



The black mat at the Water Canyon Paleoindian site near Socorro, New Mexico: A paleoenvironmental proxy data archive for the Pleistocene-Holocene transition

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2016, pp. 491-500. <https://doi.org/10.56577/FFC-67.491>

in:
Guidebook 67 - Geology of the Belen Area, Frey, Bonnie A.; Karlstrom, Karl E. ; Lucas, Spencer G.; Williams, Shannon; Zeigler, Kate; McLemore, Virginia; Ulmer-Scholle, Dana S., New Mexico Geological Society 67th Annual Fall Field Conference Guidebook, 512 p. <https://doi.org/10.56577/FFC-67>

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THE BLACK MAT AT THE WATER CANYON PALEOINDIAN SITE NEAR SOCORRO, NEW MEXICO: A PALEOENVIRONMENTAL PROXY DATA ARCHIVE FOR THE PLEISTOCENE-HOLOCENE TRANSITION

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ABSTRACT—The Water Canyon Paleoindian site near Socorro, New Mexico, is directly associated with an extensive buried wetland deposit, or black mat. This landscape-scale feature, which was extant across the late Pleistocene–early Holocene transition, represents the remains of a wetland resource that, during the early Holocene, may have served as an ecological refugium for flora, fauna and Paleoindian groups as other regional water sources disappeared. Today the organic-rich deposit has proved to be an important proxy data archive for environmental, climatic and archaeological reconstructions. Our recent paleoenvironmental reconstruction efforts at the site have focused largely on the period from ~8300 to 11,100 radiocarbon years ago, and have generated a range of proxy data, including dated pollen profiles, stable carbon isotope values, charcoal species identifications, and both faunal and macrobotanical remains. The pollen data currently provide the most robust basis for our paleoenvironmental reconstruction and, together with our chronometric data, affirm that the black-mat forming wetland served as a persistent place of ecological diversity. These findings provide us with provocative glimpses of past environments in a heretofore largely understudied region of the American Southwest, and add to a growing body of Southwest reconstructions that will ultimately enable researchers to compare paleoenvironments and paleoclimates at both local and regional scales.

INTRODUCTION

While stratigraphically intact Paleoindian sites are relatively rare in New Mexico, Paleoindian studies here and in the greater American Southwest have historically incorporated Quaternary geological investigations and often, by extension, attempts to reconstruct past climates (Antevs, 1954; Wendorf, 1961; Wendorf and Hester, 1962, 1975; Haynes, 1991). In that tradition, the Water Canyon Paleoindian site near Socorro, New Mexico, represents a relatively unique laboratory for the recovery of archaeological, chronometric, and proxy data for paleoenvironmental reconstructions, geomorphological investigations, and both paleohydrologic and paleoclimatic studies. Of these perspectives, the attribute of primary interest for this paper is an extensive buried wet meadow deposit that spans the time period from the late Pleistocene to the early Holocene (LP-EH) epochs (~13,000 to 9000 calendar years before present [cal yr BP]). The site contains multi-component archaeological remains and associated paleoenvironmental data without parallel west of the Pecos River in New Mexico.

The Water Canyon site is located within a broad confluence of several geographic zones, including the southern Basin and Range Province, the Chihuahuan Desert, the Rio Grande Rift, and the Colorado Plateau, where many faunal, insect, and floral species exist at the extremes of their biological ranges. Accordingly, the biologically diverse Water Canyon wetland could have, during past changes in climate, evinced relatively rapid and pronounced shifts in species representation and distribution (cf. Neilson, 1993), and we expect such shifts, as a consequence, to be evident in the proxy record. Thus, the

primary goal of this paper is to summarize the results of our recent research, which underscore the potential of the Water Canyon site to reveal, with fine-grained resolution, changes in the past ecological communities, paleohydrologic regimes, and human adaptations across the LP-EH transition.

REGIONAL PALEO-ENVIRONMENT

The landscape of the American Southwest, during the LP-EH transition, is thought to have been quite different from that of the subsequent eight thousand years of the Holocene (Antevs, 1955; Graham, 1987; Grayson, 1993). For example, there were herds of megafauna, such as mastodons, horses, mammoth, camel, bison and sloth, and many pluvial and lacustrine features, such as lakes, playas and other wetland areas (Benson, 2004; Allen, 2005; Kowler, 2014). While there has been some past debate about the exact nature of the climatic regimes at that time (Brackenridge, 1978; Galloway, 1983; Haynes, 1991), many researchers believe that human foragers on this landscape had to contend with significant climatic shifts from a Pleistocene glacial epoch of cold temperatures and relatively high precipitation to a warming and drier, post-glacial climate during the latest Pleistocene (e.g., Holliday, 2005; Meltzer and Holliday, 2010; Ballenger, 2010). This period was followed by continued drying in the earliest Younger Dryas chronozone (YD; 12,900 to 11,600 cal yr BP; Polyak et al., 2004), a wetter middle-to-late YD (Hall et al., 2012) and early Holocene, and a gradually warming and drying trend in the early-to-middle-Holocene, with concomitant reorganizations, geographic redistributions and extinctions of faunal and floral

communities (Grayson, 1983). Researchers have also argued that the wetland features of the LP-EH landscape were among the most critical resources at that time for megafauna and the people that hunted them (Judge and Dawson, 1972; Beck and Jones, 1997; Duke and King, 2014), although some water resources, such as playas, had largely disappeared by the early Holocene (Holliday et al., 2006, p. 797-798).

Paleoenvironmental reconstructions for this time of climatic change in the Southwest have relied on a range of different proxy records, including those derived from well-preserved woodrat middens (Betancourt et al., 1990; Holmgren et al., 2007; Hall and Riskind, 2010), arroyo soils (Waters and Haynes, 2001; Allen et al., 2009), glacial and peri-glacial settings (Armour et al., 2002), cave speleothems (Asmerom et al., 2010), paleolake shoreline records (Kowler, 2014), and both archaeological faunal assemblages and those with no evidence of human agency (Haynes and Huckell, 2007; Morgan and Rinehart, 2007). Other paleoclimatic research efforts in the Southwest have demonstrated that deposits found in bogs, marshes, wet meadows and lakes can hold significant archives of high-resolution proxy data that can inform researchers about biotic responses to climatic changes in the past (Clisby and Sears, 1956; Markgraf et al., 1984; ; Waters, 1989; Brunner-Jass, 1999; Allen and Anderson, 2000; Reasoner and Jodry, 2000; Castiglia and Fawcett, 2006; Anderson et al., 2008; Hall et al., 2012; Louderback et al., 2015).

FOSSIL BLACK MAT DEPOSITS

Many recent paleohydrologic and paleoenvironmental research efforts have focused on the characterization, dating and sampling of fossil wetlands or groundwater discharge deposits in the Nevada and Arizona deserts of the southern Basin and Range Province (Quade et al., 1998; Pigati et al., 2009, 2011, 2014). Many such deposits were initially discussed by Haynes (1991, 2008) and referred to as “black mats”, owing to high organic contents and their resulting darker color. Although the documentation of a black mat at the Murray Springs site in Arizona revealed an association between the black mat and the Clovis occupation beneath it (Haynes, 2007), it is important to recognize that such an association is not implied at every black mat location.

In the southern Basin and Range Province, Quade et al. (1998, p. 131) indicate that black mats fall into a characteristic sedimentary sequence that usually begins with a “white to pale green clayey silt” marsh or wet meadow deposit. Deposition of this sediment was typically followed, as water tables rose, by the accumulation of black mat sediments from 11,800 to ~7200 ¹⁴C yr BP, with the peak in black mat abundance occurring around 10,000 ¹⁴C yr BP. The thickness of these sequences ranges from a few centimeters to upwards of 50 cm or more.

One of the more critical limitations in the interpretation of the genesis of black mats is the problem of connecting “the age of the mat and (the) timing of climate changes driving the shifts in the height of the water table” (Quade et al., 1998, p. 131; but see Pigati et al., 2011, p. 2235-2236). Even though black mats (and their implied higher water tables) are believed

to occur during times of enhanced effective precipitation, such as portions of the YD (Pigati et al., 2009), it is also recognized that groundwater paths at shallow depths tend to be associated with very low evaporation rates. Thus, there may be a temporal lag between a climate event and the discharge of groundwater at a given location. The magnitude of such a temporal lag would be largely contingent on the nature of the sediments through which groundwaters move and the distance and differential pressure gradients from the recharge zone.

In terms of paleoenvironmental proxy data, many black mats can contain fossil mollusks and ostracodes which, generally reflect moist settings, such as the edges of spring channels, ponds or wet meadows. The stable carbon isotope values in black mats – particularly those that span the LP-EH transition – often reflect the predominance of C₃ plants, which might include grasses, shrubs or trees, and possibly sedges in more well-watered locations. This plant assemblage is interpreted to reflect generally mesic and cooler-than-present conditions (Nordt et al., 2007; Hall et al., 2012). Increasing C₄ values in upper portions of black mats, when found, may signal a warming-drying trend.

In some settings, such as the Murray Springs site, these black mat features have been associated with LP-EH human occupations (Haynes, 2008; Ballenger, 2010) and some researchers (Haynes, 2008; Ardelean, 2013) have also recognized that many of the black mats in the Southwest were associated with the YD. Examples in New Mexico, and documented by Haynes (2008), include a dark gray Stratum D at the Clovis type site in Blackwater Draw near Portales, and a soil (classified as a Mollic Aquoll) at Pounds Playa (Fig. 1). More recently, other black mats have been identified and investigated in New Mexico including those in Abo Canyon (Hall et al., 2012), in the Tularosa Basin (Allen et al., 2009; Love et al., 2014; Rachal et al., 2016), and at Water Canyon (Dello-Russo et al., 2010). To date in New Mexico, only the black mats at Blackwater Draw and Water Canyon are associated with LP-EH artifacts and faunal remains.

WATER CANYON SITE DESCRIPTION AND SETTING

The Water Canyon site is, foremost, an archaeological site with diagnostic artifacts and chronometric dates representing multiple occupational components, including clear evidence for the Clovis (ca. 13,200-12,900 cal yr BP), Folsom (ca. 12,500-11,500 cal yr BP), Cody (ca. 11,200-9800 cal yr BP), Late Paleoindian (ca. 9700-9000 cal yr BP), and Middle-to-Late Archaic (ca. 5000-3000 cal yr BP) cultural periods. The site consists of six different loci (Fig. 2) encompassing approximately nine hectares (ca. 22 acres), where Locus 1 contains a Late Paleoindian *Bison antiquus* bone bed (Fig. 3), processing area and possible campsite; Locus 2 contains a Middle-to-Late Archaic activity area; Locus 3 contains the remains of a possible campsite of currently unknown temporal affiliation; Locus 4 contains a Cody-age campsite; Locus 5 contains a *Bison antiquus* bone bed, currently believed to be of Cody Complex age and associated with Locus 4; and Locus 6 contains the remains of both Clovis and Folsom activity areas.

The Water Canyon site (LA134764) is located in west-cen-

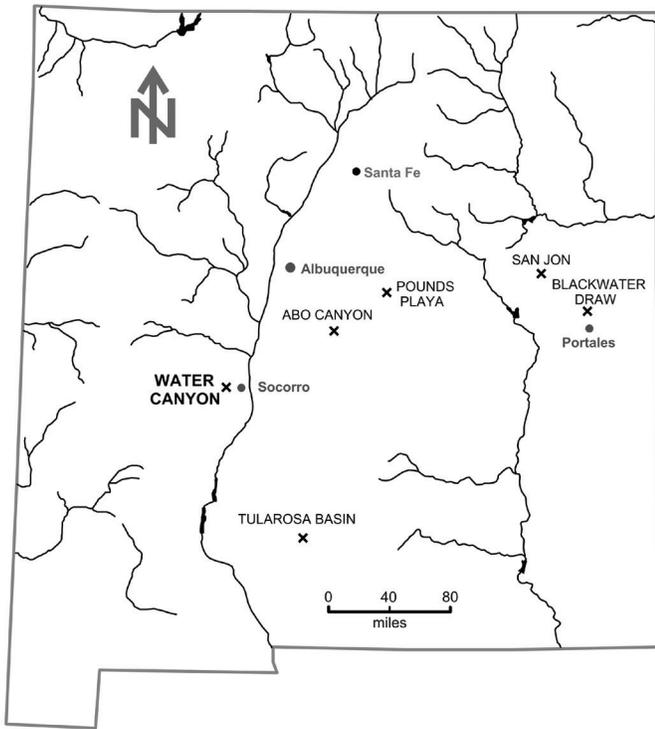


FIGURE 1. Location of the Water Canyon Site and other black mat settings in New Mexico.



FIGURE 3. Excavation of *Bison antiquus* humerus, Locus 1, Water Canyon site.

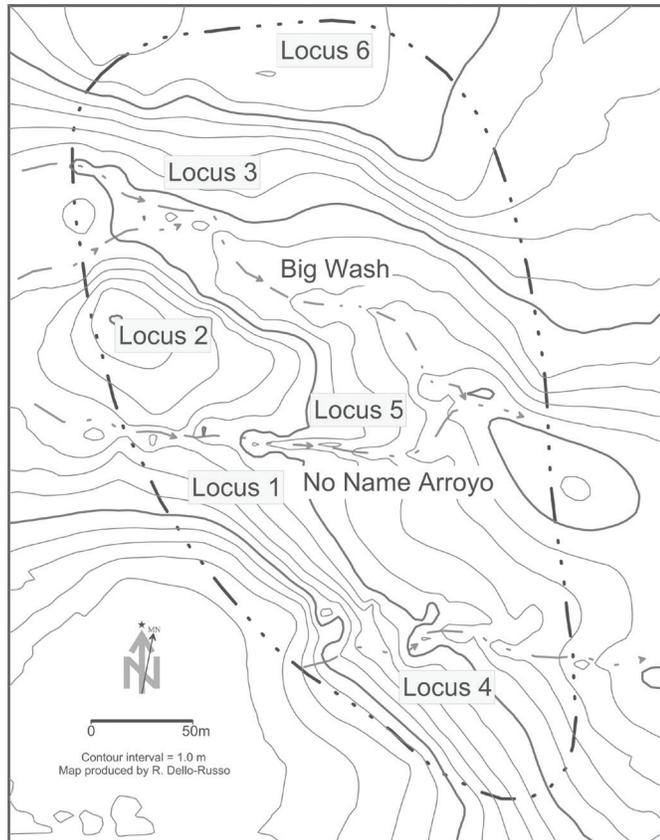


FIGURE 2. Topographic plan map of the Water Canyon Site. Site spans elevations between 1756 and 1770 m asl. Contour interval on map is 1 m.

tral New Mexico (Fig. 1), at the eastern edge of the Water Canyon fan across the La Jencia Basin, among a series of dissected ridges formed by short tributaries of the Water Canyon drainage near the western slopes of the Socorro Mountains (Chamberlin and Osburn, 2006). The Water Canyon drainage flows eastward from the crest of the Magdalena Mountains (>3,000 m ASL) across the La Jencia Basin, around the north edge of the Socorro Mountains and joins the Rio Grande as the Nogal Canyon drainage northeast of Socorro. The site was originally documented in 2001 (Dello-Russo, 2002) and is found at an elevation of approximately 1760 m (5780 ft) in a juniper savannah vegetation community (Fig. 4). The site represents one of a series of late Pleistocene and early-to-middle Holocene age archaeological sites eroding out of sediments recycled from the dissected toe of the large Water Canyon fan.

The Water Canyon site is trisected by a large north-west-to-southeast intermittent drainage (informally named “Big Wash”), a smaller intermittent arroyo (informally named “No Name Arroyo”), and a third unnamed arroyo near Locus 4 (Fig. 2). Cut-banks in all three drainages exhibit exposures of a buried black mat deposit that underlies much of the site, although the exposure in No Name Arroyo (encompassed by Locus 1) has currently received the most attention. As with many other black mats associated with alluvial fan sediments in the Southwest (e.g., Pigati et al., 2011, p. 2235), the Water Canyon black mat probably formed as a result of precipitation (snow, rain)

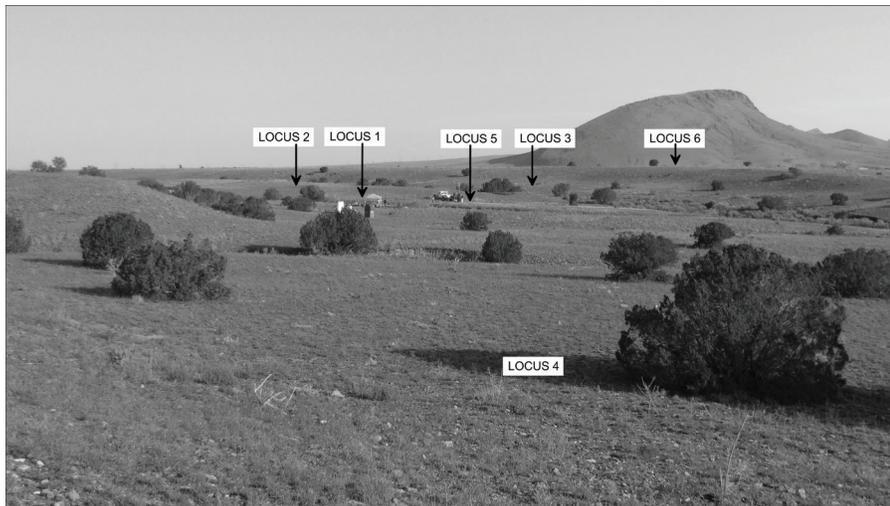


FIGURE 4. Overview of Water Canyon Site. View from southern boundary looking to north-northwest. Locus 5 behind “No Name Arroyo”. “Big Wash” at center right. Unnamed arroyo in middle ground behind Locus 4. Unnamed peak in background.

falling mainly on recharge areas of the Magdalena Mountains and the Water Canyon fan, that generated a slug of subsurface groundwater flow through the associated alluvial fan sediments to their distal end. At the Water Canyon site, the truncation of the distal end of the fan (by tributaries responding to the falling base level of the main Water Canyon channel), coupled with a thick, buried low-permeability playa facies and buried fault zones (Barroll, 1989; Chamberlin and Osburn, 2006), squeezed the groundwater discharge to the surface, leading to the formation of extensive wetlands and, ultimately, the development of the black mat (D. Love, pers. commun., 2016).

The northern portion of Locus 1 (with the Late Paleoindian *Bison antiquus* bone bed) was deposited along the banks of a paleochannel of No Name Arroyo as it cut through a Late Pleistocene-aged ridge of alluvium. This alluvium was, originally inset against older Pleistocene-age fan deposits. The south portion of Locus 1 and Locus 4 were created on colluvial deposits at the base of the toe slope of these same fan deposits. Locus 2 occurred on the Late Pleistocene ridge of alluvium while Locus 3 occurred on a remnant portion of an old Big Wash floodplain. The Locus 5 Cody Complex *Bison antiquus* bone bed was deposited at the base of a deeply incised, paleochannel of the Big Wash and the Locus 6 Clovis and Folsom artifact assemblages were deposited atop the stable, Pleistocene-aged surface of the Water Canyon fan.

BRIEF SUMMARY OF FIELD STUDIES AT WATER CANYON

After the initial site documentation in 2001 (Dello-Russo, 2002), ten field sessions were completed between spring 2008 and 2015 (Dello-Russo, 2010, 2012, 2015). The most recent sessions (2015) are currently unreported. Over these ten field sessions, researchers mapped and collected a sample of surface artifacts ($n > 400$) and collected soil descriptions and samples from 72 hand-excavated units, 82 Giddings mechanical cores, numerous hand augers and six backhoe trenches; stratigraphic

profiles from the hand-excavated units and backhoe trenches; a suite of 17 optically stimulated luminescence (OSL) samples; 487 faunal samples (largely *Bison antiquus* and land snails); 187 Paleoindian artifacts from excavated contexts; and a series of 59 radiocarbon samples on bulk soil organic matter (SOM) from buried soil horizons and organic-rich sediments, charcoal and faunal bone collagen.

The SOM samples, which were collected from mechanical soil cores, hand-excavated test units and backhoe trench profiles, underwent a standard acid-base-acid treatment to remove carbonates and to isolate specific fractions of organic matter (Abbot and Stafford, 1996). Samples collected for radiocarbon dating were sent to either Beta Ana-

lytic, Inc. or the NSF-Arizona Accelerator Mass Spectrometry (AMS) Laboratory. The radiocarbon ages reported in this paper are presented in Table 1 as radiocarbon years BP (corrected for isotopic fractionation) and as calibrated ages (cal yr BP). The OSL samples were analyzed at the University of Nebraska, Lincoln, Luminescence Geochronology Laboratory by Dr. Ron Goble and at the Utah State University Luminescence Laboratory, Logan, by Dr. Tammy Rittenour. Details about the OSL dating are provided in Dello-Russo (2015, p. 122-128; 2012, p. 143-146).

Because the buried black mat was first observed in the north wall of No Name Arroyo (Fig. 5), chronometric sampling and excavation work was initiated there. This area was eventually designated as Locus 1 and, to date, a suite of 25 hand-excavated units, three backhoe trenches and 14 hand augers have been opened there, revealing well-preserved skeletal elements of at least two adult and one juvenile *Bison antiquus* directly associated with flaked stone tools and tool debris. This archaeological bone bed has a preliminary bone collagen date of 8200 ± 40 ^{14}C yr BP (Table 1), while the black mat deposit ranges in age from $11,310 \pm 50$ ^{14}C yr BP at its base in Locus 1 to 7228 ± 46 ^{14}C yr BP at its top (as extrapolated from the Big Wash cutbank in Locus 5). The bone bed in Locus 1 is thought to be extensive and excavations have only sampled a modest portion of the assemblage.

Above the top of the black mat are numerous stratigraphic unconformities representing episodes of erosion (J. Onken, unpubl. 2012). The uppermost ~ 3100 calendar years of sediment in the black mat consist of highly organic, silty clay loam that ranges in color from medium gray to dark gray brown to black (top down). A dark olive silty clay loam comprises the lower part of the black mat, the age of which ranges over ~ 2000 calendar years (Fig. 6). Faint bedding is apparent in both the black and olive sediments (V. Holliday, unpubl., 2012). The textural similarity in both colors of sediment suggests a similar depositional origin for each, while the gleying (dark olive color) in the stratigraphically lower sediments suggests that they became water-logged as the local water table rose. The timing of this

TABLE 1. Radiocarbon and calendar ages for selected samples from Locus 1 and Locus 5, Water Canyon site.

Field Sample (FS) Number	Provenience	Grid North (m)	Grid East (m)	Grid Elevation (m)	Material Dated	Radiocarbon Age ¹	¹³ C/ ¹² C (‰)	Calibrated Age BP (2 sigma) ²	Laboratory Number ³
1037	Unit 1-12 / L6	507.830	508.100	48.310	Bone Collagen	8200 ±40	-12.3	9152 ±126	Beta-292053
1232	Unit 1-6 / L16A	509.953	509.270	47.291	SOM	11,310 ±50	-25.8	13,185 ±95	Beta-373607
1280	SE cutbank Big Wash	556.962	536.594	47.406	SOM	7228 ±46	-25.9	8064 ±97	AA-103852
5007	Unit 5-3 / L1	521.068	527.864	46.017	Charcoal	8394 ±45	-24.2	9442 ±40	AA-103920
5124	Unit 5-3 / L6	521.886	527.580	45.483	SOM	8997 ±53	-24.0	10,182 ±65 9996 ±73	AA-104111
63a (split)	Core 10-1	521.410	526.770	45.200	SOM	9640 ±40	-23.3	11,123 ±63 10,880 ±94	Beta- 317339
63a (split)	Core 10-1	521.410	526.770	45.200	Charcoal	9887 ±59	-25.2	11,305 ±107	AA-95610

¹ All radiocarbon analyses completed by accelerator mass spectrometry (AMS).

² Calibration of radiocarbon dates utilized IntCal 13 database; reported with 2 sigma error.

³ AA-numbers from NSF-Arizona Accelerator Mass Spectrometry Laboratory/Beta-numbers from Beta Analytic, Inc.

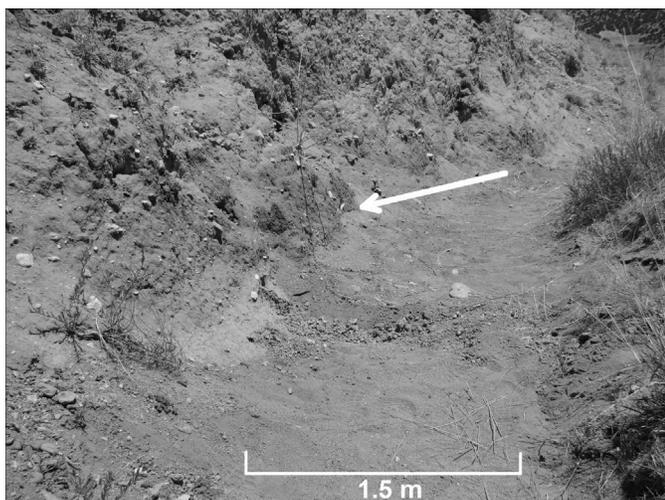


FIGURE 5. View of black mat deposit (arrow) in north side of No Name Arroyo. View northeast and downstream.

hypothesized high water table event is currently unclear. The upper boundary of the olive sediments, which would represent the upper limit of the rising water table, is considered to have no stratigraphic implications (V. Holliday, pers. commun., 2015).

The mechanical Giddings sediment cores were excavated along numerous transects across the site to determine the spatial extent of the black mat, to establish its depth and thickness, and to retrieve both chronometric and palynological samples. This approach established that the black mat is a landscape-scale feature that developed in the sediments along the floors of the channel(s) incised below the surface of the ancient Water Canyon fan. The black mat continues downstream ~1 km to its confluence with the main channel of the Water Canyon drainage, where it appears close to the current ground surface. Mechanical coring also revealed a deeply buried portion of the black mat in an area to the northeast of Locus 1. While most of the deposit across the site is found from 1 to 2 m below

the current surface, this deep portion is over 4 m below the surface and is thought to have formed within an incised paleo-channel of the Big Wash. In general, the Water Canyon black mat slopes downward from the northwest to the southeast and is, on average, almost 1 m thick.

The archaeological area that exhibited the deepest portion of the black mat was later designated as Locus 5. These black mat sediments extend from Locus 5 north to the Big Wash. Of greater interest still was the discovery of faunal bone in five of the mechanical cores in Locus 5, where black mat sediment samples in Core 10-1 immediately above and below the bone returned an average date of 9718±33 14C yr BP. Additional radiocarbon dates on SOM samples acquired from hand-excavated Unit 5-3 in the Locus 5 bone bed returned dates ranging from 8394±45 14C yr BP to 8997±53 14C yr BP (Table 1), which suggests a site occupation during the Cody Complex

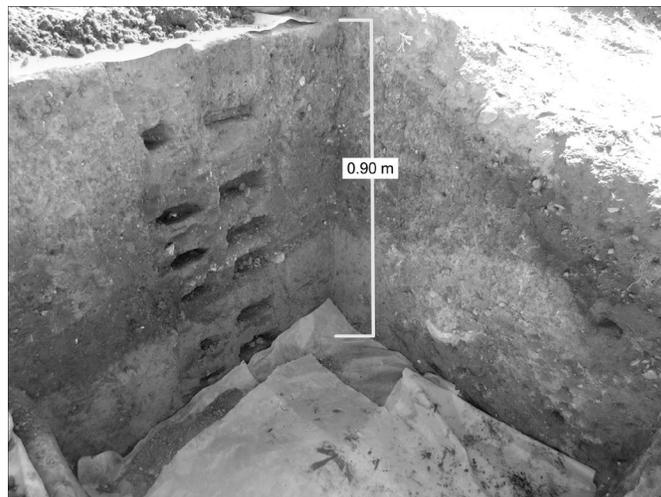


FIGURE 6. Exposure of black mat with sampling locations in Locus 1 Unit 6 along south side of No Name Arroyo. Excavated Unit 6 is approximately 90 cm deep.

era. In comparison, the only documented Cody Complex dates in New Mexico are on humates from the San Jon site and on humates and SOM from the Blackwater Draw site. The reliable date from the former site is 8275±65 14C yr BP and dates from the latter site range from 8830±160 14C yr BP to 8970±60 14C yr BP (Holliday et al., 1999).

During subsequent hand-excavations in Locus 5 at Water Canyon, a resharpened Eden projectile point (a diagnostic artifact of the Cody Complex) was found in association with the *Bison antiquus* bed. Dates from the Great Plains and Rocky Mountains for the Cody Complex range broadly from 8140 to 10,100 14C yr BP, although the date range for single-component Eden occupations is 8660 to 9649 14C yr BP (Knell and Muñiz, 2013, p. 11-13).

The more recent and ongoing analyses of the field data and samples are enabling us to refine our understanding of how the site was formed, the nature of the paleoenvironment and climate at the site and, ultimately, when and how Paleoindian and Archaic hunter-gatherers utilized the site's resources.

BRIEF PALEO-ENVIRONMENTAL RECONSTRUCTION AT WATER CANYON

The following summary of our early Holocene paleoenvironmental reconstruction is based on the analysis of pollen

samples, wood species identifications, stable carbon isotopes values measured during radiocarbon dating and identification of land snails. The land snails represent a mix of both damp and dry habitats (Hall, 2015, p. 50-51). The summary of pollen results below is extracted from the detailed reports in Smith (2012 and 2015) for 17 samples collected only in black mat deposits. All of the pollen data are reported in Smith (2015). The botanical authority used for plant names is the on-line database maintained by the USDA NRCS (2016).

The earliest dated portions of the black mat encompassing the YD and the latest Pleistocene (~13,185 to 11,100 cal yr BP) have yielded only a minimal number of pollen grains, which suggests a fluctuating water table unfavorable to pollen preservation. However, the early Holocene, from 11,100 to 9300 cal yr BP, is represented by rich pollen spectra that reflect a landscape dominated by grassland with *Artemisia* spp. (sages; Fig. 7). Previous researchers have interpreted late glacial (approximately 36,000 to 14,000 yr BP) pollen records rich in *Artemisia* and grass pollen as representing sagebrush grassland or steppe, using the modern iconic Great Basin big *Artemisia tridentata* (sagebrush) grasslands as an analog (Hall, 2005). We propose that the Water Canyon black mat *Artemisia* pollen represents herbaceous and subshrub sages that grow in meadow habitats, for example *Artemisia bigelovii*, *A. carruthii*, and *A. ludoviciana*. Supporting evidence for this interpretation

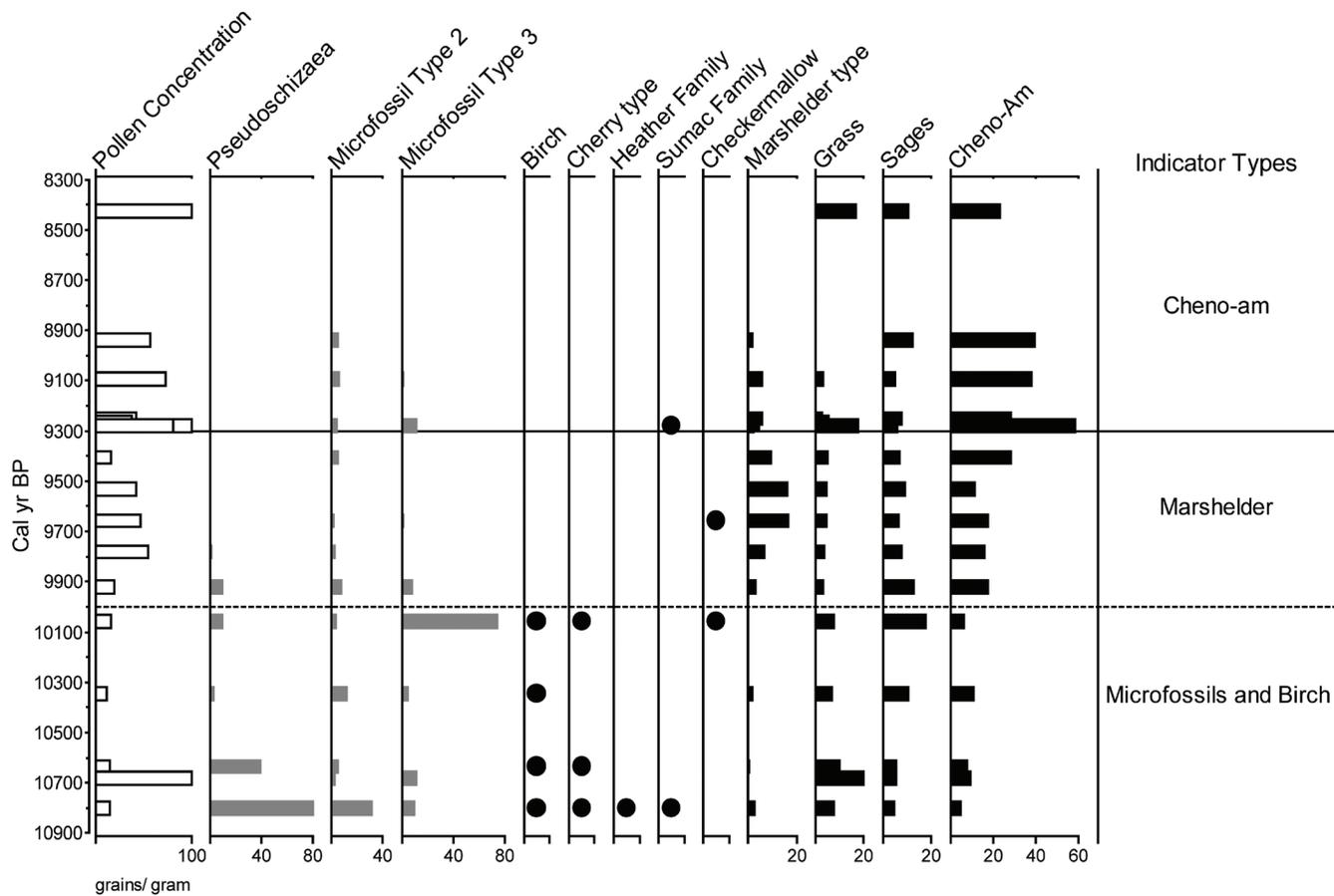


FIGURE 7. Water Canyon black mat summary pollen results. Complete database documented in Smith (2015). Legend: gray bars equal raw microfossil counts, black bars show pollen percentages, and oval symbols note presence of low-count taxa.

is found in the hundreds of packrat middens analyzed from southern New Mexico and the Chihuahuan Desert, which lack big sagebrush (*Artemisia tridentata*) macrobotanical fossils, and instead preserve herbaceous and subshrub species (Betancourt et al., 1990; Holmgren, 2005).

There is no pollen evidence for pine or juniper trees at the Water Canyon site, but early Holocene (EH) conifers were undoubtedly accessible in the nearby Socorro and Magdalena Mountains, where they grow today. Charcoal samples recovered from the uppermost portion of the black mat (corresponding to the Late Paleoindian occupation) consist of *Quercus* (oak), *Juniperus* (juniper), unknown conifer (McBride, 2015, p. 33) and possible *Pinus* sp. (pine) and *Pinus ponderosa* (Ponderosa pine) (O. Davis, unpubl., 2012).

Unique aspects of the EH pollen record at Water Canyon include identification of three distinct microfossils – two unknowns and *Pseudoschizaea* (descriptions in Smith 2012, p. 45-48). The diagnostic finger-printed form of *Pseudoschizaea* has been correlated with generally warm and wet paleoenvironments characterized by strong seasonal fluctuations, such as marshes and swamps (Scott, 1992). The consistent presence of *Betula* (birch) pollen is interpreted to represent on-site or nearby birch (Smith, 2015, p. 45). The species represented cannot be determined from pollen grain morphology, but there are two possibilities – the streamside tree called *Betula occidentalis* (western water birch) or wetland shrubs known as *Betula glandulosa* (resin birch). Today in New Mexico, *Betula occidentalis* grows only in northern counties and *Betula glandulosa* was unknown until a restricted population was found in a tiny marshy meadow in the Jemez Mountains (Brunner-Jass, 1999). Other woody shrubs that might have grown at or near Water Canyon during the EH include *Prunus* spp. (cherry members of the Rosaceae [rose] family), *Rhus* spp. (sumac) and possibly a member of the Ericaceae (heather) family, such as *Arctostaphylos* spp. (manzanita). One rare type found in only three pollen samples is *Botryococcus*, an algal form. This trace of algae in combination with the microfossils and other mesic indicators, such as *Iva* spp. (cf. marshelder), *Sidalcea* sp. (checkermallow) and lily family, indicate the presence of seasonal pools, marshy ground and other wetland habitats.

Our reconstruction of the LP-EH at Water Canyon is of a wet meadow bordering a creek or interconnected pools interspersed with wetlands and marshy areas, similar to modern cienega ecosystems in the region (Smith, 2015, p. 44-47). As a whole, the record “indicates a landscape characterized by a mosaic of different vegetation communities for which there is no modern analog” (Smith, 2015, p. 47). In addition to the presence of fresh water, the variety of browse and forage shrubs, grasses and herbs would have provided a strong attraction for bison and other game and non-game animals.

Climatic interpretation of the well-dated and detailed EH pollen record from Water Can-

yon indicates the period between 11,000 and 9300 cal yr BP was characterized by hot, wet summers and cold, perhaps dry winters (Smith, 2012, p. 56-57). This interpretation of strong seasonality is consistent with models of orbitally-induced changes in solar radiation, which suggest EH summer insolation values at 30°N. latitude that were 6-8% times greater than modern values and winter insolation values that were 8-10% lower (Kutzbach and Guetter, 1986). The Water Canyon pollen indicate a gradual warming and drying trend throughout the EH that culminated by approximately 8500 cal yr BP when “Cheno-am” pollen dominated sample assemblages. The term “Cheno-am” is a broad pollen category encompassing genera of the Chenopodiaceae family and the *Amaranthus* genus. The overwhelming Cheno-am signature is interpreted to reflect the regional expansion of salt bush (*Atriplex* spp.). After approximately 8500 cal yr BP, much, if not most, of the present-day Chihuahuan desert community became established at this locality. The warming and drying trend revealed by the pollen analysis is supported by the stable carbon isotope data. As illustrated in Figure 8, the low $\delta^{13}C$ numbers reveal a strong C3 plant signature during the late Pleistocene (indicative of a cooler, wetter climate), followed by a general trend of successively higher $\delta^{13}C$ numbers (reflecting relative increases in the amounts of C4 vegetation and a warming-drying climate) during the Younger Dryas chronozone and into the early and middle Holocene. There is a slight downturn in the $\delta^{13}C$ numbers at the time of the earliest Holocene, suggesting a slightly cooler and wetter episode, followed by a rapid increase in $\delta^{13}C$ numbers (and in warming and drying) slightly afterwards in the early Holocene.

CONCLUSIONS

While there are other known Paleoindian sites in the surrounding region (Hurt and McKnight, 1949; Judge, 1973;

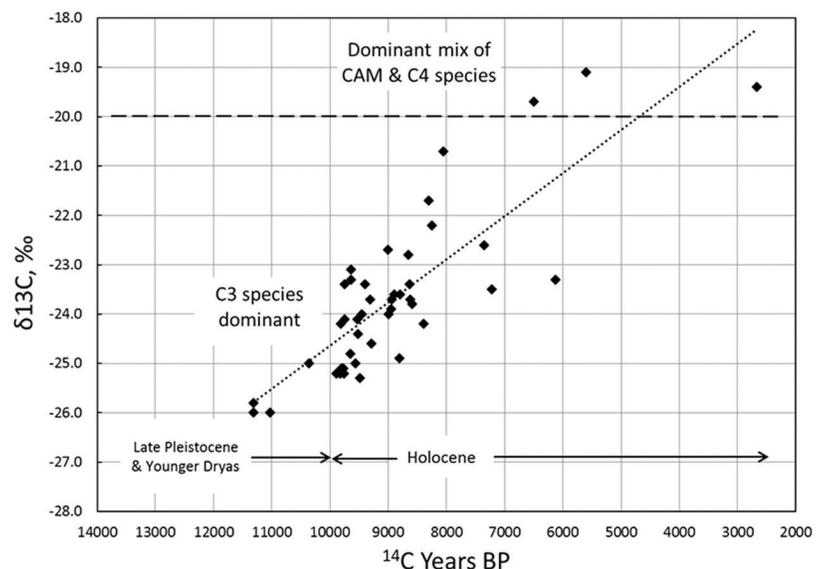


FIGURE 8. Changes over time in stable carbon isotope values for bulk sediment samples from Water Canyon black mat.

Beckett, 1980; Wessel et al., 1997; Amick et al., 1998; Dello-Russo, 1997, 2001; Hill et al., 2007; Dello-Russo and Walker, 2008; Huckell et al., 2008), the ensemble of multi-component Paleoindian deposits, well-preserved faunal remains and a high-resolution paleoenvironmental record are uniquely represented at the Water Canyon site and provide a clear warrant for further research. Plans for continued paleoenvironmental research at Water Canyon include analyses of diatom and phytolith assemblages from the earliest YD sediments.

The fact that the black mats at Water Canyon and other regional locales were essentially contemporary over the LP-EH (Rachal et al., in press) suggests a broad scale linkage with climatic processes across the greater Southwest (Pigati et al., 2011, p. 2224). However, even though it has been cautioned that the temporal link between these climatic changes and the development of wetlands is difficult to gauge (Pigati et al., 2011, p. 2237), it seems reasonable to assume that the extra moisture inputs provided by the Magdalena Mts. to its associated fan would have allowed the Water Canyon wetlands to persist during relatively dry climatic episodes (such as the Clovis drought or the early Holocene) when other regional sources of water, such as playas, were disappearing. Such a predictable niche of fresh water and biological diversity would have been attractive to grazing herbivores and the Paleoindians who hunted them over the span of the LP-EH. While Paleoindians would certainly have been able to discern the persistence of the wet meadows and cienegas, our ability to scientifically document such a phenomenon given the precision of our current chronometric methods is yet to be demonstrated (cf. Meltzer and Holliday, 2010). Clearly, continued interdisciplinary investigations at the Water Canyon site have the potential to address these issues, helping to verify that the Water Canyon paleo-wetland served as significant regional refugium for flora, fauna and the earliest people of the Southwest.

ACKNOWLEDGEMENTS

Funding for this research has come from the Argonaut Archaeological Research Fund at the University of Arizona, the Curtiss T. and Mary G. Brennan Foundation, the New Mexico Archaeological Council, the Maxwell Museum of Anthropology Office of Contract Archeology at the University of New Mexico, the Museum of New Mexico Foundation Friends of Archaeology and Office of Archaeological Studies, and numerous generous private donors and in-kind donations. The authors would like to thank V. Holliday and J. Onken for Giddings soil core data, backhoe trench profiles, and soil analysis; R. Goble, T. Rittenour and S. Hall for assistance with OSL dating; T. Stafford and D. Hood for information about the radiocarbon dating of bone; P. McBride and O. Davis for macrobotanical analyses; S. Hall and P. Kondrashov for land snail analyses; D. Rapson for thoughts about field methodology, and J. Betancourt, M. Collins, E.J. Dixon, R. Greaves, C.V. Haynes, V. Holliday, S. Hall, D. Love, L. McFadden, F. Phillips, and D. Rachal for meaningful conversations about the nature of the black mat and the evolution of the site. Thanks as well to S. Gunn (OCA) for GPS and GIS guidance and assistance with maps

and figures. Finally, the authors thank D. Love, L. McFadden, S. Hall, S. Williams and K. Zeigler for careful and detailed review comments. This paper is very much improved as a result. Any errors or omissions are attributable to the authors.

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