutes apart. The photographer who took the other two photographs was standing slightly higher and to the right of the view shown above.

FIGURE 4. Repeat photograph of Figure 3 taken by Moira Ellis on March 26, 2008, about 12 noon facing west; locality 1 in Figure 2. This photograph shows the presence of low bars in the channel. All of the woody shrubs in the channel are salt cedar. Some increase in juniper has occurred on the far hillside on the left since 1905.

FIGURE 5. "2nd Crossing Abo River, Sand Canyon in background," Kansas Historical Society (ATSF Series 5-Photo 2.33), 1903-1907. Alluvium in the area of the late Holocene terrace shown to the right of the channel and in front of the new concrete bridge supports has been partly excavated for fill.

FIGURE 6. Repeat photograph of Figure 5 taken by Moira Ellis on March 26, 2008; locality 2 in Figure 2. Water flows away from the viewer. Since the first photograph, the channel has widened and cut westward (left) approximately 50 meters in the meander bend and an inside channel bar has been deposited. Note the increase in numbers and density of juniper trees during the twentieth century on slopes where for the most part junipers were already present in small numbers in 1903-1907. The shrubs in the channel near the bridge and next to the arroyo bank on the right are salt cedar. The small shrubs of snakeweed (*Gutierrezia* sp.) on the late Holocene alluvial terrace on the left and in the foreground do not appear to be present in the early photograph. The hill of dark-colored rock (Sais quartzite, Precambrian; Luther et al., 2005) at the left of the bridge has been quarried away since the 1905-07 photograph was taken. It should be noted that this is not a "perfect" repeat; the camera position for the repeat is lower than that for the earlier photograph.

The 2008 channel is deeper than shown in the 1903-1907 photographs. The 2008 channel has been incised 6 to 8 meters below the top of the late Holocene terrace in Abo Canyon. The depth of incision is greater upstream from the canyon and less downstream west of the canyon. The arroyo bank shown photographed in 1903-1907 and shown in Fig. 7 is estimated 5.0 m deep. The gravel exposed in the channel (Fig. 7) is the exhumed top of an extensive mid-Holocene gravel deposit that occurs throughout the lower half of the canyon, especially downstream from the junction of Priest Canyon with Abo Canyon arroyo near locality 3 (Fig. 2). The two-meter thick gravel deposit has been cut through during the twentieth century. The gravel is poorly sorted with clasts ranging from granule to boulder that are recycled into the present-day channel and bars (Hall, unpublished report, 2009).

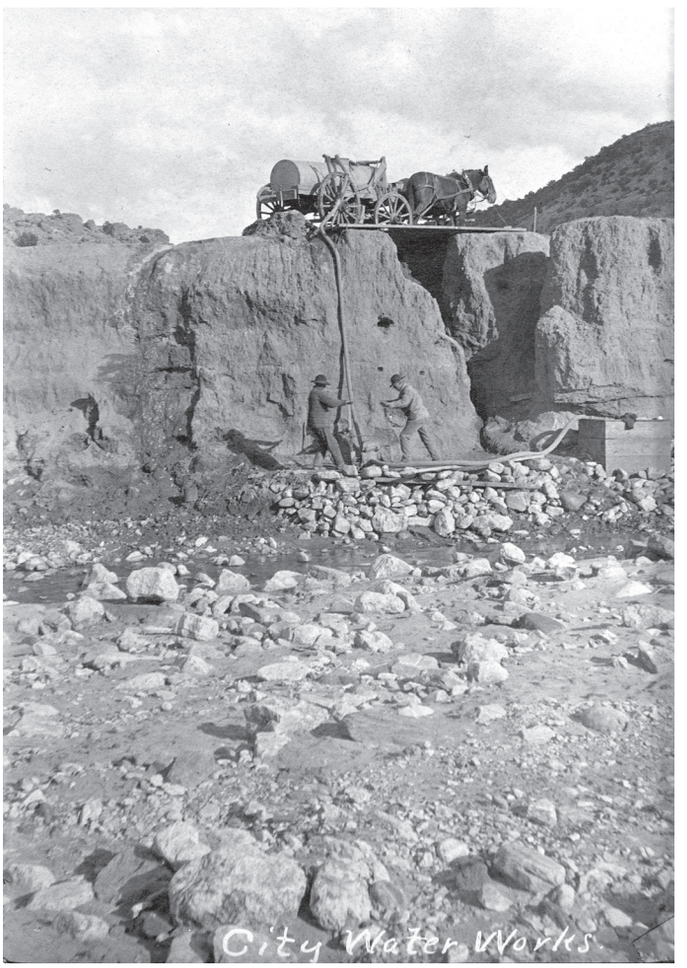

FIGURE 7. "City Water Works," Kansas Historical Society (ATSF Series 5-Photo 2.66), 1903-07. The location of this photograph was not found although it probably occurs between localities 2 and 3 in Figure 2. Cobbles are piled up forming a platform near the cement-box water well (to the right) in Abo Arroyo, a source of water for the construction camps. The mule and water wagon seem to be on a wooden platform, and water appears to be gushing off the arroyo wall to the left. The gravel-based channel is estimated to be 5.0 m below the late-Holocene terrace surface where the wagon is positioned. The gravel exposed in the channel is the top surface of an exhumed deposit of mid-Holocene gravel that occurs in alluvial fill in the lower half of the canyon (Hall, unpublished report, 2009).

An incised channel also occurs at the east end of the canyon as shown in the pre-1903 photograph (locality 4; Fig. 2). The pre-1903 arroyo exposes limestone blocks in the channel than may be a rockslide deposit on the narrow canyon floor. Fine textured alluvium is exposed in the right cut bank (Fig. 8). The 2008 repeat photograph along the channel was difficult to make because of the infestation by salt cedar (Fig. 9). The 2008 channel does not resemble the pre-1903 channel. The active 2008 channel is 2 to 3 meters wide and 0.5 to 1.0 m deep. The pre-1903 channel banks have slumped, and the channel is more than half filled with sandy alluvium. However, the pre-1903 channel has not completely filled in, and rounded edges of slumped banks are visible. The

FIGURE 8. Incised channel of Abo Arroyo, east end of canyon, before railroad construction, Kansas Historical Society (ATSF Series 5-Photo 2.77), pre-1903. The cut through the limestone escarpment of the Madera Group (Upper Pennsylvanian) (Scott et al., 2005) was not yet made when this photograph was taken; water flows away from the viewer. The limestone blocks exposed in the channel may represent a rock slide in the narrow canyon.

FIGURE 9. Repeat of "pre-1903" photograph of Figure 8 taken by Moira Ellis on February 28, 2008; locality 4 in Figure 2. Narrow valley and channel of Abo Arroyo to right is choked with salt cedar. A slight increase in juniper since before 1903 can be seen on the steep limestone slope on the right. Note modifications to lower canyon slopes by railroad construction in left foreground and the cut through the escarpment in mid-photo.

abundant salt cedar along this reach of the arroyo may have contributed to in-filling of the old channel. Also, the rail line is within 30 m of the channel, and there is a strong possibility that some of the channel fill may have originated from railroad activities.

LATE NINETEENTH CENTURY ARROYO CUTTING IN NEW MEXICO

The causes of early historic channel incision in the Southwest have been summarized by Graf (1983) under the broad categories of livestock grazing, climate change, and catastrophic floods. While a review of arroyo cutting is beyond the scope of this paper, we wish to mention a few related case studies from the region around Abo Canyon.

In the classic paper on the initiation of arroyo cutting in the Southwest, Kirk Bryan (1925) concluded that the channel erosion occurred in the 1880s although observing that some streams were undissected where headward cutting had not yet taken place at that time. In another study, Bryan (1928) evaluated local historic records from the Rio Puerco, Sandoval County, New Mexico, and concluded that the channel was deepened and widened between 1885 and 1890, although an earlier deep channel with pools of brackish water in the Rio Puerco was noted by Lt. James H. Simpson in 1849 during his march from Santa Fe to Navajo country (McNitt, 1964, p. 29). Finally, Balling and Wells (1990) examined channel cutting of the Zuni River in the vicinity of Zuni Pueblo from the perspective of local weather records going back to 1897. They postulated that channel incision occurred after 1905 during a three-year period of high rainfall following several years of drought. The connection of increased rainfall and resulting arroyo cutting is appealing, especially at the level of stream-table experiments. Nevertheless, early historic photographs of the Zuni Pueblo area show conclusively that downcutting of the Zuni River channel occurred instead between 1879 and 1899, similar to the timing of arroyo cutting at Abo Canyon and elsewhere in New Mexico (Hall, 1988).

TWENTIETH CENTURY VEGETATION CHANGE AT ABO CANYON

Juniper expansion

One of the clear changes in vegetation that took place during the twentieth century is an increase in trees and shrubs of juniper on the limestone slopes in the canyon. One early and repeat pair of photographs shows a wide limestone slope that permits a coarse quantitative measure of juniper trees. An area of about 26 hectares shows the presence of 266 juniper trees in the 1903-07 photograph (Fig. 10), and the same area has 823 juniper trees in the 2008 photograph (Fig. 11). These numbers translate to about 10 individuals per hectare in 1903-07 and 32 individuals per hectare in 2008, a times-three increase during the twentieth and twenty-first centuries. The other photographs from the canyon also show increases in juniper on canyon slopes although attempts to quantify those changes have not been made. In most cases, the increased numbers and density of juniper occur on slopes where some junipers are already present in 1903 to 1907. Based on spot checks in the canyon, the trees are all one-seed juniper (*Juniperus monosperma*). Pinyon pine (*Pinus edulis*) that has the appearance of juniper from a distance is not present on the canyon slopes today.

Increases in juniper have been noted throughout the western states during the twentieth and twenty-first centuries (Rogers, 1982; Stone, 2003, p. 148-149; Tennesen, 2008). The circumstances and causes of increased juniper have been widely discussed in the literature (see Knight, 1994, p. 139-140). Fire suppression is one of the dominant, direct factors leading to increased abundance of juniper. Secondary influences may be related to land use changes, such as livestock grazing and tree regrowth following periods of woodcutting (Huebner, 2002). The twentieth century increase in juniper in Abo Canyon may be a consequence of fire suppression.

Salt cedar invasion

Salt cedar or tamarisk (*Tamarix* sp.) was imported into the United States from southern Europe in the early nineteenth century and by the 1870s had spread throughout many drainages in the western states (Robinson, 1965). Based on the 1903-07 photography from Abo Canyon, however, salt cedar had not invaded Abo Arroyo at the time that the Santa Fe rail line was constructed. The 2008 photographs show that salt cedar is now well established in Abo Arroyo (Figs. 4, 6, 9).

A series of aerial photographs of Abo Canyon taken in 1935, 1954, 1971, and 1987 in the vicinity of photography station 3 (Fig. 2) provides some information on possible salt cedar invasion. The 1935 aerial photograph shows the arroyo channel entirely free of vegetation. However, the 1954 aerial, although not sharply in focus, shows occasional, scattered trees in the channel that might be salt cedar. In 1971, clumps of trees in the channel have become common and by 1987 are even more abundant. Therefore, based on the series of aerial photographs, salt cedar invasion of Abo Canyon may have occurred between 1935 and 1954 with expanded growth through 1971 and 1987. Today, in 2008, salt cedar is the predominant tree in the channel in this part of the canyon, indicating that the trees in the aerial photographs are also salt cedar.

SUMMARY AND CONCLUSIONS

A series of photographs taken pre-1903 and 1903-1907 during the construction of the Santa Fe rail line through Abo Canyon shows the presence of an eroding channel in Abo Arroyo. The narrowness of the channel and the state of erosion of the cut banks are consistent with incision occurring in the 1880s, a period of arroyo cutting also documented elsewhere in New Mexico. Repeat photographs in 2008 show that Abo Arroyo channel has become wider and deeper and that bars have been deposited in the channel during the twentieth and twenty-first centuries.

The photographs also show that trees of one-seed juniper (*Juniperus monosperma*) have increased in numbers on the limestone escarpments of the canyon. In the one case measured, the abun-

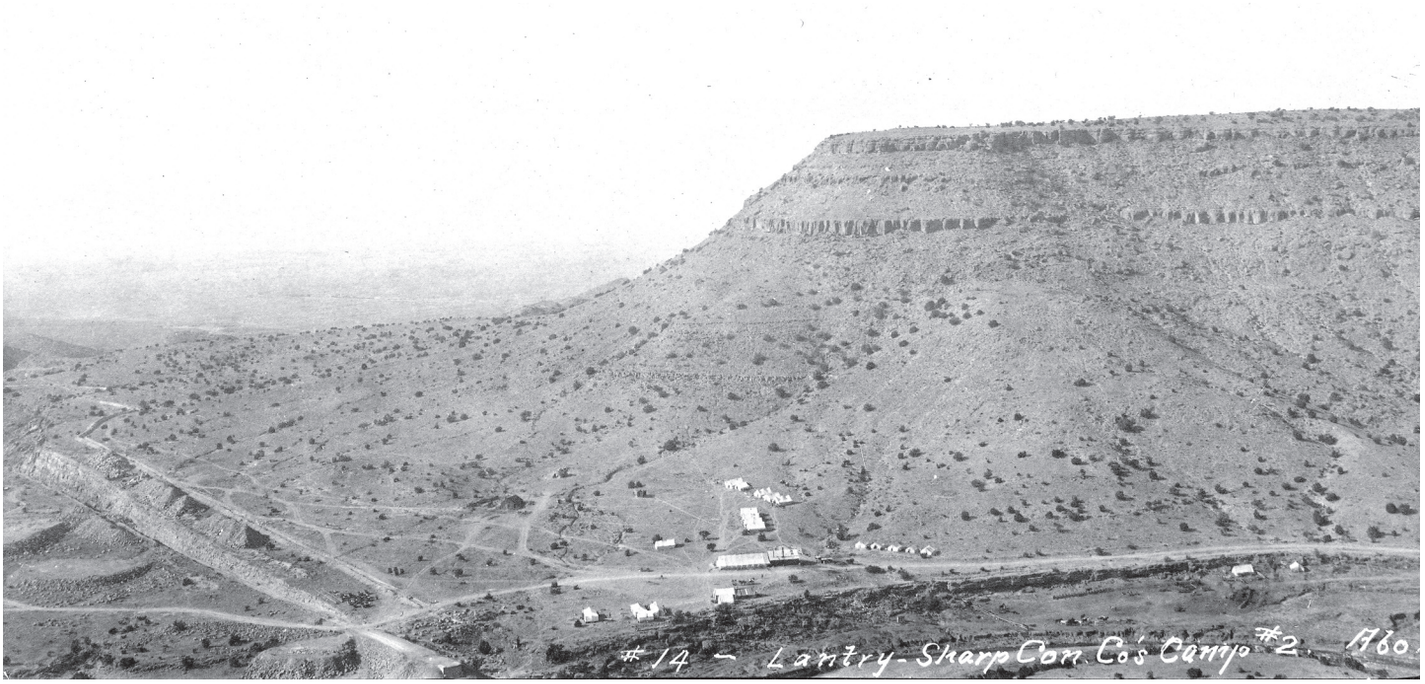

FIGURE 10. "Lantry-Sharpe Con[struction] Co's Camp #2-Abo," Kansas Historical Society (ATSF Series 5-Photo 2.20), 1903-07. Abo Arroyo channel is at the base of the photograph obscured by the lettering. The construction of the railroad bridge across Abo Arroyo in the lower left is incomplete when this photograph was taken. This is one of five construction camps set up for building the rail line through Abo Canyon. The escarpment bedrock is limestone of the Madera Group (Upper Pennsylvanian) (Scott et al., 2005). Juniper trees have a density of 10 individuals per hectare on the slope below the lower prominent escarpment and above the road through the camp.

Figure 11. Repeat photograph of Figure 10 taken by Moira Ellis on March 26, 2008; locality 3 in Figure 2. Juniper trees have a density of 32 individuals per hectare in the same area as tabulated in Figure 10, an increase by about three-fold during the twentieth century. Note the BNSF freight train in the distance on the piedmont leading down to the Rio Grande.

dance of juniper increased from 10 to 32 individuals per hectare during the period from 1905-1907 to 2008. Today, as shown in the 2008 photographs, Abo Arroyo channel has a profusion of salt cedar (*Tamarix* sp.) although the pre-1903 and 1903-1907 photographs show that salt cedar was absent. Based on aerial photographs, salt cedar invasion of Abo Canyon occurred sometime between 1935 and 1954 with continuing expansion and increase in numbers in the canyon through 1987 and today.

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