GEOARCHAEOLOGY OF THE WATER CANYON PALEOINDIAN SITE, WEST-CENTRAL NEW MEXICO

by Vance T. Holliday^{1*}, Robert D. Dello-Russo², and Susan M. Mentzer³

¹School of Anthropology & Department of Geosciences, University of Arizona, Tucson, Arizona

²Office of Contract Archaeology, University of New Mexico, Albuquerque, New Mexico ³Institute of Archaeological Sciences, Eberhard Karls University of Tübingen, Tübingen, Germany

*Corresponding author: Vance T. Holliday, vthollid@email.arizona.edu

Abstract

Water Canyon is a rare buried, multi-component, stratified Paleoindian site in west-central New Mexico. This paper presents a geoarchaeological assessment of the site as part of a broader interdisciplinary investigation of its paleoenvironmental history and archaeology. The archaeology is associated with ancient wetland deposits (Stratum 6) within an alluvial fan. The fan formed initially through the late Pleistocene. Formation of the fan stopped and wetland deposition began ~11,310 ¹⁴C yr BP (~13,170 cal yr BP). Stratum 6 evolved via wetland deposition and cut-and-fill cycles. The bulk of Stratum 6 dates <10,300 ¹⁴C yr BP (<12,200 cal yr BP). One, or possibly two, beds of bison bone, likely processing-stations, were found on the margin of the paleo-wetland and date to ~9200 ¹⁴C yr BP (~10,400 cal yr BP) (lower bone bed) and ~8200 ¹⁴C yr BP (~9150 cal yr BP) (upper bone bed). Farther out in the paleo-wetland a probable kill site was discovered with an in situ Eden projectile point dated to at least ~8955 ¹⁴C

yr BP (~10,070 cal yr BP). The wetland landscape returned to an alluvial fan system <8000 ¹⁴C yr BP (<8900 cal yr BP) with two more cycles of fan deposition by ~6500 cal yr.

Key Words: alluvial fan; paleo-wetland; bison kill; bison processing; Paleoindian; Eden point

1 INTRODUCTION

Paleoindian archaeological research in North America has been significantly influenced by work in the greater Southwest and neighboring areas¹. The Folsom type site, which resolved the debate over a late Pleistocene human presence in the Americas, is in northeast New Mexico (Figgins 1927; Meltzer 2006). The Clovis type site at Blackwater Draw, with a rich record of long-term Paleoindian occupation that established the classic Clovis-Folsom-unfluted artifact sequence, is in east-central New Mexico (Hester 1972; Howard 1933, 1935). In the heart of the Southwest, *in situ*, stratified Paleoindian sites are rare. Exceptions include the San Pedro River valley in southeastern Arizona, with at least four Clovis mammoth kills (e.g. Haynes and Huckell 2007), and in northern Sonora, Mexico, a Clovis-gomphothere kill and camp site is reported (Sanchez et al. 2014). To the north, in the San Luis Valley of Colorado, are Folsom age bison kill / campsites, such as Stewart's Cattle Guard site (Jodry 1999).

¹ Geologically, the Basin and Range country west of the Pecos River Valley to the foot of the Sierra Nevada is one definition of the Southwest in the U.S. More informally, Reed (1964) offers a useful shorthand definition of the Southwest as extending from Durango, Colorado, to Durango, Mexico, and from Las Vegas, New Mexico, to Las Vegas, Nevada.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Paleoindian archaeology in the American Southwest is challenged by the rarity of terminal Pleistocene and early Holocene paleoenvironmental data from continuous stratigraphic sequences. Except for Clovis mammoth hunting, the chronologies for artifacts and occupations and the nature of subsistence activities must often be inferred from neighboring regions, usually the Great Plains to the east (e.g., Haynes 1975; Johnson 1987; Holliday 2000; Meltzer 2006; Haynes and Warnica 2012). The region’s paleovegetation and paleoclimate data tend to come from discontinuous records (e.g., packrat middens) and the sources of both types of paleoenvironmental data are widely scattered.

Here we report on the Water Canyon site in west-central New Mexico (Figure 1) (Dello-Russo et al. 2010). The site is unusual in the region, yielding evidence for multiple Paleoindian activity areas spanning the period from ~11,000 to ~8300 radiocarbon years before present (¹⁴C yr BP) or ~13,000 to ~9200 calendar years before present (cal yr BP). Bone and stone artifacts, plant remains, and other classes of paleoenvironmental proxy data such as pollen, phytoliths, diatoms, stable carbon isotopes and land snails, were recovered from stratified, dateable deposits (Dello-Russo 2010, 2012, 2015; Dello-Russo et al. 2016a, 2016b). The *in situ* Paleoindian components, buried in wetland deposits, are immediately adjacent to upland surfaces with additional evidence for Paleoindian activities. This paper focuses primarily on the stratigraphic and geochronologic record as they inform on the landscape evolution of the site and archaeological formation processes.

1.1 Site Location and Setting

The Water Canyon site is in west-central New Mexico on the southeast side of the La Jencia Basin just west of the Socorro Mountains and at the toe of an extensive bajada on the northeast side of the Magdalena Mountains (Figure 1). The site is along a tributary of the Water Canyon drainage which is, in turn, part of a tributary system of the Rio Grande (Machette 1988). The Water Canyon drainage heads on the northeast side of the Magdalena Mountains and flows east then north across a broad bajada (coalesced alluvial fans). Water Canyon joins South Canyon southeast of and upstream from the Water Canyon site. The combined drainage flows northeast and divides the Socorro Mountains and the Lemitar Mountains, at which point the drainage becomes Nogal Canyon and flows east to join the Rio Grande north of the city of Socorro. The mountains are composed of Oligocene volcanic rock. The volcanism and subsequent faulting, uplift of the mountains, and dropping of the basin are linked to the evolution of the Rio Grande Rift (Chapin et al. 2004; Hawley 2005).

The bajada with the Water Canyon site is known locally as the Water Canyon fan (Chamberlin and Osburn, 2006), but is referred to in this paper as the Water Canyon bajada. The site is currently dissected by three arroyos that formed in and emanate from a series of swales incised into the toe of this bajada (Figures 2, 3A, 3B). “No Name Arroyo”, formed in “No Name Swale”, is the middle of the three and cuts through the middle of the site exposing black paludal muds that led to the discovery of the Paleoindian-age bone and associated artifacts (Dello-Russo 2010). A smaller, unnamed arroyo occurs in the southeastern portion of the site.

The north side of the site is cut by “Big Wash.” Big Wash and No Name Arroyo converge in the eastern portion of the site. The combined drainages meet the unnamed arroyo at the far eastern edge of the site. From there the drainage flows east another 500 meters to join the main Water Canyon drainage. The site formed where the three aforementioned drainages emerge from narrow arroyos cut into the old bajada deposits.

2 FIELD AND ANALYTICAL METHODS

The geological and geoarchaeological investigations in and near the Water Canyon site included the recognition and mapping of landforms, and the examination, documentation, and dating of the stratigraphic record. All exposures and cores were measured and described using standard geologic and pedologic nomenclature and conventions (Table 1) (AGI 1982; Birkeland 1999; Holliday 2004). The site covers an area of over 9 hectares and is divided into seven “loci” (Figures 2, 3A). Stratigraphic exposures were available from archaeological hand-excavations in three loci (1, 3, and 5); six backhoe trenches (BHT-1, -2, -3 and -6 in Locus 1; BHT-4 in Locus 3; and BHT-5 in Locus 2), 75 cores (via Giddings coring rig), hand augers, and the three arroyos that cut across the site (Figures 2, 3A, 3B, S1). Numerous pollen and radiocarbon samples, together with a few bone samples, were recovered from these various exposures. A micromorphological study of sediments was carried out in Locus 1 (Supporting Information). Most of the archaeological excavations focused on Locus 1 North, along two sides of No Name Arroyo, and in a 12 x 12 m pit in Locus 5.

Assessing the chronology of the cultural deposits and the site stratigraphy was accomplished using radiocarbon and optically stimulated luminescence (OSL) dating techniques (Table 2). Radiocarbon ages were determined for soil organic matter (SOM) from buried soil horizons and organic-rich sediments, as well as for charcoal and bone collagen samples. The radiocarbon dating of organic-rich sediments can be somewhat problematic owing to the potential for contamination by younger humic acids (Martin and Johnson 1995; Abbot and Stafford 1996; McGeehin et al. 2001) but, with proper pretreatment, these materials can provide accurate, reproducible, stratigraphically consistent age control, especially in drier environments (e.g., Haas et al. 1986; Holliday et al. 1994, 1996; Quade et al. 1998; Rawling et al. 2003; Mayer and Mahan 2004). The Water Canyon SOM samples underwent a standard acid-base-acid treatment to remove carbonate and isolate specific fractions of organic matter (after Abbot and Stafford 1996). Radiocarbon ages were determined for the residue (NaOH insoluble) and humic acid (NaOH soluble) fractions using 1) the liquid scintillation method at the University of Arizona Isotope Geochemistry Laboratory (i.e., conventional radiocarbon; A-#s), and 2) accelerator mass spectrometry (AMS) at the NSF - Arizona AMS Laboratory (AA#s), the Beta Analytic, Inc. laboratory (Beta #s), Pennsylvania State University (PSU-#s), and the International Chemical Analysis laboratory (16OS/ and 16B/#s). Radiocarbon ages were corrected for isotopic fractionation and are presented as uncalibrated radiocarbon years before present (^{14}C yr BP) in the text and in Table 2. Calibrated ages and statistical means were determined using the CALIB 7.0.4 program (Stuiver and Reimer 1993) and the IntCal 13.14c

database.

Dating by optically stimulated luminescence (OSL) was carried out on sediment samples by the University of Nebraska – Lincoln (UNL- #s; Goble 2014, 2015) and Utah State University (USU- #s; Rittenour 2011) (Tables 2, S1, S2). OSL ages are given simply as calendar years (yr) in the text. Calibrated radiocarbon years are considered to be equivalent to OSL calendar years.

3 RESULTS OF GEOLOGICAL STUDIES

The landforms and strata at the Water Canyon site can be grouped into two categories defined by age: those created during the older Pleistocene (defined here as Last Glacial Maximum [LGM] and older), including Strata 1, 2, 3, and 4; and landforms and more localized strata created in the terminal Pleistocene and early Holocene (TPEH) and later Holocene epochs (<18,000 yr), consisting of Strata 5, 6, 7 and 8, which are inset against the older strata.

3.1 Older Deposits and Landforms

3.1.1 Strata 1, 2, and 3

The topographic setting in the immediate area of the Water Canyon site is directly or indirectly related to geomorphic processes that created and modified the large, prominent Water Canyon bajada that characterizes the landscape of the southern La Jencia Basin (Figures 1, 3A). As noted, the arroyos that dissect the site are parts of drainages incised into the lower end, or toe, of the Water Canyon bajada. The uplands north of Big Wash and Locus 3, those

1 southwest of Locus 4, west of Locus 1, and the surface of Locus 6, represent the surface of the
2
3 toe of the Water Canyon bajada (Figure 4A). The bajada sediments (Stratum 1) consist of
4
5 “poorly to moderately sorted, bouldery to cobbly, volcanic-rich gravel, gravelly sand and
6
7 muddy silts. [They are] generally reddish orange to reddish brown, locally light brown to tan in
8
9 color
10
11 [and are] mostly non-indurated, however, the uppermost beds beneath its graded surfaces are
12
13 variably cemented by pedogenic carbonate horizons approximately 0.6 m to 0.1 m thick”
14
15 (Chamberlin 2005:6). The surface sediments have undergone some modification in the
16
17 immediate site area where they are characterized by carbonate-engulfed gravel. Less than a
18
19 kilometer to the west, the Water Canyon bajada surface is covered by sandy fines that display
20
21 an exceptionally well-developed soil (Bt horizon with red color almost 2.5YR, pervasive illuvial
22
23 clay, strong structure, and a Bk horizon with Stage III carbonate development). Because the
24
25 carbonate forms beneath the Bt horizon (Machette 1988), the areas of exposed carbonate on
26
27 the fan surface (e.g., the surface of Locus 6) are indicative of erosion of the less resistant Bt
28
29 horizon.
30
31
32
33
34
35
36
37
38
39

40 The age of the Water Canyon bajada is estimated at >500,000 to 25,000 years old based
41
42 on the degree of development of surface and buried soils nearby and radiometric age control
43
44 elsewhere (Machette 1988). Bajada construction probably ended when drainages in the La
45
46 Jencia Basin integrated with the Rio Grande through Nogal Canyon (Machette 1988:5).
47
48

49 A younger bajada-related surface was identified at Locus 2, lower in elevation than the broader
50
51 bajada surfaces to the north, west and south (Figures 2, 3A). The archaeological
52
53
54

materials at Locus 2 are emplaced on this younger surface which is expressed as a narrow, flat ridge roughly two to three meters below the local bajada surface. This surface was created when the upper portions of the older bajada deposits were eroded. The sediments underlying this ridge represent an early episode of filling (Stratum 2) following incision of the bajada surface sometime before 42,000 years ago (Figure 4B; see OSL discussion below). Backhoe trench 5 (BHT-5; Figure 2B) exposed a paleochannel in the Stratum 2 fill below this surface (Figure 4C). Designated as Stratum 3, the fill in this paleochannel includes sandy, loamy and slightly gravelly alluvium inset into the older, coarse, well-sorted and well-rounded gravel of Stratum 2. Minimal soil development on this surface suggests that Locus 2 has been undergoing continued erosion.

Two OSL ages on the sand indicate that both strata below the Locus 2 surface are pre-LGM in age. The age of Stratum 2 alluvium ranges between ~32,000 and 41,000 yr and the age of the inset Stratum 3 sediment is between ~29,100 and 37,500 yr (Table 2). The ages appear to be reasonable given the estimated age of the stratigraphically older bajada surface (Middle Pleistocene) and the dating of the younger terminal Pleistocene fill (discussed below).

3.1.2 *Stratum 4*

Stratum 4 is topographically lower than Strata 1, 2, and 3, inset against the eroded toe of the bajada (Figures 4E). It consists of sandy and pebbly alluvium with more local clayey facies. A strongly developed soil (Bt horizon with 7.5YR hues and thick, continuous clay films,

and pervasive carbonate coatings on ped faces) formed through most of the stratum. Stratum 4 is most obvious on the south side of the site. It is found along the southwest margin of Locus 1 (Locus 1 South), at the foot of the scarp that leads up to the old bajada surface, exposed in BHT-6 (Figure 5) and in cores through the area (Figure S1). It is inferred to be present to the south in Locus 4 based on an exposure in the unnamed arroyo that separates Locus 1 from Locus 4.

In Locus 1 South the top of Stratum 4 forms a bench, likely an alluvial terrace, almost imperceptible topographically (Figure 5). This bench was initially recognized because of the dense concentration of coarse gravel at the surface along with a high concentration of lithic artifacts, including conjoining fragments of a probable Paleoindian projectile point and related artifacts. The layer of gravel with the artifacts rests on Stratum 4 and its associated soil.

The dating of Strata 2 and 3 suggests that Stratum 4 is <30k years old, assuming that the OSL dating in Locus 2 is accurate. Unweathered alluvium at the base of Stratum 4 (below the Stratum 4 soil) in BHT-6 yielded an OSL date of ~18,000 yr (Table 2). This date could be accurate or it is a minimum age. The degree of development of the soil formed in Stratum 4 suggests that the surface stabilized and then underwent pedogenesis for at least a few tens of thousands of years, based on dating of soils in similar settings across the Southwestern U.S. (Gile et al. 1981; Machette 1988; Birkeland 1999; Holliday 2004). Stratum 4 is also present near the north end of the site in Locus 3 and was exposed in BHT-4. At the base of the sequence in BHT-4 is a reddish sandy layer that yielded another OSL date of ~18,000 yr (Table 2). Soil development in this deposit and the OSL dating at the base of the deposit indicate that this layer is equivalent

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

to Stratum 4 in Locus 1 South. These dates suggest that there must have been an additional phase of local (if not regional) deep incision between ~30,800 and ~18,000 yr.

The gravel layer on the bench in Locus 1 South and resting on the Stratum 4 soil may be entirely redeposited from the adjacent scarp and bajada surface, but more likely the gravel was in place on the bench. The artifacts on that bench probably represent in situ occupation because the archaeological debris is continuous from Locus 1 South to and across Locus 1 North. Artifacts within the gravel may have been mixed in via bioturbation and soil shrink-swell.

3.2 Terminal Pleistocene and Holocene Deposits

The TPEH deposits at the Water Canyon site are the focus of our research. They contain the *in situ* archaeological record at the site. The deposits are divided into five stratigraphic units: four lithostratigraphic units (5, 6, 7, and 8) and one soil-stratigraphic unit (the La Jencia Soil). Facies of the strata are defined on the basis of lithological characteristics or color or both. Color variation includes post-depositional alteration, primarily by groundwater modification.

3.2.1 Stratum 5

Stratum 5 is a pebbly to gravelly to cobbly and locally sandy deposit that underlies Stratum 6 throughout much of the site. Data from Locus 1 suggest that Stratum 5 deposits are inset against Stratum 4 in a channel cut below Stratum 4 (Figure 4G). Exposures of Stratum 5 were limited to Unit 1-6 in Locus 1 and adjacent No Name Arroyo walls (Figure 3B), and in Unit

5-1 of the Locus 5 excavation block (Figure 6B). The coring rig rarely penetrated deeply into the gravel and, therefore, we could not determine the thickness of the deposit in most cores nor the character of it or its underlying deposits.

Stratum 5 is complex topographically, stratigraphically, and geochronologically. For example, where initially observed along No Name Arroyo (Units 1-6 and 1-5 in Locus 1 North), the top of Stratum 5 gravel is at 47.00 m and 47.03 m grid elevation, respectively. But 10 meters to the northeast, in the southwest corner of the deep Locus 5 excavation block (Unit 5-1), the top of the gravel is at 45.39 m grid elevation (Figures 6B, 7). Similarly, running from Locus 1 North to the east-southeast (based on coring) elevations for the contact between the top of Stratum 5 and the base of overlying Stratum 6 show a dramatic change in elevation of almost 4 meters (Figure 8). The mud of Stratum 6 engulfs the Stratum 5 gravel in some areas of the site (Locus 1: Cores 9-2, -6, -7, -10, -15, -18; Locus 3: Cores 10-15, -17; Locus 5: southwest corner of main pit and Core 10-10). In contrast, in BHT-4, cut across Locus 3, a time-stratigraphic valley-margin equivalent is composed of gravelly sand that is likely from slope wash based on thickening and facies changes toward the old bajada uplands (Figure 9).

The age and sequence of Stratum 5 deposition is difficult to interpret, limiting our understanding of the site formation processes. The estimated age range of the deposit can only be based on dates from above and below. As noted previously, the two OSL ages from the older (pre-TPEH) Stratum 4 deposits in Locus 1 (BHT-6; Figure 5; UNL-3856) and Locus 3 (BHT-4; Figure 9; UNL-3859) provide an approximate minimum age for the base of Stratum 5 at ~18,000

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

yr (Table 2). The oldest radiocarbon age for overlying Stratum 6 is ~11,310 ¹⁴C yr BP (~13,170 cal yr BP).

As a whole, the paleo-topographic expression of Stratum 5 is that of an alluvial fan (Figure 4G). Elevations on top of Stratum 5 in and near Locus 1 and Locus 5 show that, at the mouth of the No Name Swale, Stratum 5 slopes down by several meters to the northeast across Locus 5 and to the southeast away from Locus 1; i.e., it has the shape of a fan with apex at the mouth of No Name Swale. The layer varies in content of sand, pebbles, and gravel, and degree of sorting from exposure to exposure. Alluvial fans are characterized by cut-and-fill cycles and that could account for the dramatic variability in lithology. Big Swale has a larger drainage area than No Name and likely contributed to deposition and erosion of Stratum 5. But very little of our stratigraphic or geochronological data can be directly linked to alluvial processes in Big Wash because very little late Quaternary fill is preserved there.

3.2.2 Stratum 6

Stratum 6 contains most of the archaeological remains recovered *in situ* at the Water Canyon site, primarily in Locus 1 North and Locus 5. It is up to ~200 cm thick and is primarily a dark gray to black mud, but there are several facies. Lighter gray and olive green facies are locally common as is an upland soil facies. In some areas of the site the mud encases underlying gravel, producing a mix (vertical facies) of Strata 5 and 6. Along the margins of the site there is also an upland soil facies. Stratum 6 in at least one of its facies was found everywhere across

1
2
3 the site except at the far east central portion of the site, east of Locus 1 and north of Locus 4
4
5 (Cores 10-23 to 29), due to erosion. One of the thickest and most complete sections of Stratum
6
7 6 is located in and just east of Locus 5. Stratum 6 rests unconformably on Stratum 5 and is
8
9 locally inset against it or Stratum 4. Along No Name Arroyo and south across Locus 1, Stratum
10
11 6 is both atop and inset into Strata 4 and 5 (Figures 3B, 5, 7).
12
13
14

15 The dark gray-to-black mud facies of Stratum 6 with its distinctive color and presence of
16
17 bone, is the most ubiquitous stratigraphic marker at the site (Figure 10). The dark color, fine-
18
19 grained lithology, based on field texture and micromorphology (below and Supporting
20
21 Information), and dating suggest slow aggradation of fines under conditions of high biological
22
23 activity. The dark, subdued coloration and apparent biological activity tends to inhibit evidence
24
25 for physical weathering such as root casts or cracking.
26
27
28
29

30 The olive green facies is a local biochemical alteration of Stratum 6. Where observed,
31
32 the olive green facies is always below the black/dark gray facies and just above the gravel of
33
34 Stratum 5 (Figure 10). The colors (gleyed or low chroma) are typical of reducing conditions in
35
36 the presence of a high water table and abundant organic matter (Schaetzl and Thompson
37
38 2015: 483). The absence of mottled redoximorphic features (i.e., colors of both reduced and
39
40 oxidized iron) are indicative of year-round saturation rather than seasonal water table
41
42 fluctuation
43
44
45
46
47 (Schaetzl and Thompson 2015: 356-358, 484). The gleyed facies is common only in the area of
48
49 Locus 1 and to the southeast of Locus 1, but also minimally present far to the northeast along
50
51 Big Wash (section 12-9) and in an abandoned pit by an old windmill (Windmill Pit, Figure 2A).
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

This patterning puts the gleyed facies in proximity to the older pre-TPH gravels and the bajada gravels, which, along with flow down the local drainages, could have been a source of seep or spring water that kept Stratum 6 saturated along the site margins.

The micromorphological analyses of thin sections collected in the Locus 1 excavation block provide some clues to the origin of Stratum 6 (Supporting Information). The thin sections (Figures S4-S11) show that there are subtle differences in the lithology of Stratum 6 in Locus 1, thus we subdivide it in Locality 1 into 6A and 6B. The lower part of the layer (6A) is finer (silt and clay), weakly laminated and pervasively gleyed. This suggests very low energy alluvial aggradation and perhaps additions of dust followed by reduction. Upper Stratum 6 (6B) is likewise dominated by fines and exhibits some weak bedding, but it contains some fine to medium gravel. The coarser particles are sub-rounded to angular, suggestive of short-distance transport.

Stratum 6B is mostly dark gray to black, but the micromorphology shows that the gleying characteristic of 6A also crossed the boundary between 6A and 6B and modified the lowermost portion of Stratum 6B. This discovery highlights the importance of differentiating facies based on sedimentological characteristics from those based on post-depositional characteristics. Stratum 6B exhibits localized gleying and some redoximorphic features, indicative of short-term saturation. The incomplete gleying and persistence of darker coloration is suggestive of either high original organic matter content or rapid burial shortly after deposition of 6B. However, development of soil structure and coatings of illuvial clay in 6B

1
2
3 demonstrate a period of subaerial weathering of 6B prior to burial. All thin sections also
4
5 provide evidence of syndepositional or post-depositional bioturbation.
6
7

8 The gray facies is a deposit locally above and disconformably on the black/dark gray
9
10 facies. It is common in the east-central area of the site, in and around Locus 5. The gray facies
11
12 of Stratum 6 are sandy and locally pebbly near the site margins, probably picking up coarser
13
14 clastics as slope wash. The upper gray mud also tends to be generally sandier. Influxes of sand
15
16 (probably by both eolian and slope wash processes) would dilute the organic matter content
17
18 and make the color lighter. The presence of oxidized iron staining (redoximorphic features) in
19
20 the exposures of upper gray muds upstream of Locus 1 in the No Name Arroyo cut banks
21
22 suggests the occurrence of seasonal water table fluctuations during the early Holocene.
23
24
25
26

27 A well-drained upland soil facies of Stratum 6 is located on topographically slightly
28
29 higher settings in the north-central portion of the site (along the northeast edge of Locus 3)
30
31 and on the bench along the southeast margin of Locus 1 South (Figures 9 and 5, respectively).
32
33 This upland facies is a dark gray to black soil A-horizon. The sub-horizons of this soil (formed in
34
35 Stratum 4; discussed above) vary from Bk horizons in sand to a clayey, well developed Bt
36
37 horizon (Table 1; Figures 5 and 9). The topographic and stratigraphic facies relationships
38
39 between the black mud facies and the soil facies show well at the south end of BHT-6 in Locus
40
41 1 where the soil is formed on two levels of the bench (Figure 5). Soil formation was on stable,
42
43 slightly elevated landscapes roughly contemporaneous with aggradation of the other facies in
44
45 lower settings.
46
47
48
49
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Stratum 6 apparently was subjected to several phases of erosion. This interpretation is based on the variable thickness of the layer, the abrupt and locally irregular contacts between Stratum 6 and overlying Stratum 7, the local presence of gravel lenses within Stratum 6 and on the Strata 6/7 contact, and radiocarbon dating. Otherwise, erosional contacts within Stratum 6 are difficult to identify due to the uniformly dark coloration which, as noted, obscures contacts such as erosional surfaces. In the exposure along the north side of No Name Arroyo, in the area of Locus 1 North and in the Locus 5 deep excavation block, at least one disconformity was observed within the gray facies of Stratum 6. More prominent is a disconformity at the top of Stratum 6 in Loci 1 and 5 and a disconformity cross-cutting Stratum 6 in the south and west walls of Locus 5. The latter erosion is due to the action of a re-routed paleo-arroyo (an earlier version of No Name Arroyo, discussed more fully below) that cut down through Stratum 6 and subsequently filled with Stratum 8.

The radiocarbon age estimates for the base of the Stratum 6 muds, either resting on top of the Stratum 5 gravel or encasing it, tend to be in the range of ~10,000 to ~9500 ¹⁴C yr BP (~11,450 to ~10,800 cal yr BP) across much of the site (Table 2). There are several significant exceptions to this trend, however. In Locus 1, on top of the Stratum 5 fan, the base of Stratum 6 yielded dates of 11,310 and 11,030 ¹⁴C yr BP (~13,170 and ~12,895 cal yr BP). Just northeast in the Locus 5 excavation block, lower Stratum 6 is dated 10,280 to 10,000 ¹⁴C yr BP (~12,005 and ~11,450 cal yr BP). Along the northeast margin of the site in or near Big Wash the base of Stratum 6 dates to ~8810 ¹⁴C yr BP (~9820 cal yr BP). Further, dating and distribution of bone

and lithic artifacts in Locus 1 North suggest an unconformity in the range of ~9200 to ~8300 ¹⁴C yr BP (~10,390 to ~9100 cal yr BP) (Figure 11). All of these ranges in radiocarbon ages suggest several episodes of significant erosion and incision. The earliest phase of erosion isolated, and left in place, a small pocket of Clovis-age muds in Locus 1 just beyond the mouth of No Name Swale and on top of the Stratum 5 fan. This erosion may have been between ~11,000 and ~10,360 ¹⁴C yr BP (~12,890 and ~12,240 cal yr BP) given the absence of dates in this age span across the remainder of site. Another cycle of erosion apparently was relatively widespread, given the extent of basal dates in the range of ~10,000 to ~9500 ¹⁴C yr BP (~11,450 to ~10,800 cal yr BP) across the site. The degree of erosion is highlighted by the topographically lowest component of Stratum 6 in Core 10-26, downstream (~130 meters) far to the east of Locus 1 and at grid elevation 41.8 m (compared to 47.0 m in Locus 1 and 46.2 m in core 9-10) (Figure 8). The base of Stratum 6 in that core dates to ~9745 ¹⁴C yr BP (~11,170 cal yr BP).

Sedimentation resumed, and then another phase of erosion ensued along Big Wash >8810 ¹⁴C yr BP (~9820 cal yr BP) and then along paleo-No Name Arroyo >8300 ¹⁴C yr BP (>9100 cal yr BP).

In Locus 5, the Stratum 6 black facies began to develop by ~10,280 ¹⁴C yr BP (~12,005 cal yr BP), which is older than some of the dating of the gleyed facies in Locus 1. The gleyed facies of Stratum 6 in Locus 1 and elsewhere in the site likely started as the black facies (the presence of abundant organic matter would help drive the gleying, as noted above). The process of gleying, therefore may have begun after ~10,280 ¹⁴C yr BP, but it is not isochronous across the site. The gleyed facies at the base of Stratum 6 in Section 12-9 along Big Wash is dated to ~8810

¹⁴C yr BP (~9820 cal yr BP), but the gleying could post-date the carbon that was dated.

The transition of the black facies to the gray facies is not well dated, but numerical age estimates in Loci 1 and 5, and in Core 10-7 (Figures 2A, S1; Table 2), provide some clues. In Locus 1, Unit 1-9, the upper black facies is dated to ~9310 ¹⁴C yr BP (~10,535 cal yr BP). A concentration of charcoal fragments in the upper part of the gray facies, interpreted as hearth Feature 1 (Unit 1-11), produced a mean date of ~8321 ¹⁴C yr BP (~9365 cal yr BP). In Locus 5, charcoal from the upper black facies dated ~8775 ¹⁴C yr BP (~9755 cal yr BP) and charcoal from the gray facies dated ~8395 ¹⁴C yr BP (~9400 cal yr BP). Similarly, just east of Locus 5 in Core 10-7, the transition occurred between ~8630 ¹⁴C yr BP (black facies) (~9660 cal yr BP) and ~8305 ¹⁴C yr BP (gray facies) (~9280 cal yr BP).

This transition from black to gray is usually indicated by an abrupt contact and locally accompanied by gravel, thus denoting some erosion. This likely explains some of the variable dating among the three areas of the site. Erosion across the top of the black facies clearly provides some variability. The timing of the black-to-gray transition could also be locally variable across the site depending on influx of coarse clastics. The much younger ages for the two facies on Core 10-7 may also be due to unknown contaminants.

The upper gray facies of Stratum 6 yielded broadly similar dates in Loci 1 and 5 and in Core 10-7: ~8395 ¹⁴C yr BP (~9400 cal yr BP) in Locus 5; ~8321 ¹⁴C yr BP (~9365 cal yr BP) in Locus 1; and ~8050 ¹⁴C yr BP (~8940 cal yr BP) in Core 10-7.

The age of the upland soil facies of Stratum 6 is, in part, a function of localized upland

geomorphic processes. On the northeast side of Big Wash, in the Windmill Pit (Figure 2A), the upland soil facies yielded two dates of ~5600 ^{14}C yr BP (~6385 cal yr BP) (upper) and ~6500 ^{14}C yr BP (~7395 cal yr BP) (lower). Downstream from the Windmill Pit, approximately 320 meters along Big Wash (section 15-20, a black mud facies produced a date of ~6125 ^{14}C yr BP (~7050 cal yr BP). This could indicate that the black, upland soil on the north side of Locus 3 is a facies of a younger version of the Stratum 6 black muds. Deposition of Stratum 6 spanned ~11,310 to ~8000 ^{14}C yr BP (~13,170 to ~8900 cal yr BP). Breaks in the geochronology are indicative of erosion, in particular between ~11,030 and ~10,360 ^{14}C yr BP (~12,895 and ~12,240 cal yr BP) and between ~9900 to ~9500 ^{14}C yr BP (~11,310 and ~10,800 cal yr BP). These breaks and even erosion could also be due to drying conditions that precluded formation of a wetland.

3.2.3 Strata 7 and 8

Strata 7 and 8 are discussed together because of their similar lithologies and depositional environments. They are distinct stratigraphic entities, however. This inference is based on the presence of a mappable erosional disconformity between the two (Figure 6A). Both layers are sandy and gravelly, but fines are more common than in Strata 4 or 5 (Table 1). The exposures in the excavation block in Locus 5 show that Stratum 7 was deposited on top of the Stratum 6 gray facies following a phase of east-dipping erosion and gravel deposition across Stratum 6 (Figure 6A). A moderately well-developed soil formed in upper Stratum 7 where it is unburied and in upper Stratum 8. The soil varies in thickness from 30 to >100 cm, depending on

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

the thickness of the parent material (i.e., the thickness of Stratum 8 or unburied Stratum 7). It is usually a red Bt horizon that forms a distinct soil stratigraphic unit, here referred to as the La Jencia Soil. The degree of development of this soil was one of the stratigraphic characteristics that led to the realization that the black muds (Stratum 6) underlying Stratum 7 are of some antiquity.

The thickness of the combined Strata 7 and 8 decreases to the northeast, east, and southeast away and downstream from both Locus 1 and the mouth of No Name Arroyo (Figures 4I, 7). Similarly, the surface of these deposits (i.e., the present-day surface of the Water Canyon site) slopes down in the same directions, following the topography trending downslope with the present-day No Name Arroyo. These characteristics, together with the coarse nature of the sediments and the cut-and-fill stratigraphy, provide further indications that these strata comprise the upper portions of an alluvial fan at the mouth of No Name Swale.

Some cores revealed evidence of a buried soil (in the form of a Bw horizon or weakly expressed Bt horizon) in alluvium resting on Stratum 6 and, in turn, buried by younger alluvium, although this buried soil is not continuous across the site. In Locus 3 and Locus 1 South, the upland facies of Stratum 6 is locally, but not completely, buried by a layer of cobbles or by finer sediments with an A-Bt soil. The relative ubiquity and similar morphology of this covering soil, distributed discontinuously across the site, suggests that it is the same soil in each instance. As such, the alluvium in Loci 3 and 1 South most likely represents an eroded remnant of early Strata 7/8. Further, the presence of at least one buried soil shows that Strata 7/8 aggraded

1
2
3 episodically, at least in local settings.
4

5
6 An ancient channel of No Name Arroyo (referred to in this paper as paleo-No Name
7
8 Arroyo) cut across the middle of the Water Canyon site, down through Stratum 7 and deep
9
10 into Stratum 6. It was subsequently filled with Stratum 8. This paleo-arroyo was exposed in the
11
12 southwest corner of the Locus 5 excavation block (Figures 6A, 6B) and can be traced upstream
13
14 to the north wall of the present-day No Name Arroyo. The north wall of the paleo-arroyo was
15
16 relatively steep (i.e., as exposed on the Locus 5 block) as was the lower half of the south wall of
17
18 the paleo-arroyo as exposed in the modern No Name arroyo. But on the south side of the
19
20 modern arroyo and in BHT-3, erosion by the upper half of the paleo-arroyo was more nearly
21
22 horizontal, cutting across the top of the Stratum 6 black facies. Where it fills the paleo-arroyo,
23
24 and prior to subsequent erosion, Stratum 8 is >3 m thick. Deposition of Stratum 8 was in at
25
26 least two cycles, as indicated in the Locus 5 exposure (Figure 6A). The upper deposit of Stratum
27
28 8 thins to the south and is ~1 m thick as exposed in No Name Arroyo in Locus 1 (Figure 3B) and
29
30 thins to less than 1 m further to the south (Figure 5).
31
32
33
34
35
36

37
38 There are no reliable dates directly from Stratum 7 in the areas of Locus 1 or Locus 5. It
39
40 is younger than the Stratum 6 gray facies (<8050 ^{14}C yr BP; ~8940 cal yr BP) and older than
41
42 Stratum 8, which is inset against it. The sheet of alluvium across the surface of Locus 3
43
44 produced an OSL age of ~8070 yr (Figure 9), further suggesting that it is a facies of Stratum 7.
45
46 Stratum 8 produced a wide range of OSL dates and no radiocarbon dates. The OSL age
47
48 estimates range from ~9210 to ~8540 to ~6560 yr among the five dates from Locus 5 and one
49
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

date of ~9770 yr from BHT-3 in Locus 1 (Table 2). The sequence from Locus 5 comes from the fill in the paleo-arroyo (precursor to No Name Arroyo) and also contains several reversals. Given the upper radiocarbon age of <8050 ¹⁴C yr BP from upper Stratum 6, the three OSL dates in the range of ~9770 to ~9020 yr (with large standard deviations) likely do not date the deposition of Stratum 8. Given the short transport distances of sediments in the fan and potential problems of OSL dating of alluvium (Walker 2005: 99; Bradley 2015: 97), partial bleaching is a likely problem. The same problem could also apply to the date of ~8540 yr (R. Goble, personal communication, Feb. 3, 2017). The two youngest OSL dates from the sequence, ~6480 yr from the lower paleo-arroyo fill, and ~6560 yr from the top of Stratum 8, appear to provide the best age estimates and suggest no significant break in time between deposition of lower and upper Stratum 8.

4 ARCHAEOLOGICAL SUMMARY

After the site’s initial discovery, The Water Canyon site has been subjected to both archaeological survey and excavation. The artifact assemblages in surface contexts at Loci 1, 2, 3, 4, and 6 were mapped and analyzed in the field. These assemblages included hundreds of core flakes, biface thinning flakes, other debitage, projectile points, and tools. Fourteen diagnostic projectile points and point fragments were collected from the surface and one diagnostic projectile point was recovered from an *in situ* buried provenience (Table 3).

The faunal assemblage retrieved thus far from Locus 1 consists primarily of ~177 *Bison*

sp. bone elements and bone fragments (of which 60 are identifiable to element), and tooth enamel pieces representing at least one bull, one to two cows, and three juveniles (Akins 2012; Dello-Russo et al. 2017). The horizontal extent of the Locus 1 faunal deposit is currently not completely defined and, although it may continue a little further to the east, no faunal remains were encountered in BHT-3, so it is likely that the majority of the assemblage has been recovered. Collagen samples from six elements have been radiocarbon dated and have returned ages ranging from ~9240 to ~8200 ^{14}C yr BP (~10,390 to ~9150 cal yr BP) (Figure 11; Table 2), suggesting that the bone bed might represent the remains of at least two, and possibly three, chronologically separate events (Dello-Russo et al. in press).

Given these possibilities, a further exploration of the chronometrics in Locus 1 N is warranted. Three of the bone collagen radiocarbon dates from Locus 1 N (~9180 ^{14}C yr BP, PSU-3564; ~9240, PSU-3565; ~9185; PSU-3566; Table 2) are from the lower bone cluster and they are statistically the same (Figure 11). These three collagen samples were subjected to ultra-filtration during pretreatment and their C/N ratios were each 2.8, indicating that the collagen in each sample was of sufficient quality to provide a reliable date. Their mean radiocarbon date (~9204 ^{14}C yr BP ± 30) is statistically different than that of the dated collagen sample in the upper portion of the bone bed (~8200, Beta 292053) (Figure 11). This suggests that the upper portion of the bone bed represents a later depositional event than the lower portion of the bone bed. It also suggests that the upper bone bed is similar, although statistically different, in age to the Feature 1 hearth at a mean date of ~8321 (Figure 11). No C/N value is available for

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

this upper bone collagen date, nor was the sample subjected to ultra-filtration during pretreatment, so it is likely that the date for this collagen sample is a little too young.

In addition, there are two other bone collagen dates in Locus 1 N (~8810, PSU-3567; ~8640, 16B/0713; Table 2) which, being only slightly different themselves ($t=4.446$), suggest a third possible bone cluster whose mean radiocarbon age (8682 ± 35) is statistically different in age than both the lower bone bed and the upper bone bed (Figure 11). The collagen sample for the ~8810 date was subjected to ultra-filtration during pretreatment, while the collagen sample for the ~8640 date was not, so the latter date is probably a little too young. The three groupings of bone, artifacts, and charcoal illustrated in a back plot (Figure 11) present hypothesized temporal relationships of cultural materials and highlight the location of 1) the disconformities that we infer to exist between the upper and lower *Bison sp.* bone beds in Stratum 6 and 2) a possible disconformity between the western *Bison sp.* bone bed and the eastern *Bison sp.* bone cluster. Given the known potential for erosional unconformities in Locus 1 N, therefore, these dates and artifact groupings may reflect the processes involved in creating the cultural deposit.

Feature 1 in Locus 1 North (Figure 11) produced a dense concentration of charcoal fragments. Ten were identified as oak, pine, Ponderosa pine, juniper, and an unknown hardwood species (McBride 2012; Davis 2012). These 10 samples returned radiocarbon ages that are statistically similar ($t=5.079$) with a pooled mean ranging from ~8307 to ~8339 ^{14}C yr BP (~9113 to ~9525 cal yr BP). Only two of the charcoal dates fall within the range of ages provided by the dated bone (~8160 to ~8240 ^{14}C yr BP) in the upper portion of the bone bed.

1
2
3 These charcoal fragments were also directly associated with burned and calcined bone
4
5 fragments, and carbonized amaranth and goosefoot seeds. From these data, we infer the past
6
7 presence of a small thermal feature or hearth (Buenger 2003; c.f. Surovell et al. 2016:83)
8
9
10 spatially associated with the uppermost portion of the Locus 1 bone bed.
11
12

13 The lithic artifact assemblage recovered from Locus 1 North includes 141 unutilized
14
15 debitage flakes, three retouched or utilized flakes, four bifaces, and four multipurpose tools,
16
17 five scrapers, and two projectile point or hafted knife fragments, as well as a small, slab
18
19 grinding / anvil implement. The types of artifacts in the assemblage, together with hearth
20
21 charcoal, burned/calcined bone and a number of long bones that exhibited percussion marks,
22
23 bone flakes and green-bone fracture edges comprise what we infer to be the remains of one,
24
25 and possibly two, open-air activity areas utilized for bison processing during the Late
26
27 Paleoindian (Allen-Frederick?) and the Cody (Eden) periods (Dello-Russo et al. in press). The
28
29 affiliation of the upper open-air activity area with a possible Allen-Frederick occupation and
30
31 the lower activity area with a possible Cody (Eden) era occupation are based on the probable
32
33 dates of the bone beds themselves, at ~8200 ¹⁴C yr BP and ~9200 ¹⁴C yr BP, respectively. No
34
35 temporally diagnostic artifacts were found in direct association with either of the bone beds.
36
37
38 The Locus 1 N Allen-Frederick era date conforms well with the 9350-7900 ¹⁴C yr BP range
39
40 suggested by Pitblado (2003:112) for Allen-Frederick in the southern Rocky Mountains and the
41
42 Locus 1 N Cody (Eden) date conforms well with the ~9800-8800 ¹⁴C yr BP range suggested by
43
44 Knell and Muñiz (2013:11) for Eden on the High Plains.
45
46
47
48
49
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

An additional *Bison sp.* bone bed was discovered by mechanical coring in Locus 5, at approximately 3.5 m below the present-day ground surface in the black facies of Stratum 6. Directly associated with this deposit and recovered *in situ* in hand-excavated Unit 5-1, was the resharpened Eden projectile point. This is the only diagnostic artifact recovered from Locus 5, to date. Only 10 other lithic artifacts have been recovered from Stratum 6 in Locus 5 so far. We have also recovered, to date, more than 91 faunal elements, fragments, and tooth enamel pieces from the Locus 5 *Bison sp.* bone bed. These faunal elements recovered from Locus 5 represent an unknown number of individuals and their analyses are continuing. The bone bed is thought to cover more than 50 square meters and hand excavations in this area, thus far have only opened 10 one-by-one m units.

Determining the age of the *Bison sp.* bone bed and the associated Eden point in Locus 5 has proven problematic. Samples of bison bone and teeth yielded no collagen, thus far precluding the possibility of direct dating. When the feature was first encountered in core 10-1, Stratum 6 encased the bone. Two samples were collected and the SOM was dated (Figure 12; Table 2). The samples produced two dates between ~9887 and 9640 ¹⁴C yr BP (~11,305 and ~10,975 cal yr BP), from below and above the bone, respectively. These dates are stratigraphically correct and statistically different and could, thus, be accurate. Accordingly, the age of the encased bone could be the mean of these two dates, or ~9718 ¹⁴C yr BP. However, the difference in the dating could also be in part a matter of inter-laboratory variation (Taylor and Bar-Yosef 2014:147). Elsewhere in Locus 5, a similar SOM date of ~9750 ¹⁴C yr BP (~11,180

cal yr BP) from a sample taken just below the bone bed in Unit 5-1 provided confirming evidence that the bone bed was no older than this and in the range of ~9718 to ~9750 ¹⁴C yr BP. This falls at the older end of the age range for Eden points as currently known for western North America (Knell and Muñiz, 2013:11-12).

Alternatively, the Locus 5 bone bed age might be indicated by an SOM date of ~8955 ¹⁴C yr BP (~10,070 cal yr BP) determined on a sample collected near the Eden point found in the uppermost portion of the bone bed (Table 1) (Dello-Russo et al. in press). This date is well within the age range for Eden points on the northern and central Great Plains (Knell and Muñiz 2013:11-12) and within the range for Firstview points on the southern Great Plains (Holliday 2000). This leaves two scenarios for the age of the bone bed: the older dates could be due to mixing (from bison and human trampling during the kill and initial butchering and/or via bioturbation as the paleo-wetland evolved) or Eden occupations may be older in the Southwest than on the Great Plains.

5 DISCUSSION and CONCLUSIONS

The Water Canyon site is notable in the Southwest for its multiple Paleoindian occupations in an intact, stratified context (the only such documented Paleoindian site in New Mexico west of the Pecos River), its multiple *Bison sp.* bone beds, and its extensive paleo-wetland with abundant paleoclimatic and paleoenvironmental proxy data. The Water Canyon site is also unusual in being one of the few Paleoindian sites preserved in an alluvial fan. The

1
2
3 site formed at the mouths of several swales cut into the distal toe of the old bajada flanking
4
5 the Magdalena Mountains and emptying into the Water Canyon drainage (Figure 4).
6
7
8 Archaeological materials are found at the surface on older, stable coalesced fan surfaces and
9
10 on stable surfaces formed on Late Pleistocene sediments inset against those older fan surfaces.
11
12
13 Buried, *in situ* cultural deposits are found in a paludal deposit that formed in the fans of
14
15 intermittent drainages, here identified as No Name Arroyo and Big Wash.
16
17

18 **5.1 Soils and Geomorphology**
19

20 Incision of the main Water Canyon bajada (Stratum 1) likely began sometime before
21
22 42,000 years ago and the initial formation of the site landscape (cutting and filling associated
23
24 with deposition of Strata 2 and 3) probably took place ~30,000 years ago (Figure 4). Deep
25
26 incision then followed and there was at least one phase of alluvial deposition (Stratum 4) inset
27
28 against the original Water Canyon bajada. This deposit is dated to ~18,000 yr, but soil
29
30 development suggests that it could be older. It was incised and left as remnant benches in
31
32 Locus 1 South and in Locus 3 (Figure 4). Stratum 5 alluvium is inset against Stratum 4.
33
34
35
36

37 Buried, *in situ* archaeological deposits are found in paludal mud (Stratum 6). The most
38
39 common facies is black to very dark gray, but an underlying olive green or gleyed facies is
40
41 present atop Stratum 5 gravels, and a lighter gray facies is on top of the black facies. The
42
43 darker colors and fine-grained nature of much of Stratum 6 suggest the slow aggradation of
44
45 fines, including alluvium and perhaps dust, under wetland conditions. The green coloration
46
47 seen locally in Stratum 6 is due to iron reduction (gleying) under conditions of a high water
48
49 table and
50
51
52
53
54

1
2
3 abundant organic matter. The gleying is likely post-depositional and, in at least Locus 1, was
4
5 superimposed over at least one older disconformity within Stratum 6. The gleying is apparent
6
7 along the southern flank and, to an extremely limited extent, along the northern flank of the
8
9 site in proximity to the eroded margins of the bajada. The grayer facies is somewhat sandier
10
11 than the black and green facies and likely represents a period of aggradation with more coarse
12
13 alluvial and possibly eolian clastics, diluting the input of organic remains.
14
15
16

17
18 Stratum 6 does not represent uninterrupted sedimentation. Several disconformities are
19
20 apparent. The oldest muds, dated ~11,310 to ~11,030 ¹⁴C yr BP (~13,170 to ~12,895 cal yr BP)
21
22 and ≤~10,365 ¹⁴C yr BP (~12,240 cal yr BP), are in Locus 1, on a high bench of Stratum 5 gravel,
23
24 and suggest several cycles of erosion just before and during the Younger Dryas Chronozone of
25
26 the Terminal Pleistocene. Above those deposits are more Stratum 6 muds and sandy muds
27
28 dated ~9750 to ~9200 ¹⁴C yr BP (~11,180 to ~10,390 cal yr BP) and to ≤~8321 ¹⁴C yr BP (~9365
29
30 cal yr BP). Elsewhere in the site, the oldest Stratum 6 deposits are slightly older than ~10,280
31
32 ¹⁴C yr BP (~12,005 cal yr BP) (Locus 5) and are on topographically lower Stratum 5 gravel. Thus,
33
34 the oldest Stratum 6 deposits were removed from much of the site by erosion. In particular,
35
36 Folsom-age (i.e., dating to the Younger Dryas Chronozone) and older deposits are largely
37
38 missing with the exception of those on the high bench of Stratum 5 gravel. Mud deposition in
39
40 Locus 5 then resumed after ~10,280 ¹⁴C yr BP (~12,005 cal yr BP) and continued until <~8395
41
42 ¹⁴C yr BP (~9400 cal yr BP). Away from Loci 1 and 5, another cycle of erosion was relatively
43
44 widespread, given the extent of basal dates in the range of ~9900 to ~9500 ¹⁴C yr BP (~11,310
45
46
47
48
49
50
51

and ~10,800 cal yr BP) across the site, i.e., there was erosion just prior to that time. The youngest deposit of Stratum 6 is the younger sandy gray facies, dated ~8395 to ~8050 ¹⁴C yr BP (~9400 to ~8940 cal yr BP). The top of Stratum 6 was heavily eroded <~8050 ¹⁴C yr BP, based on obvious disconformities in stratigraphic exposures and variable dating. The relatively long and continuous suite of dates for Stratum 6 from the Locus 5 area, beginning at ~10,280 ¹⁴C yr BP (~12,005 cal yr BP), suggests that this area of the site was spared significant early Holocene erosion, perhaps because of its position on a divide between No Name and Big Wash Arroyos.

The age range of Stratum 6 along Big Wash is significantly younger than it is on the fan emanating from the mouth of No Name arroyo. In section 12-9 on the south side of Big Wash, a base date is ~8810 ¹⁴C yr BP (~9820 cal yr BP). An upper black facies is dated <~8655 and >~7230 ¹⁴C yr BP (<9620 and >8065 cal yr BP). Above is a layer of dark gray mud dated to ~7230 ¹⁴C yr BP. Wetland conditions apparently persisted much longer (or are better preserved) along Big Wash. North of the wash in the Windmill Pit is an upland soil facies of Stratum 6 (with some gleying) dating from ~6500 to ~5600 ¹⁴C yr BP (~7395 to 6385 cal yr BP). The limited dating suggests that the paleo-wetland shifted north away from the No Name fan in the early Holocene. There are few dates along Big Wash because there are limited exposures. Moreover, there are no stratigraphic or geomorphic indicators of significant fan construction. This seems unusual given the much larger drainage area for Big Wash. But the swale that defines the wash (as opposed to the channel or arroyo) is also much wider (~82 m) just above the point at which it widens at the site, compared to No Name Swale (~22 m) just above where it opens up. No

Name Arroyo is in a position to create a fan, with flow confined to a relatively narrow swale until it reaches the end of the swale and water is no longer confined (a classic setting for a fan). The swale with Big Wash is wider and, as it gets into the site area, it becomes progressively wider. This geomorphic characteristic may have gradually dissipated discharge, rather than changing abruptly (as in the case of No Name Swale).

The characteristics of Stratum 6, as delineated previously, are indicative of a wetland and this interpretation is strongly supported by paleoenvironmental reconstructions based on proxy data recovered from Stratum 6 (Dello-Russo et al. 2016a, 2016b). These proxy data included stable carbon isotopes and other data derived from pollen (Smith 2010, 2012, 2015), land snails and snail eggs (Hall 2015), phytoliths (Yost 2016) and diatoms (Winsborough 2016). The Stratum 6 muds represent the remains of a TPEH wetland environment, characterized by wet meadows bordering a creek or interconnected pools and interspersed with marshy areas, similar to modern cienega ecosystems in the region. Taken as a whole, the record at the Water Canyon site indicates a landscape mosaic of different vegetation communities that, along with the presence of fresh water, would have provided a variety of shrubs, grasses and herbs strongly attractive to browsing bison and other game and non-game animals (Dello-Russo et al. 2016a).

The paleoenvironmental reconstruction suggests the presence of at least local shallow standing water. How this standing water was maintained is unclear. Today the site drainage drops almost 20 meters over a distance of less than 1 kilometer to the confluence with the

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

main channel of the Water Canyon channel itself. Stream flow is easy to maintain after rains. The coarse character of Stratum 5 and some of Strata 7 and 8 suggest flashy discharges from the No Name drainage and likely from Big Wash in the late Pleistocene and in the middle Holocene. Except for the evidence of erosion, Stratum 6, in striking contrast, is indicative of a high water table supporting a long-lasting wetland habitat.

Even with a high water table some sort of impoundment downstream from the Water Canyon site seems likely. The lower Big Wash drainage and, at its mouth, Water Canyon are both incised into either coarse gravel or bedrock so there are no clues to the terminal Pleistocene history of either drainage at their confluence. There is some evidence for mass movement along a bedrock slope failure on the south side of Water Canyon just downstream of its confluence with Big Wash (David Love, personal communication, 2009). Such a mass movement could have blocked the drainage and impounded stream flow, but that geologic record has not been investigated and, in any case, the mass movement is not dated.

Another possible mechanism for impounding the Big Wash drainage is the Water Canyon system itself. Aggradation of the drainage above, below, and at the confluence with Big Wash could have impounded flow in Big Wash and also could raise the local water table. Some fluctuations in the flow along Water Canyon could also account for the evidence of erosion in Stratum 6.

The Terminal Pleistocene stratigraphic record at Water Canyon contrasts with that from other localities in the Southwest. The Mockingbird Gap site to the east-southeast (Holliday et al.

2009) and the Scholle site to the northeast (Hall et al. 2012) as well as Murray Springs and other Clovis sites in the upper San Pedro Valley of southeast Arizona (Haynes 2008; Haynes and Huckell 2007) all exhibit conformable stratigraphic sequences for the period ~13,500 to ~10,000 cal years. In particular, the Stratum 6 wetland mud is broadly similar lithologically and chronologically to that proposed for the “black mats” of the San Pedro Valley, the “wet meadow” zone at the Scholle site, and the palustrine muds (stratum 2) at the Mockingbird Gap site. But in detail, Stratum 6 is characterized by several cycles of erosion. Sediments of Younger Dryas age are largely missing and later phases of erosion are indicated between >~9500 ¹⁴C yr BP (>~10,800 cal yr BP) and >~8320 ¹⁴C yr BP (>~9365 cal yr BP). The Younger Dryas erosion may just represent local instability or may be indicative of regional variability at that time (e.g., Meltzer and Holliday 2010). Likewise, the early Holocene cycles of erosion have no direct correlates in the area (Onken 2015).

Strata 7 and 8 represent a return to more energetic cycles of fan deposition and erosion. They are sandier than Stratum 6 and both have common pockets and lenses of gravel. Stratum 7 rests unconformably on Stratum 6 and was truncated by erosion in the middle Holocene (Figure 4). Inset against Stratum 7 (on the north) and burying the eroded surface of Stratum 6 is more sand and gravel (Stratum 8). The erosion that truncated Stratum 7 also produced a deep paleo-arroyo (Figure 6A) that cut down through Stratum 7 and into Stratum 6 in a west-to-east direction across the middle of the site. Stratum 8, which filled the lower portion of the paleogully, is dated to ~6500 yr. A well-expressed soil (A-Bt morphology; the La Jencia Soil) formed

across the surface of the site in Strata 7 and 8.

The cutting and filling cycles of Strata 7 and 8 broadly mirror trends in the evolution of arroyos across the Southwest. Incision, fan construction, and another phase of incision are documented at Water Canyon between 6800 and 6200 yr. Localized and episodic but not necessarily synchronous incision is documented from ~8000 to ~5600 ¹⁴C yr BP (~8900 to ~6400 cal yr BP) across the Southwest (e.g., Waters and Haynes 2001; Mann and Meltzer 2007; Onken 2015) and attributed to the evolving Holocene climate, but the specific drivers are debated.

The gross sedimentological evolution of the landforms on which the Water Canyon site is located began with deposition of coarse, high energy, pre-LGM and LGM, Pleistocene gravel in an alluvial fan followed by erosion and then formation of a terminal Pleistocene/early Holocene wetland. Following another phase of erosion, thick sand and gravel deposits accumulated during cut and fill cycles as another fan formed. This stratigraphic trend is roughly similar to stratigraphic sequences across the Southwest and parts of the Great Plains (e.g., Holliday and Mandel 2006; Holliday and Miller 2013).

5.2 Archaeology

The Water Canyon archaeological site encompasses five different surface loci (1 South, 2, 3, 4 and 6) and two, possibly more, significant subsurface loci (1 North and 5). The subsurface cultural deposits are in fan sediments and consist of intact, buried Paleoindian materials in a stratified context. The fan contains several significant cultural deposits, including a bed of poorly preserved *Bison sp.* bone with an associated Eden projectile point (Locus 5); and a

possible palimpsest of two additional, but very well-preserved, *Bison sp.* bone beds with associated activity areas consisting of butchered bison bones, flaked and ground stone artifacts and the remains of an ephemeral hearth (Locus 1 North). The bone bed in Locus 5, associated with the Eden point, could be dated between ~9887 and ~9640 ^{14}C yr (~11,305 and ~10,975 cal yr BP), although the projectile point itself is more closely associated with a date of ~8955 ^{14}C yr BP (~10,070 cal yr). The upper portion of the bone processing area in Locus 1 North has a mean age estimate of ~8321 ^{14}C yr BP (~9365 cal yr BP) (based on dated charcoal in the Feature 1 hearth), while the lower portion of that bone processing area is dated ~9240 ^{14}C yr BP (based on dated bone collagen). The Locus 1 North bone bed is upslope of, and stratigraphically above, the Locus 5 bone bed. Clovis and Folsom occupations at the site are evidenced by diagnostic projectile point fragments documented in Loci 6 and 3, together with a suite of broken blade fragments repurposed into small, spurred end scrapers (Collins 1999) documented in Locus 6. Subsurface cultural deposits associated with these artifact types have not yet been identified at the site, although sediments dated to those respective time periods have been identified in Locus 1 North.

Buried, stratified Paleoindian sites are rare in southwestern North America west of the Pecos River. Between the Great Plains (northwest Texas/eastern New Mexico) to the east and the San Pedro Valley (Arizona) to the west, only two others are reasonably well-documented and both are in New Mexico: Boles Wells, a Folsom occupation in the Tularosa Basin just south of Alamogordo (Mauldin and O'Leary 1994; Amick et al. 1996, 1998), and LA111429, a Folsom

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

camp site in the Jornada del Muerto, southeast of the town of Truth or Consequences (Figure 1) (Akins and Moore 2012: 82-98; Moore and Akins 2014). Sandia Cave (Figure 1) probably had intact and stratified Paleoindian deposits, but they were obscured by animal burrowing (Haynes and Agogino 1986) and the archaeological record was further mired in controversy (Preston 1995). A buried Cody occupation may be preserved at the R-6 site near Las Vegas, New Mexico (Figure 1) (Stanford and Patten 1984). None of the aforementioned sites west of the Great Plains are securely dated nor are the stratigraphic contexts clear, however. So, the lack of dateable Paleoindian deposits from buried, multi-component stratified contexts makes the discoveries at the Water Canyon site all the more significant.

The Water Canyon site contains two Paleoindian bison bone beds (one of which is a possible palimpsest of two distinct processing events and the second which is the remains of a kill), another rarity west of the southern Great Plains in New Mexico and Arizona. Bison kills are stereotypical characteristics of Paleoindian sites on the Southern Great Plains and across the Southwest, expressed both as buried bone beds (Hester 1972; Johnson 1987; Jodry 1999; Meltzer 2006; Haynes and Huckell 2007; Holliday et al. 2017) and surface assemblages of bison tooth enamel or highly fragmented and desiccated bison skeletal elements (Beckett 1980; Holliday et al. 2006, 2009; Huckell et al. 2008). The Water Canyon site is thus unique west of the Pecos River in New Mexico for the reasons cited above and because it contains rare, intact, open air processing areas.

6 SUMMARY

The Water Canyon site is a buried, multi-component, stratified Paleoindian site in the Southwestern United States. The archaeological materials are within an alluvial fan at the toe of a large bajada. It contains three late Paleoindian occupation features in ancient paludal deposits on and beneath coarser, higher energy deposits more typical of an alluvial fan. The oldest, well-dated occupation zone, at ~9240 ¹⁴C yr BP (~10,390 cal yr BP), is a bed of *Bison sp.* bones on the margin of the ancient wetland, interpreted as an open-air processing station. A nearby *Bison sp.* bone bed, farther out in the paleo-wetland and downslope from the processing station, and a probable kill site with an *in situ* Eden projectile point, currently dates to ~8955 ¹⁴C yr BP (~10,070 cal yr), but it may be older. It may be functionally related to the older processing area. The youngest, well-dated occupation level, at ~8321 ¹⁴C yr BP (~9365 cal yr BP), is also along the margins of the paleo-wetland and may also contain processed *Bison sp.* bone and a hearth. Both Clovis and Folsom artifacts have been found on the surface of the site, and remnants of both Clovis- and Folsom-aged paludal strata are preserved in the site but may be of limited extent. Nevertheless, the data show that the palustrine environment that interrupted fan construction attracted ancient foragers since at least ~11,000 ¹⁴C yr BP (late Clovis time) through the early Holocene.

FUNDING SOURCES

Funding for this research was provided by the Argonaut Archaeological Research Fund (VTH Executive Director; University of Arizona Foundation), the UNM Office of Contract Archeology, the NM Office of Archaeological Studies, the Curtiss T. and Mary G. Brennan Foundation, the UNM College of Arts and Sciences, the NM Historic Preservation Division, and numerous private donors.

ACKNOWLEDGMENTS

This research was conducted through several field permits issued to RDR since 2008 by the New Mexico State Historic Preservation Division and the Energetic Materials Research and Testing Center of the New Mexico Institute of Mining and Technology. Geoarchaeological field assistance was provided by William T. Reitze and Andrew J. Richard. The authors jointly thank the following people for their helpful advice or collaboration, without which our current understanding of the Water Canyon site would not have been possible: Patrice Walker Dello-Russo, Ron Goble, Paul Goldberg, C. Vance Haynes, and Jill Onken. VTH thanks Bruce Huckell and Greg Hodgins, and RDR thanks Mike Collins, Russell Greaves, Stephen Hall, David Love, Les McFadden, Keith Prufer, David Rachal, and Christian Solfisburg. Figures 1, 5, 8, and 9 were created by Jim Abbott; Figures 3A, 3B, 6A, and 6B were jointly created by RDR and VTH; Figures 2, 4, 7, and S1 were created by RDR; Figure 10 was jointly created by RDR and Scott Gunn; and Figure 11 was jointly created by RDR, Alex Kurota and Scott Gunn. The manuscript was

improved by a review from Lee Nordt and two anonymous reviewers.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

FIGURE CAPTIONS

Figure 1. Geographic setting of the Water Canyon site west of the Rio Grande in central New Mexico illustrating the general geomorphic features of the area (based on Machette 1988: figure 1). Inset shows the location of the figure area (dashed rectangle) in New Mexico along with archaeological sites mentioned in the text: BW = Boles Wells; C = Clovis (Blackwater Draw Locality 1); F = Folsom; LA = LA111429; R6 = R-6 site; S = Sandia Cave; SJ = San Jon; WM = Williamson-Plainview and Milnesand.

Figure 2. Topographic map of the Water Canyon site showing locations of: (A) Loci, soil sections, and lines of sections A-A' (Figure 7) and B-B' (Figure 8) and (B) excavation blocks and backhoe trenches (BHT). See Figure S1 for locations of all cores.

Figure 3. Views overlooking the Water Canyon site. (A) View to the north with excavations

under way in Locus 1. The area from the foreground north to Big Wash is the surface of the Terminal Pleistocene/Holocene fan encasing the buried archaeological materials, inset well below the surface of the Pleistocene bajada where Locus 6 is situated. (B) View east down No Name Arroyo at the head of the Terminal Pleistocene/Holocene fan showing the exposure of Strata 4, 6, and 8 (with 6 pinching out against 4) at section 10-30 with Locus 1N immediately beyond and the north end of BHT 6 (Figure 2B) visible at right center. Exposure of Unit 1-47 in Locus 1N (Figure 2B) is on the opposite arroyo wall.

Figure 4. Late Pleistocene and early Holocene landscape evolution sequence. (A) Original Magdalena fan (bajada) surface on Stratum 1 at > 100 kya. (B) Paleo-channel incises Stratum 1 at >42.0k yr BP; Stratum 2 sediments fill paleo-channel at ~40.0k years BP. (C) Paleo-channel incises Stratum 2 at <40.0 kya; Stratum 3 sediments fill paleo-channel at ~30.0 kya. (D) Initial incision of Big Wash between ~30.8k and ~18.0k years BP. (E) Initial incision of No Name Arroyo at <18k years BP; Deposition of Stratum 4 at or <18.0k years BP. (F) Shallow bench cut on Stratum 4 then deep incision of Stratum 4 at <18.0k years BP. (G) Construction of Stratum 5 fan at <18.0k to >13.0k cal years BP. H) Paludal deposition of Stratum 6 at ~13.1k through ~ 8.0k cal years BP. (I) Deposition and erosion of Strata 7 and 8 from ~8.0k cal years BP to present.

Figure 5. Lithostratigraphy and soil stratigraphy exposed in a segment of Backhoe Trench 6 in Locus 1 (Figures 2B, 3B) illustrating position of OSL sample, erosion on Stratum 4, inset

relationship of Stratum 6 against Stratum 4, and facies relationship of Stratum 6 and its soil facies. Secondary calcium carbonate is common throughout Strata 4 and 6 as films and threads.

Figure 6. (A) The west wall of the Locus 5 excavation block (Figure 2B) illustrating the stratigraphic relationships of Strata 6 (black and gray facies), 7, and 8, and paleo-arroyo. (B) Close-up of the excavations (Units 5-1, 5-6 and 5-8) and profile in the southwest corner of the Locality 5 excavations (keyed to Figure 6A), illustrating the bottom of paleo-arroyo infilled with laminated sediments of Stratum 8 and inset into Stratum 6, a portion of the *Bison sp.* bone bed (Unit 5-8), and Stratum 5 cobbles beneath the black facies of Stratum 6.

Figure 7. Generalized stratigraphic sequence of the Water Canyon site along section A-A' (Figure 2A) running northeast from Locus 1 South.

Figure 8. Generalized stratigraphic sequence of the Water Canyon site along section B-B' running east-southeast from Locus 1 North (Figure 2A), illustrating the change in elevation across the top of Strata 5 and 6. Radiocarbon means are provided for the base of Stratum 6 in cores 9-10, 9-11, and 10-26 (Table 2).

Figure 9. Lithostratigraphy and soil stratigraphy exposed in Backhoe Trench 4 east of Locus 3 (Figure 2B) illustrating position of OSL samples, erosion on Stratum 4, and sloping fan-like

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

character and facies of Stratum 5. Secondary calcium carbonate is common throughout Stratum 5 and 6 as films and threads.

Figure 10. An example of the black and olive green (gleyed) facies of Stratum 6 along the North wall of Unit 1-47 on the north side of No Name Arroyo in Locus 1 North (Figures 2B, 3B). Cobbly Stratum 5 is overlain by the olive facies of Stratum 6 (6A) and, above, the black facies (6B). The dot on the aluminum can is the location for radiocarbon sample A-15021 (Table 2). It and the other sampling locations (dots) are labeled with their respective mean dates (Table 2).

Figure 11. West-to-east backplot of dated and undated bones, artifacts, and charcoal in Locus 1 North. Dates for bone collagen and Feature 1 hearth are in ¹⁴C yr BP (Table 2). Shaded areas illustrate inferred groupings of different age bone beds (upper and lower) and eastern-most bone cluster. Unshaded areas between bone beds/cluster represent inferred disconformities. The three bone collagen dates in the lower bone bed (bone cluster 2) are statistically the same ($t=0.823$) and their mean radiocarbon date is statistically different ($t=26.765$) than that of the bone collagen sample in the upper bone bed Bone cluster 1). The bone collagen date in the upper bone bed is statistically different than ($t=7.466$), but only slightly younger than, the Feature 1 hearth in the same bone bed. The third potential bone cluster, on the eastern side of Figure 11 (Bone cluster 3), has two dated bone collagen samples that are only slightly different in age ($t=4.446$) but whose mean date is very different than both the upper ($t=82.239$) and

1
2
3 lower ($t=128.228$) bone beds.
4
5

6
7 Figure 12. Bison bone found within the black facies of Stratum 6 in core 10-1 (Figure S1). The
8
9 mud that encased the bone produced radiocarbon samples AA-95610 and Beta-317339 (Table
10
11 2).
12
13
14
15

16 REFERENCES 17 18 19 20

21 Abbot, M.B., & Stafford Jr., T.W. (1996). Radiocarbon geochemistry of modern and ancient
22
23 Arctic Lake Systems, Baffin Island, Canada. *Quaternary Research*, 45, 300–311.
24
25
26
27

28 AGI (1982). *AGI data sheets*. Falls Church, VA: American Geological Institute, 157 p.
29
30
31
32

33 Akins, N. (2012). Analysis of Water Canyon faunal recovery for 2009 and 2010 field seasons. In
34
35 R. Dello-Russo (Ed.), *Continued interdisciplinary research at the Water Canyon Paleoindian site*
36
37 *(LA 134764), Socorro County, New Mexico – Interim Report for the 2010 Field Season and Data*
38
39 *Recovery Plan for the 2012 Season* (pp. 166-170). OAS PR 42. Santa F: Office of Archaeological
40
41 Studies, Museum of New Mexico.
42
43
44
45
46
47

48 Akins, N.J., & Moore, J.L. (2012). *Test excavations at eight sites at the Spaceport America*
49
50 *Facility, Sierra County, New Mexico*. Archaeology Notes 435. Santa Fe: Museum of New Mexico,
51
52

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Office of Archaeological Studies.

Amick, D.S., Mauldin, R.P., & O’Leary, B.L. (1996). The Boles Wells Folsom locality in the Tularosa Basin, New Mexico. *Current Research in the Pleistocene*, 13, 1-3.

Amick, D.S., Mauldin, R.P., & Tagg, M.D. (1998). Paleoindian archaeology at Holloman Air Force Base, New Mexico. *Current Research in the Pleistocene*, 15, 1-4.

Beckett, P.H. (1980). *The Ake site: Collection and excavation of LA 13423, Catron County, New Mexico*. Report 357 prepared for the National Radio Astronomy Observatory. Las Cruces: Department of Sociology and Anthropology, Cultural Resources Management Division.

Birkeland, P.W. (1999). *Soils and geomorphology* (3rd ed.). New York: Oxford University Press, 430 p.

Bradley, R.S. (2015). *Paleoclimatology: Reconstructing climates of the Quaternary* (3rd ed.). New York: Academic Press.

Buenger, B.A. (2003). *The impact of wildland and prescribed fire on archaeological resources* (unpublished PhD Dissertation). Department of Anthropology, University of Kansas, Lawrence.

Chamberlin, R.M., & Osburn, G.R. (2006). Geologic map of the eastern half of the Water Canyon 7.5 Minute Quadrangle, Socorro County, New Mexico, New Mexico Bureau of Geology and Mineral Resources Open-file Geologic Map Series, 1:24,000, OF-GM-118.

Chapin, C.E., McIntosh, W.C., & Chamberlin, R.M. (2004). The late Eocene-Oligocene peak of Cenozoic volcanism in southwestern New Mexico. In G.H. Mack & K.A. Giles (Eds.), *The Geology of New Mexico: A Geologic History* (pp. 271-293). Socorro: New Mexico Geologic Society Special Publication 11.

Collins, M.B. (1999). *Clovis blade technology: A comparative study of the Keven Davis cache, Texas*. Austin: University of Texas Press.

Davis, O.K. (2012). Charcoal species identifications for Water Canyon samples. In R.D. Dello-Russo (Ed.), *Archaeological excavations at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim Report for the 2012 and 2013 Field Seasons* (pp. 47-51). OCA Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New Mexico.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Dello-Russo, R.D. (2001). *A cultural resources inventory of 472 acres in Socorro County, New Mexico. The Archaeology of the EMRTC / GLINT Project Area*. Report No. 2001-03 for Energetic Materials Research and Testing Center, New Mexico Institute of Mining and Technology. Socorro, NM: Escondida Research Group.

Dello-Russo, R.D. (2010). *Archaeological testing at the Water Canyon site (LA134764), Socorro County, New Mexico – Interim report for the 2008 and 2009 field seasons*. ERG Report No. 2009-09 for New Mexico Historic Preservation Division, Department of Cultural Affairs. Socorro, NM: Escondida Research Group, LLC.

Dello-Russo, R.D. (2012). *Continued interdisciplinary research at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2010 field season and data recovery plan for the 2012 Season*. OAS PR 42. Santa Fe: Office of Archaeological Studies, Museum of New Mexico.

Dello-Russo, R.D. (2015). *Archaeological excavations at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2012 and 2013 field seasons*. OCA Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New Mexico.

Dello-Russo, R.D., Walker, P.A., & Holliday, V.T. (2010). Recent research results from the Water

Canyon site, a Clovis and late Paleoindian locale in west-central New Mexico. *Current Research in the Pleistocene*, 27, 72-75.

Dello-Russo, R.D., Smith, S.J., Yost, C., Winsborough, B., Hall, S.A., McBride, P. & Davis, O.K. (2016a). The Black Mat at the Water Canyon Paleoindian site and a new paleoenvironmental record for the Pleistocene-Holocene transition in west-central New Mexico. Poster presentation at the American Quaternary Association Conference, Retooling the Quaternary to Manage the Anthropocene. Santa Fe. https://www.academia.edu/26962887/Poster_Presentation

Dello-Russo, R.D., Smith, S.J., & Walker, P.A. (2016b). The Black Mat at the Water Canyon Paleoindian site near Socorro, New Mexico: A paleoenvironmental proxy data archive for the Pleistocene-Holocene transition. *New Mexico Geological Society Guidebook*, 67th Field Conference, Geology of the Belen Area (pp. 491-500). Socorro: New Mexico Geological Society.

Dello-Russo, R.D., Cordero, R., & Leonard, B., in review. Analytical and interpretive challenges posed by late Paleoindian activity areas at the Water Canyon site, west-central New Mexico. In K. Carlson & L. Bement (Eds.), *Open air camps of the Terminal Pleistocene and early Holocene: Intra-camp spatial organization, activity areas, and technology*. Boulder: University of Colorado Press.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figgins, J.D. (1927). The antiquity of man in America. *Natural History*, 27, 229-239.

Gile, L.H., Hawley, J.W., & Grossman, R.B. (1981). *Soils and geomorphology in the Basin and Range area of southern New Mexico - Guidebook to the Desert Project*. Socorro: New Mexico Bureau of Mines and Mineral Resources, Memoir 39.

Goble, R.J. (2014). *OSL analysis and sample preparation*. Report submitted by Luminescence Geochronology Laboratory, University of Nebraska, Lincoln.

Goble, R.J. (2015). *OSL analysis and sample preparation*. Report submitted by Luminescence Geochronology Laboratory, University of Nebraska, Lincoln.

Haas, H., Holliday, V.T., & Stuckenrath, R. (1986). Dating of Holocene stratigraphy with soluble and insoluble organic fractions at the Lubbock Lake archaeological site, Texas: An ideal case study. *Radiocarbon*, 28, 473-485.

Hall, S.A. (2015). Fossil Snails from the Water Canyon Site, Preliminary Analysis. In R.D. Dello-Russo (Ed.), *Archaeological excavations at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2012 and 2013 field seasons* (pp. 47-51). OCA Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New

Mexico.

Hall, S.A., Penner, W.L., Palacios-Fest, M.R., Metcalf, A.L., & Smith, S.J. (2012). Cool, wet conditions late in the Younger Dryas in semi-arid New Mexico. *Quaternary Research*, 77, 87-95.

Haynes, C.V., Jr. (1975). Pleistocene and Recent Stratigraphy. In F. Wendorf and J. J. Hester (Eds.). *Late Pleistocene environments of the Southern High Plains* (pp. 57-96. Taos, New Mexico: Publication of the Fort Burgwin Research Center 9.

Haynes, C.V., Jr. (2008). Younger Dryas “black mats” and the Rancholabrean termination in North America. *Proceedings of the National Academy of Science, U.S.A.*, 105, 6520–6525.

Haynes, C.V., Jr., & Agogino, G.A. (1986). *Geochronology of Sandia Cave*. Smithsonian Institution Press, Smithsonian Contributions to Anthropology 32.

Haynes, C.V., Jr., & Huckell, B.B. (Eds.) (2007). *Murray Springs: A Clovis site with multiple activity areas in the San Pedro Valley, Arizona*. Tucson: University of Arizona Press.

Haynes, C.V., Jr., and Warnica, J.M. (2012). *Geology, Archaeology and Climate Change in Blackwater Draw, New Mexico: F. Earl Green and the Geoarchaeology of the Clovis Type Site*.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Contributions in Anthropology, volume 15. Portales: Eastern New Mexico University.

Hester, J.J. (1972). *Blackwater Locality No. 1 – A stratified Early Man site in eastern New Mexico*. Fort Burgwin Research Center Publication 8, Southern Methodist University, Dallas.

Holliday, V.T. (2000). The evolution of Paleoindian geochronology and typology on the Great Plains. *Geoarchaeology*, 15, 227-290.

Holliday, V.T. (2004). *Soils in archaeological research*. New York: Oxford University Press.

Holliday, V.T., & Miller, D.S. (2013). The Clovis landscape. In K. E. Graf, C. V. Ketron, & M.R. Waters (Eds.). *Paleoamerican odyssey* (pp. 221-245). College Station: Texas A&M University Press.

Holliday, V.T., & Mandel, R.D. (2006). Paleoindian geoarchaeology of the Great Plains, Central Lowlands, and Southwestern U.S. In D.H. Ubelaker (Ed.), *Environment, origins, and populations, Volume 3, Handbook of North American Indians* (pp. 23-46). Washington, D.C.: Smithsonian Institution Press.

Holliday, V.T., Haynes, C.V., Hofman, J.L., & Meltzer, D.J. (1994). *Geoarchaeology and*

geochronology of the Miami (Clovis) site, Southern High Plains of Texas. *Quaternary Research*, 41, 234-244.

Holliday, V.T., Gustavson, T.C., & Hovorka, S.D. (1996). Stratigraphy and geochronology of playa fills on the Southern High Plains. *Geological Society of America Bulletin*, 108, 953-965.

Holliday, V.T., Huckell, B.B., Mayer, J.M., & Forman, S.L. (2006). Geoarchaeology of the Boca Negra Wash Area, Albuquerque Basin, New Mexico. *Geoarchaeology*, 21, 765-802.

Holliday, V.T., Huckell, B.B., Hamilton, M., Weber, R.H., Reitze, W.T., & Mayer, J.H. (2009). Geoarchaeology of the Mockingbird Gap (Clovis) site, Jornada del Muerto, New Mexico. *Geoarchaeology*, 24, 438-370.

Holliday, V.T., Johnson, E., Warnica, J., & Haynes, C.V., Jr. (2017). The Williamson-Plainview and type Milnesand sites on the Southern High Plains, New Mexico. *PaleoAmerica*, 3, 122-149.

Howard, E.B. (1933). Association of artifacts with mammoth and bison in eastern New Mexico. Paper presented at the National Academy of Sciences Meeting, Boston.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Howard, E.B. (1935). Evidence of Early Man in North America. *The Museum Journal, University Museum, University of Pennsylvania*, 24 (2-3), Philadelphia.

Huckell, B.B., Holliday, V.T., Hamilton, M.J., Sinkovec, C., Merriman, C., Shackley, M.S., & Weber, R.H. (2008). The Mockingbird Gap Clovis site: 2007 investigations. *Current Research in the Pleistocene*, 25, 95-97.

Jodry, M.A.B. (1999). *Folsom technological and socioeconomic strategies: Views from Stewart’s Cattle Guard and the upper Rio Grande basin, Colorado* (unpublished PhD dissertation). Department of Anthropology, American University, Washington, D.C.

Johnson, E. (Ed.) (1987). *Lubbock Lake: Late Quaternary studies on the Southern High Plains*. College Station: Texas A&M University Press.

Knell, E.J., & Muñiz, M.P. (2013). Introducing the Cody Complex. In E.J. Knell & M.P. Muñiz (Eds.), *Paleoindian lifeways of the Cody Complex* (pp. 3-28). Salt Lake City: University of Utah Press.

Machette, M.N. (1988). *Quaternary movement along the La Jencia fault, central New Mexico*. U.S. Geological Survey Professional Paper 1440. U.S. Government Printing.

Mann, D.H., & Meltzer, D.J. (2007). Millennial-scale dynamics of valley fills over the past 12,000 ^{14}C yr in northeastern New Mexico, USA. *Geological Society of America Bulletin*, 119, 1433–1448. doi:10.1130/B26034.1

Martin, C.W., & Johnson, W.C. (1995). Variation in radiocarbon ages of soil organic matter fractions from late Quaternary buried soils. *Quaternary Research*, 43, 232-237.

Mauldin, R.P., & O’Leary, B.L. (1994). HAR-074 (LA104, 267), *The Boles Wells Paleoindian site, data collection and test excavations, Holloman Air Force Base, Otero County, New Mexico*. HAFB Report No. 1994-021 (HSR 9349E) for Holloman Air Force Base, White Sands Missile Range, Contract No. DAAD07-89-D-0050, delivery order No. 0062. Tularosa, NM: Human Systems Research.

Mayer, J.H., & Mahan, S.A. (2004). Late Quaternary stratigraphy and geochronology of the Western Killpecker Dunes, Wyoming, USA. *Quaternary Research*, 62, 72-84.

McBride, P.J. (2012). Analysis of flotation and wood charcoal samples from Water Canyon (LA 134764), In R.D. Dello-Russo (Ed.), *Continued interdisciplinary research at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2010 field*

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

season and data recovery plan for the 2012 season (pp. 38-40). OAS PR 42. Santa Fe: Office of Archaeological Studies, Museum of New Mexico.

McGeehin, J., Burr, G.S., Jull, A.J.T., Reines, D., Gosse, J., Davis, P.T., Muhs, D., & Southon, J.R. (2001). Stepped-combustion ¹⁴C dating of sediment: A comparison with established techniques. *Radiocarbon*, 43, 255-261.

Meltzer, D.J. (2006). *Folsom: New archaeological investigations of a classic Paleoindian bison kill*. Berkeley: University of California Press.

Meltzer, D.J., & Holliday, V.T. (2010). Would North American Paleoindians have noticed Younger Dryas age climate changes? *Journal of World Prehistory*, 23, 1-41.

Moore, J.L., & Akins, N.J. (2014). *10,000 years of transient occupation in the Jornada del Muerto: Excavations at eight sites at the Spaceport America Facility, Sierra County, New Mexico*. Archaeology Notes 453 for the Federal Aviation Administration and the New Mexico Spaceport Authority. Santa Fe: Museum of New Mexico, Office of Archaeological Studies.

Onken, J. (2015). *Late Quaternary climatic geomorphology, volcanism, and geoarchaeology of Carrizo Wash, Little Colorado River headwaters, USA* (unpublished PhD Dissertation),

Department of Geosciences, University of Arizona, Tucson.

Pitblado, B.L. (2003). *Late Paleoindian occupation of the Southern Rocky Mountains – early Holocene projectile points and land use in the High Country*. Boulder: University Press of Colorado.

Preston, D. (1995). The mystery of Sandia Cave. *The New Yorker* (June 12, p. 66-83).

Quade, J., Forester, R.M., Pratt, W.L., & Carter, C. (1998). Black mats, spring-fed streams, and late-glacial-age recharge in the southern Great Basin. *Quaternary Research*, 49, 129-148.

Rawling, J.E., 3rd, Fredlund, G.G., & Mahan, S. (2003). Aeolian cliff-top deposits and buried soils in the White River Badlands, South Dakota, USA. *The Holocene*, 13, 121-129.

Reed, E.K., 1964. The greater Southwest. In: Jennings, D., Norbeck, E. (Eds.), *Prehistoric man in the Southwest*. University of Chicago Press, Chicago, pp. 175-191.

Rittenour, T. (2011). *Final age report for Project 093*. Report submitted to Office of Archaeological Studies by Utah State University Luminescence Laboratory, North Logan, Utah.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Sanchez, G., Holliday, V.T., Gaines, E.P., Arroyo-Cabral, J., Martinez-Tagüena, N., Kowler, A., Lange, T., Hodgins, G.W.L., Mentzer, S.M., & Sanchez-Morales, I. (2014). Human (Clovis) – gomphothere (*Cuvieronius* sp.) association ~13,390 calibrated yBP in Sonora, Mexico. *Proceedings of the National Academy of Sciences, U.S.A.* 111, 10972-10977.

Schaetzl, R.J., & Thompson, M.L. (2015). *Soils: Genesis and geomorphology* (2nd ed.). New York: Cambridge University Press.

Smith, S.J. (2010). Water Canyon pilot pollen study In R.D. Dello-Russo (Ed.), *Archaeological testing at the Water Canyon site (LA134764), Socorro County, New Mexico – Interim report for the 2008 and 2009 field seasons* (pp. 31-32). ERG Report No. 2009-09 for the New Mexico Historic Preservation Division, Department of Cultural Affairs. Santa Fe: Escondida Research Group, LLC.

Smith, S.J. (2012). Pollen results from LA 134764. In R.D. Dello-Russo (Ed.), *Continued interdisciplinary research at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2010 field season and data recovery plan for the 2012 season* (pp. 41-59). OAS PR 42. Santa Fe: Office of Archaeological Studies, Museum of New Mexico.

1
2
3 Smith, S.J. (2015). Pollen results from the 2012 Water Canyon Field Season, In R.D. Dello-Russo
4
5 (Ed.), *Archaeological excavations at the Water Canyon Paleoindian site (LA 134764), Socorro*
6
7 *County, New Mexico – Interim report for the 2012 and 2013 field seasons* (pp. 34-47). OCA
8
9 Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New Mexico.
10
11
12
13

14
15 Stanford, D., & Patten, R. (1984). R-6, a preliminary report on a Cody site in north central New
16
17 Mexico. *Proceedings of the New Mexico Archeological Council*, 6(1), 198-199.
18
19
20
21

22
23 Stuiver, M., & Reimer, P.J. (1993). Extended ^{14}C database and revised CALIB radiocarbon
24
25 calibration program. *Radiocarbon*, 35, 215-230.
26
27
28
29

30 Taylor, R.E., & Bar-Yosef, O. (2014). *Radiocarbon dating: An archaeological perspective* (2nd
31
32 ed.). Walnut Creek, CA: Left Coast Press.
33
34
35
36

37 Surovell, T.A., Boyd, J.R., Haynes, C.V., Jr., & Hodgins, G.W.L. (2016). On the dating of the
38
39 Folsom complex and its correlation with the Younger Dryas, the end of Clovis, and megafaunal
40
41 extinction. *PaleoAmerica*, 2(2):81-89.
42
43
44
45

46
47 Walker, M. (2005). *Quaternary dating methods*. Chichester, UK: John Wiley & Sons.
48
49
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Waters, M.R., & Haynes, C.V. (2001). Late Quaternary arroyo formation and climate change in the American Southwest. *Geology*, 29, 399–402.

Winsborough, B. (2016). *Diatom paleoenvironmental analysis of sediments from the Water Canyon Paleoindian site (LA134764)*. Report prepared by Winsborough Consulting for Office of Contract Archeology, University of New Mexico, Albuquerque.

Yost, C.L. (2016). *Phytolith analysis of late Pleistocene and early Holocene sediments from the Water Canyon Paleoindian site, LA134764, New Mexico*. Technical Report 16003 for Office of Contract Archeology, University of New Mexico. Tucson, AZ: Paleoscapes Archaeobotanical Services Team, LLC.

Table 1. Selected stratigraphic descriptions from the Water Canyon site, south (core 9-02) to north (section 12-09).

Core 9-02, Locus 1 South

Stratum	Depth, cm	Soil Horizon ^a	Description ^b
8	0-3	C	loose fS; sl redder than 10YR 4/4sm; abrupt bndy
8 with surface soil	3-8	A	fSL; brown 7.5YR 4/3sm; str cr & wk sbk; clear bndy
	8-28	Bt	SCL w/few rock frags; brown 7.5YR 4/4d; wk med pr & str med sbk; thin cont clay films on ped faces & rock clasts; clear bndy
	28-48	Btwk	SCL; brown 10YR 5/3d; v wk pr & str med sbk; thin patchy clay films; few carb films & thr; clear bndy
	48-68	Bw1	fSL; brown 10YR 5/3d; v wk pr & str med sbk; clear bndy
	68-81	Bw2	fSL; brown 10YR 5/3d; v wk pr & wk sbk; clear bndy
6 black/gray	81-109	Ak1b1	mud w/common sl rounded rock frags; dark brown 7.5YR 4/2sm; wk med abk; common faint carb films & thr on ped faces and rock frags (indistinct owing to slightly moist soil); clear bndy PW ³
	109-136	Ak2b1	mud w/common slightly rounded rock frags; brown 7.5YR 5/3d matrix; med mod abk; almost cont carb coatings on ped faces & rock frags; clear bndy PW
	136-183	Ak3b1	mud w/v common rock frags; brown 7.5YR 5/3d; med mod abk; carb coats not as cont but still prominent; v common Fe-ox stains; 10YR 5/6d; clear bndy PW
	183-208	Ak4b1	as above but fewer rock frags; clear bndy PW
	208-256	Ak5b1	as above but fLS and no rock frags; some platiness below 240cm; upper 10cm grades from the overlying mud down to the f loamy sand; common carb films on ped faces; clear bndy PW
	256-280	Ak6b1	as above but less f sand w/depth; by 280 f sandy mud; common carb films on ped faces; clear bndy PW

	280-295	Ak7b1	sandy mud; mixed dark brown 7.5YR 4/5 & 3/3sm; mod pr & str sbk; common carb films on ped faces; clear bndy PW
4	295-300	Bkb1	dense gravelly clay; brown 7.5YR 4/4sm; carb films on peds and clasts

Locus 1 North, Section 10-30 (corner with No Name Arroyo)

Stratum	Thickness, cm	Soil Horizon ^a	Description ^b
7/8	21	Bt	Gravelly SCL; dark brown 7.5YR 4.5/d; v wk pr & mod med sbk; thin patchy clay films; clear bndy
	11	Bw	SCL; brown 7.5YR 5/4d; mod med sbk; scattered gravel; clear bndy
6 gray	23	ABk1b1	Mud; brown 7.5YR 4/3d; wk cse sbk; common faint carb films & thr; clear bndy
	35	ABk2b1	SCL, gravel common; slighty grayer than brown 7.5YR 4/3dsm; common faint carb films & thr; clear bndy
6 black^d	25	Ab1	Mud ^c dark gray 10YR 4/1d; f str sbk; common fine patches of carb; clear, smooth bndy PW
6 green	30	Cgb1	S mud, locally gravelly; gray brown 2.5Y 5.5/2d (transition from Ab to Cb); massive; clear, smooth bndy PW
5	20+	Cb1	S mud; gray brown 10YR 5/2d w Fe-ox mottles of brownish yellow 10YR 6/6d; massive

Locus 5 pit, Section 13-03 (just N of center of W wall)

Stratum	Depth, cm	Soil Horizon ^a	Description ^b
7	0-3	A	SCL, brown 7.5YR 4/4d; f mod sbk & wk gr; clear bndy
	3-17	Bt	SCL, strong brown 7.5YR 4/6d; f wk pr & f mod sbk; common thin clay films; clear bndy

	17-30	Btwk	SCL, brown 7.5YR 4.5/4d; med str sbk & v wk cse pr; common carb films & thr; thin patchy clay films; clear bndy
	30-60	C1	loose sand & gravel; 7.5YR 5.5/4d; abrupt bndy
	60-75	C2	mS w/fine gravel; 7.5YR 5.5/4d; abrupt bndy
	75-90	C3	massive cse gravel; abrupt bndy (90cm = top of upper bench)
	90-135	C4	massive fSL; 7.5YR 5.5/4d; abrupt bndy
	135-160	C5	pocket of gravel; abrupt bndy
	160-177	C6	f gravel & cS; 7.5YR 5.5/4d; abrupt bndy
	177-200	C7	loose fSL; 7.5/10YR 5.5/6d; v wk sbk; abrupt bndy (200cm = top of lower bench)
	200-220	C8	lens of cse, dense rubble (cse sand to left & right); abrupt bndy
	220-238	C9	LfS w cS & f pebbles; 10YR 5.5/2d; abrupt bndy
6 gray	238-273	Ab1	LfS; brownish gray 10YR 6/2d; wk med sbk; local, disc gravel clasts at base; fine carb root casts in lower 5cm; abrupt, wavy bndy PW
6 black	273-300	Ab2	S mud; dark gray 10YR 4/1d; med mod sbk to abk; few faint carb films (300+ cm, bottom of pit) PW

Section 12-09 (Big Wash)

Stratum	Depth, cm	Soil Horizon ^a	Description ^b
7?	0-50	A-Btw?	SL w/common rocks; dark brown 7.5YR 3/3m; wk pr & wk sbk; clear bndy
	50-65	Bk	As above w few films & thr carbonate; abrupt, wavy bndy
	65-160		loose sand and gravel w some rock rubble; abrupt, wavy bndy
6 gray/black	160-180		dark gray brown SCL; dark grayish brown 2.5Y 3/2m; clear, smooth bndy PW

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

	180-185		black SCL; very dark gray 2.5Y 3/1m; faint bedding; wavy, abrupt bndy PW
	185-191		medium gray SCL; dark grayish brown 2.5Y 4/2m; wavy, abrupt bndy PW
	191-205		black SCL; very dark gray 2.5Y 3/1m; faint bedding; v wavy, abrupt bndy PW
6 green	205-215+		dark olive SCL; dark olive brown 2.5Y 3/3m PW

^a Variations to standard USDA horizon nomenclature follow Holliday (2004, appendix 1).

^b Abbreviations for descriptions:

Colors = Munsell d = dry; sm = slightly moist; m = moist

Textures: S = Sand; SL = Sandy Loam; SCL = Sandy Clay Loam; f = fine;

Structure: cr = crumb; sbk = subangular blocky; abk = angular blocky; pr = prismatic; wk = weak; mod = moderate; str = strong; f = fine; med = medium; cse = coarse;

Miscellaneous descriptors: bndy = boundary; carb = carbonate; cont – continuous; disc = discontinuous; Fe-ox = iron oxides; frags = fragments; sl = slightly

^c PW = Paleo-wetland deposits/soils

^d black Stratum 6 has increasing amounts of gravel moving east to west (i.e., upstream).

Table 2. Radiocarbon and optically stimulated luminescence dates from the Water Canyon site (see also Tables S1 and S2).

Stratum	Grid Elev. (m)	Material ¹	F.S. Number	Lab Number	¹⁴ C yr B.P.	Cal yr B.P. Range (1-sigma)	Relative Area under Probability Distribution	Cal yr B.P. Range (2-sigma)	Relative Area under Probability Distribution	Mean Highest 2-sigma Probability (Cal yr B.P.)
<i>LOCUS 1</i>										
Unit 1-9, ¹⁴ C										
6 black	48.03	SOM	1274	AA103849	9310±52	10,508-10,524 10,530-10,553	0.437 0.563	10,498-10,568	1.000	10,533±35
	47.82	SOM	1273	AA103848	9482±62	10,596-10,624 10,650-10,791 10,967-11,003 11,026-11,064	0.089 0.668 0.113 0.130	10,572-10,881 10,927-11,082	0.728 0.272	10,727±155
	47.7	SOM	1272	AA103847	9776±61	11,168-11,246	1.000	10,887-10,924 11,085-11,313	0.023 0.977	11,199±114
	47.57	SOM	1271	AA103815	9815±48	11,201-11,248	1.000	11,173-11,311	1.000	11,242±69
6 olive	47.41	SOM	1270	AA103814	9752±47	11,169-11,229	1.000	11,095-11,249	1.000	11,172±77
	47.28	SOM	1269	AA103813	9010±55	10,156-10,241	1.000	9925-10,066 10,118-10,251	0.226 0.774	10,815±67
Unit 1-6, ¹⁴ C										
6 olive	47.29	SOM	1231	Beta-373606	11,310±50	13,099-13,207	1.000	13,074-13,268	1.000	13,171±97
	47.29	SOM	1232	Beta-373607	11,310±50	13,099-13,207	1.000	13,074-13,268	1.000	13,171±97
Section 08-1/Unit 1-47, ¹⁴ C										
6 Black	47.66	SOM	29	A-15021	9285±85	10,299-10,324 10,342-10,353 10,373-10,579	0.084 0.035 0.881	10,251-10,674	1.000	10,463±212
	47.54	SOM	22	AA88080	9763±62	11,152-11,243	1.000	10,872-10,946 11,074-11,291 11,300-11,301	0.059 0.941 0.000	11,183±109
	47.44	SOM		A-15022	7820±220	8421-8799 8804-8806 8826-8870 8880-8977	0.751 0.003 0.078 0.168	8193-9155 9160-9254	0.973 0.027	8674±481
6 Black/ olive	47.43	SOM	24	AA88078	9568±62	10,761-10,878 10,932-11,080	0.441 0.559	10,706-11,144	1.000	10,925±219
	47.42	SOM	23	AA88079	10,363±85	12,079-12,393	1.000	11,842-11,870 11,948-12,536	0.013 0.987	12,242±294

6 olive	47.39	Charred material (charcoal?)	31	AA83855	9750±50	11,162-11,232	1.000	10,895-10,920 11,089-11,250	0.020 0.980	11,170±81
	47.29	SOM	32	AA83854	11,030±60	12,812-12,982	1.000	12,744-13,043	1.000	12,894±150
Unit 1-11, ¹⁴ C (Feature 1 hearth)										
6 gray	48.25	Charcoal	1036	AA94458	8354±58	9304-9365 9367-9450	0.424 0.576	9142-9175 9207-9220 9238-9494	0.027 0.008 0.964	9366±128
	48.23	Charcoal	1049	AA94459	8349±49	9305-9364 9369-9439	0.469 0.531	9150-9166 9249-9484	0.011 0.989	9367±118
	48.22	Charcoal	1051	AA94460	8314±56	9269-6430	1.000	9137-9187 9191-9463	0.088 0.912	9327±136
	48.23	Charcoal	1052	AA94461	8447±64	9433-9526	1.000	9306-9363 9372-9387 9393-9540	0.105 0.018 0.877	9467±74
	48.20	Charcoal	1053	AA94462	8324±52	9287-9429	1.000	9139-9178 9201-9228 9231-9469	0.054 0.027 0.919	9350±119
	48.20	Charcoal	1054	AA94463	8385±48	9321-9354 9400-9476	0.237 0.763	9286-9499	1.000	9393±107
	48.20	Charcoal	1055	AA94464	8346±51	9304-9436	1.000	9145-9172 9242-9484	0.022 0.978	9363±121
	48.19	Charcoal	1058	AA94465	8338±48	9303-9430	1.000	9145-9173 9241-9477	0.024 0.976	9359±118
	48.15	Charcoal	59b	AA94466	8186±47	9031-9141 9175-9206 9219-9239	0.712 0.183 0.105	9017-9276	1.000	9147±130
	48.15	Charcoal	59a	Beta-288067	8280±50	9141-9174 9208-9217 9241-9329 9342-9403	0.152 0.041 0.490 0.318	9094-9100 9121-9436	0.004 0.996	9279±158
Unit 1-12, ¹⁴ C										
	48.17	Charcoal	1066	AA94467	9454±51	10,589-10,630 10,646-10,750	0.238 0.762	10,560-10,800 10,851-10,863 10,957-11,067	0.886 0.007 0.107	10,680±120
	48.31	Bone collagen	1037	Beta-292053	8200±40	9035-9047 9088-9148 9167-9250	0.068 0.402 0.530	9027-9277	1.000	9152±125
Unit 1-20, ¹⁴ C										
	48.00	Bone collagen	1613	PSU-3564	9180±60	10,250-10,402	1.000	10,234-10,500	1.000	10,367±133
	47.88	Bone collagen	1605	PSU-3567	8810±70	9695-9934 9995-10,004 10,064-10,120	0.819 0.023 0.157	9613-9617 9621-10,161	0.003 0.997	9891±270

Unit 1-21, ¹⁴ C										
	48.09	Bone collagen	1528	PSU-3566	9185±50	10,255-10,309 10,310-10,397	0.389 0.611	10,240-10,442 10,452-10,493	0.905 0.095	10,341±101
Unit 1-45, ¹⁴ C										
	48.14	Bone collagen	1510	PSU-3565	9240±50	10,298-10,328 10,340-10,354 10,372-10,498	0.165 0.078 0.757	10,258-10,524 10,531-10,552	0.970 0.030	10,391±133
BT 3, OSL, ¹⁴ C										
8	48.37	Quartz	50	USU-768	---	---	---	9770±630	---	---
6 black	48.06	Quartz	51	USU-767	---	---	---	9580±640	---	---
	48.06	SOM	46	Beta-281149	8275±30	9144-9172 9244-9316 9358-9398	0.164 0.586 0.250	9135-9330 9342-9403	0.770 0.230	9233±98
BT 6, OSL										
4		Quartz	1288	UNL-3856	---	---	---	18,000±800	---	---
<i>EAST of LOCUS I</i>										
Core 9-10/15, ¹⁴ C										
6 black	46.61	SOM	1081	A-15340	9520±135	10,608-10,614 10,658-10,903 10,917-11,090	0.010 0.576 0.414	10,440-10,454 10,492-11,206	0.005 0.995	10,849±357
	46.55	SOM	1087	A-15346	9650+100/-95	10,793-10,855 10,857-10,963 11,006-11,023 11,065-11,191	0.177 0.348 0.047 0.428	10,719-11,230	1.000	10,975±256
Core 09-11, ¹⁴ C										
6 Black	45.73	SOM	1084	A-15343	8895±65	9916-10,099 10,110-10,166	0.770 0.230	9745-9752 9762-10,200	0.004 0.996	9981±219
	45.65	SOM	1083	A-15342	9455±110	10,558-10,808 10,847-10,865 10,954-11,069	0.715 0.035 0.250	10,420-11,141	1.000	10,781±361
	45.60	SOM	1085	A-15344	9825±115	11,098-11,406 11,454-11,468 11,561-11,595	0.932 0.020 0.048	10,789-10,970 10,997-11,029 11,063-11,654 11,657-11,709	0.096 0.011 0.875 0.019	11,359±296
	45.55	SOM	1086	A-15345	9805+115/-110	10,884-10,925 11,084-11,397	0.060 0.940	10,775-11,040 11,046-11,620 11,680-11,688	0.168 0.829 0.003	11,333±287
Core 10-26, ¹⁴ C										
6 black	41.79	SOM	104	A-15630	9745±70	11,105-11,240	1.000	10,792-10,964 11,003-11,024 11,065-11,272	0.173 0.009 0.818	11,169±104

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

<u>LOCUS 2</u>										
BT 5, OSL										
3	53.243	Feldspar	1285	UNL-3854	---	---	---	30,800±1700	---	---
2	53.681	Feldspar	1286	UNL-3855	---	---	---	36,500±4500	---	---
<u>LOCUS 5</u>										
Locus 5, main pit, OSL										
8	48.80	Quartz	5139	UNL-3864	---	---	---	9020±490	---	---
	48.68	Quartz	5027	UNL-3860	---	---	---	6560±260	---	---
	47.93	Quartz	5138	UNL-3863	---	---	---	9210±440 Minimum Age Model provides date of 6200±570	---	---
	46.76	Quartz	5137	UNL-3862	---	---	---	8540±390	---	---
	46.12	Quartz	5136	UNL-3861	---	---	---	6480±250	---	---
Locus 5, main pit, ¹⁴ C ²										
6 gray	46.02	Charcoal	5007	AA103920	8394±45	9327-9344 9402-9482	0.118 0.882	9297-9501	1.000	9399±102
6 black	45.81	Charcoal	5071	AA103921	8776±62	9635-9635 9662-9910	0.002 0.998	9566-9952 9989-10,013 10,023-10,039 10,060-10,137	0.889 0.018 0.011 0.083	9754±198
	45.67	SOM	5096	AA104050	8955±57	9940-9992 10,008-10,030 10,035-10,062 10,127-10,208	0.280 0.100 0.136 0.484	9912-10,228	1.000	10,070±158
	45.57	SOM	5105	AA104051	8623±89	9521-9698	1.000	9472-9890	1.000	9681±209
6 black	45.48	SOM	5124	AA104111	8997±53	9964-9985 10,152-10,237	0.098 0.902	9923-10,068 10,117-10,246	0.287 0.713	10,182±65
6 black	44.98- 44.88	SOM	64	A-15621	9530±65	10,712-10,828 10,838-10,868 10,951-11,070	0.433 0.102 0.465	10,605-10,619 10,654-11,109 11,112-11,124	0.010 0.983 0.008	10,882±228
	45.57	SOM	5166	16OS/0643	10,080±40	11,411-11,429 11,495-11,546 11,601-11,764	0.052 0.167 0.781	11,396-11,824 11,888-11,935	0.975 0.025	11,610±214
	45.54	SOM	5163	16OS/0640	9750±40	11,174-11,222	1.000	11,110-11,111 11,112-11,241	0.001 0.999	11,182±60
	45.49	SOM	5164	16OS/0641	10,000±40	11,351-11,415 11,423-11,500 11,527-11,603	0.291 0.352 0.358	11,274-11,629 11,633-11,637 11,671-11,700	0.964 0.004 0.032	11,452±178
	45.44	SOM	5165	16OS/0642	10,280±40	11,971-12,130	1.000	11,826-12,180 12,204-12,237 12,248-12,374	0.957 0.026 0.017	12,003±177

EAST of LOCUS 5Core 10-1, ¹⁴C

6 gray/ black	45.20	Sediment mixed with bone	63a(1)	Beta-317339 ³	9640±40	10,870-10,948 11,072-11,169	0.440 0.560	10,787-10974 10,989-11,031 11,061-11,185	0.505 0.051 0.444	10,881±94
	45.20	Dark organic matter	63a(2)	AA95610 ³	9887±59	11,224-11,349	1.000	11,198-11,412 11,429-11,495 11,546-11,601	0.908 0.046 0.046	11,305±107

Core 10-6/7, ¹⁴C

6 gray	46.00	SOM	65	A-15622	8050±160	8649-8677 8683-9128	0.048 0.952	8548-9332 9340-9404	0.971 0.029	8940±392
	45.83	SOM	67	A-15623	8255±140	9035-9048 9087-9414	0.034 0.966	8783-8831 8862-8918 8954-8962 8968-9531	0.017 0.018 0.003 0.962	9250±282
	45.63	SOM	69	A-15624	8305±90	9140-9175 9205-9220 9239-9437	0.119 0.047 0.834	9032-9057 9076-9483	0.023 0.977	9280±204
6 black	45.33	SOM	72	A-15625	8630±85	9527-9695	1.000	9482-9834 9837-9887	0.959 0.041	9658±176
	45.23	SOM	73	A-15626	8795+75/-70	9673-9931 9999-10,001 10,065-10,119	0.866 0.004 0.130	9564-9571 9585-9588 9592-9968 9982-10,155	0.007 0.002 0.757 0.234	9780±188
	45.09	SOM	75	A-15627	8940±75	9923-10,070 10,116-10,200	0.627 0.373	9782-9850 9858-9879 9881-10,235	0.049 0.015 0.936	10,058±177
6/5	44.89	SOM	77	A-15628	9405+70/-65	10,524-10,530 10,553-10,725	0.021 0.979	10,417-10,794 10,854-10,860 10,961-11,007 11,020-11,065	0.950 0.002 0.023 0.025	10,606±189
	44.69	SOM	79	A-15629	9640±80	10,795-10,853 10,861-10,960 11,007-11,020 11,066-11,178	0.183 0.364 0.035 0.418	10,745-11,204	1.000	10,975±230

NORTHEAST of LOCUS 5Core 09-18, ¹⁴C

2 Black	45.59	SOM	1082	A-15341	8590±95	9489-9671	1.000	9432-9834 9836-9887	0.971 0.029	9633±201
---------	-------	-----	------	---------	---------	-----------	-------	------------------------	----------------	----------

Section 12-9, ¹⁴C

	45.41	SOM	1280	AA103852	7228±46	7976-8054 8093-8108 8119-8132 8141-8153	0.731 0.102 0.082 0.084	7967-8161	1.000	8064±97
	45.2	SOM	1279	AA103851	8653±47	9544-9632 9645-9656	0.910 0.090	9533-9705 9721-9731	0.989 0.011	9619±86
	44.99	SOM	1278	AA103850	8810±47	9705-9722 9730-9917 10,096-10,112	0.060 0.890 0.050	9676-9963 9985-10,044 10,052-10,152	0.785 0.061 0.154	9820±144
<u>LOCUS 3</u> BHT 4, OSL										
7? 8?	50.80	Quartz	1289	UNL-3857	---	---	---	8070±380	---	---
5	50.46	Quartz	1290	UNL-3858	---	---	---	12,300±500	---	---
4	49.99	Quartz	1291	UNL-3859	---	---	---	18,000±700	---	---
Windmill Pit, ¹⁴ C										
6 black upland	47.85	SOM	26	A-15303	5600±50	6313-6411	1.000	6297-6475	1.000	6386±89
	47.75	SOM	27	A-15304	6500±80	7324-7476	1.000	7268-7519 7534-7564	0.950 0.050	7394±126
<u>BIG WASH</u> 15-2, ¹⁴ C										
6 black upland	40.80 ⁴	SOM	1331	AA106885	6126±28	6948-7020 7123-7151	0.749 0.251	6938-7157	1.000	7048±110

¹ SOM = soil organic matter
² Units 5-1, 5-3 & core 10-2/3
³ Sediment associated with bone; Split of same sample; charcoal was mixed in with sediment
⁴ Estimate derived from a GPS coordinate in feet

Table 3. Projectile Points recovered from Water Canyon site.

Point Type	Cultural Period	Provenience	Frequency	Comments
Clovis	Paleoindian	Locus 3 / surface	1	Base; rhyo-dacite
Clovis	Paleoindian	Locus 3 / surface	1	Complete; small; silicified rhyolite
Folsom	Paleoindian	Locus 6 / surface	1	Base / silicified rhyolite
Folsom	Paleoindian	Loci 3, 6 / surface	2	Fragment / silicified rhyolite
Eden / Firstview	Late Paleoindian	Locus 5 / In situ, sub-surface	1	Complete, resharpened, broken tip; quartzite
Eden / Firstview	Late Paleoindian	Locus 4 / surface	1	Base, silicified rhyolite
Undetermined	Late Paleoindian (probable)	Locus 4 / surface	1	Preform; shallow, convex-sided, concave base; preform; quartzite
Undetermined	Late Paleoindian (probable)	Locus 3 / surface	2	Small; parallel-sided; shallow, concave bases; 1 black chert complete but heavily resharpened; other obsidian lateral fragment; similar to Angostura, Golondrina, Belen, St. Mary's Hall
Gypsum	Archaic	Loci 2, 3 / surface	2	Stemmed; made on flakes
Armijo	Archaic	Loci 1, 4 / surface	2	Concave base

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

158x204mm (200 x 200 DPI)

Figure 2. Topographic map of the Water Canyon site showing locations of: (A) Loci, soil sections, and lines of sections A-A' (Figure 7) and B-B' (Figure 8) and (B) excavation blocks and backhoe trenches (BHT). See Figure S1 for locations of all cores.

158x204mm (200 x 200 DPI)

Figure 3. Views overlooking the Water Canyon site. (A) View to the north with excavations under way in Locus 1. The area from the foreground north to Big Wash is the surface of the Terminal Pleistocene/Holocene fan encasing the buried archaeological materials, inset well below the surface of the Pleistocene bajada where Locus 6 is situated. (B) View east down No Name Arroyo at the head of the Terminal Pleistocene/Holocene fan showing the exposure of Strata 4, 6, and 8 (with 6 pinching out against 4) at section 10-30 with Locus 1N immediately beyond and the north end of BHT 6 (Figure 2B) visible at right center. Exposure of Unit 1-47 in Locus 1N (Figure 2B) is on the opposite arroyo wall.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

Figure 4. Late Pleistocene and early Holocene landscape evolution sequence. (A) Original Magdalena fan (bajada) surface on Stratum 1 at > 100 kya. (B) Paleo-channel incises Stratum 1 at >42.0k yr BP; Stratum 2 sediments fill paleo-channel at ~40.0k years BP. (C) Paleo-channel incises Stratum 2 at <40.0 kya; Stratum 3 sediments fill paleo-channel at ~30.0 kya. (D) Initial incision of Big Wash between ~30.8k and ~18.0k years BP. (E) Initial incision of No Name Arroyo at <18k years BP; Deposition of Stratum 4 at or <18.0k years BP. (F) Shallow bench cut on Stratum 4 then deep incision of Stratum 4 at <18.0k years BP. (G) Construction of Stratum 5 fan at <18.0k to >13.0k cal years BP. (H) Paludal deposition of Stratum 6 at ~13.1k through ~ 8.0k cal years BP. (I) Deposition and erosion of Strata 7 and 8 from ~8.0k cal years BP to present.

215x279mm (300 x 300 DPI)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

South

match

North

Sand
and
Gravel

Mud

Silty
Clay
Loam

Sandy
Clay
Loam

A Bt Bk
Soil Horizons

OSL

0 1m

Figure 6. (A) The west wall of the Locus 5 excavation block (Figure 2B) illustrating the stratigraphic relationships of Strata 6 (black and gray facies), 7, and 8, and paleo-arroyo. (B) Close-up of the excavations (Units 5-1, 5-6 and 5-8) and profile in the southwest corner of the Locality 5 excavations (keyed to Figure 6A), illustrating the bottom of paleo-arroyo infilled with laminated sediments of Stratum 8 and inset into Stratum 6, a portion of the Bison sp. bone bed (Unit 5-8), and Stratum 5 cobbles beneath the black facies of Stratum 6.

Figure 6. (A) The west wall of the Locus 5 excavation block (Figure 2B) illustrating the stratigraphic relationships of Strata 6 (black and gray facies), 7, and 8, and paleo-arroyo. (B) Close-up of the excavations (Units 5-1, 5-6 and 5-8) and profile in the southwest corner of the Locality 5 excavations (keyed to Figure 6A), illustrating the bottom of paleo-arroyo infilled with laminated sediments of Stratum 8 and inset into Stratum 6, a portion of the *Bison* sp. bone bed (Unit 5-8), and Stratum 5 cobbles beneath the black facies of Stratum 6.

GEOARCHAEOLOGY OF THE WATER CANYON PALEOINDIAN SITE, WEST-CENTRAL NEW MEXICO

by Vance T. Holliday^{1*}, Robert D. Dello-Russo², and Susan M. Mentzer³

¹School of Anthropology & Department of Geosciences, University of Arizona, Tucson, Arizona

²Office of Contract Archaeology, University of New Mexico, Albuquerque, New Mexico

³Institute of Archaeological Sciences, Eberhard Karls University of Tübingen, Tübingen, Germany

*Corresponding author: Vance T. Holliday, vthollid@email.arizona.edu

Abstract

Water Canyon is a rare buried, multi-component, stratified Paleoindian site in west-central New Mexico. This paper presents a geoarchaeological assessment of the site as part of a broader interdisciplinary investigation of the site's landscape evolution, geochronology, paleoenvironmental history, and archaeology during the Paleoindian occupation. The archaeology is associated with ancient wetland deposits (Stratum 6) within an alluvial fan. The fan formed initially through the late Pleistocene. Formation of the fan stopped and wetland deposition began ~11,310 ¹⁴C yr BP (~13,170 cal yr BP). Stratum 6 evolved via wetland deposition and cut-and-fill cycles. The bulk of Stratum 6 dates <10,300 ¹⁴C yr BP (<12,200 cal yr BP). One, or possibly two, beds of bison bone, likely processing-stations, were found on the margin of the paleo-wetland and date to ~9200 ¹⁴C yr BP (~10,400 cal yr BP) (lower bone bed) and ~8200 ¹⁴C yr BP (~9150 cal yr BP) (upper bone bed). Farther out in the paleo-wetland a

probable kill site was discovered with an in situ Eden projectile point dated to at least ~8955 ¹⁴C yr BP (~10,070 cal yr BP). The wetland landscape returned to an alluvial fan system <8000 ¹⁴C yr BP (<8900 cal yr BP) with two more cycles of fan deposition by ~6500 cal yr.

Key Words: alluvial fan; paleo-wetland; bison kill; bison processing; Paleoindian; Eden point

1 INTRODUCTION

Paleoindian archaeological research in North America has been significantly influenced by work in the greater Southwest and neighboring areas¹. The Folsom type site, which resolved the debate over a late Pleistocene human presence in the Americas, is in northeast New Mexico (Figgins 1927; Meltzer 2006). The Clovis type site at Blackwater Draw, with a rich record of long-term Paleoindian occupation that established the classic Clovis-Folsom-unfluted artifact sequence, is in east-central New Mexico (Hester 1972; Howard 1933, 1935). In the heart of the Southwest, *in situ*, stratified Paleoindian sites are rare. Exceptions include the San Pedro River valley in southeastern Arizona, with at least four Clovis mammoth kills (e.g. Haynes and Huckell 2007), and in northern Sonora, Mexico, a Clovis-gomphothere kill and camp site is reported (Sanchez et al. 2014). To the north, in the San Luis Valley of Colorado, are Folsom age bison kill /

¹ Geologically, the Basin and Range country west of the Pecos River Valley to the foot of the Sierra Nevada is one definition of the Southwest in the U.S. More informally, Reed (1964) offers a useful shorthand definition of the Southwest as extending from Durango, Colorado, to Durango, Mexico, and from Las Vegas, New Mexico, to Las Vegas, Nevada.

1
2
3 campsites, such as Stewart's Cattle Guard site (Jodry 1999).
4

5
6 Paleoindian archaeology in the American Southwest is challenged by the rarity of
7
8 terminal Pleistocene and early Holocene paleoenvironmental data from continuous
9
10 stratigraphic sequences. Except for Clovis mammoth hunting, the chronologies for artifacts and
11
12 occupations and the nature of subsistence activities must often be inferred from neighboring
13
14 regions, usually the Great Plains to the east (e.g., Haynes 1975; Johnson 1987; Holliday 2000;
15
16 Meltzer 2006; Haynes and Warnica 2012). The region's paleovegetation and paleoclimate data
17
18 tend to come from discontinuous records (e.g., packrat middens) and the sources of both types
19
20 of paleoenvironmental data are widely scattered.
21
22
23

24
25 Here we report on the Water Canyon site in west-central New Mexico (Figure 1) (Dello-
26
27 Russo et al. 2010). The site is unusual in the region, yielding evidence for multiple Paleoindian
28
29 activity areas spanning the period from ~11,000 to ~8300 radiocarbon years before present
30
31 (^{14}C yr BP) or ~13,000 to ~9200 calendar years before present (cal yr BP). Bone and stone
32
33 artifacts, plant remains, and other classes of paleoenvironmental proxy data such as pollen,
34
35 phytoliths, diatoms, stable carbon isotopes and land snails, were recovered from stratified,
36
37 dateable deposits (Dello-Russo 2010, 2012, 2015; Dello-Russo et al. 2016a, 2016b). The *in situ*
38
39 Paleoindian components, buried in wetland deposits, are immediately adjacent to upland
40
41 surfaces with additional evidence for Paleoindian activities. This paper focuses primarily on the
42
43 stratigraphic and geochronologic record as they inform on the landscape evolution of the site
44
45 and archaeological formation processes.
46
47
48
49
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1.1 Site Location and Setting

The Water Canyon site is in west-central New Mexico on the southeast side of the La Jencia Basin just west of the Socorro Mountains and at the toe of an extensive bajada on the northeast side of the Magdalena Mountains (Figure 1). The site is along a tributary of the Water Canyon drainage which is, in turn, part of a tributary system of the Rio Grande (Machette 1988). The Water Canyon drainage heads on the northeast side of the Magdalena Mountains and flows east then north across a broad bajada (coalesced alluvial fans). Water Canyon joins South Canyon southeast of and upstream from the Water Canyon site. The combined drainage flows northeast and divides the Socorro Mountains and the Lemitar Mountains, at which point the drainage becomes Nogal Canyon and flows east to join the Rio Grande north of the city of Socorro. The mountains are composed of Oligocene volcanic rock. The volcanism and subsequent faulting, uplift of the mountains, and dropping of the basin are linked to the evolution of the Rio Grande Rift (Chapin et al. 2004; Hawley 2005).

The bajada with the Water Canyon site is known locally as the Water Canyon fan (Chamberlin and Osburn, 2006), but is referred to in this paper as the Water Canyon bajada. The site is currently dissected by three arroyos that formed in and emanate from a series of swales incised into the toe of this bajada (Figures 2, 3A, 3B). “No Name Arroyo”, formed in “No Name Swale”, is the middle of the three and cuts through the middle of the site exposing black paludal muds that led to the discovery of the Paleoindian-age bone and associated artifacts

(Dello-Russo 2010). A smaller, unnamed arroyo occurs in the southeastern portion of the site. The north side of the site is cut by "Big Wash." Big Wash and No Name Arroyo converge in the eastern portion of the site. The combined drainages meet the unnamed arroyo at the far eastern edge of the site. From there the drainage flows east another 500 meters to join the main Water Canyon drainage. The site formed where the three aforementioned drainages emerge from narrow arroyos cut into the old bajada deposits.

2 FIELD AND ANALYTICAL METHODS

The geological and geoarchaeological investigations in and near the Water Canyon site included the recognition and mapping of landforms, and the examination, documentation, and dating of the stratigraphic record. All exposures and cores were measured and described using standard geologic and pedologic nomenclature and conventions (Table 1) (AGI 1982; Birkeland 1999; Holliday 2004). The site covers an area of over 9 hectares and is divided into seven "loci" (Figures 2, 3A). Stratigraphic exposures were available from archaeological hand-excavations in three loci (1, 3, and 5); six backhoe trenches (BHT-1, -2, -3 and -6 in Locus 1; BHT-4 in Locus 3; and BHT-5 in Locus 2), 75 cores (via Giddings coring rig), hand augers, and the three arroyos that cut across the site (Figures 2, 3A, 3B, S1). Numerous pollen and radiocarbon samples, together with a few bone samples, were recovered from these various exposures. A micromorphological study of sediments was carried out in Locus 1 (Supporting Information). Most of the archaeological excavations focused on Locus 1 North, along two sides of No Name

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Arroyo, and in a 12 x 12 m pit in Locus 5.

Assessing the chronology of the cultural deposits and the site stratigraphy was accomplished using radiocarbon and optically stimulated luminescence (OSL) dating techniques (Table 2). Radiocarbon ages were determined for soil organic matter (SOM) from buried soil horizons and organic-rich sediments, as well as for charcoal and bone collagen samples. The radiocarbon dating of organic-rich sediments can be somewhat problematic owing to the potential for contamination by younger humic acids (Martin and Johnson 1995; Abbot and Stafford 1996; McGeehin et al. 2001) but, with proper pretreatment, these materials can provide accurate, reproducible, stratigraphically consistent age control, especially in drier environments (e.g., Haas et al. 1986; Holliday et al. 1994, 1996; Quade et al. 1998; Rawling et al. 2003; Mayer and Mahan 2004). The Water Canyon SOM samples underwent a standard acid-base-acid treatment to remove carbonate and isolate specific fractions of organic matter (after Abbot and Stafford 1996). Radiocarbon ages were determined for the residue (NaOH insoluble) and humic acid (NaOH soluble) fractions using 1) the liquid scintillation method at the University of Arizona Isotope Geochemistry Laboratory (i.e., conventional radiocarbon; A-#s), and 2) accelerator mass spectrometry (AMS) at the NSF - Arizona AMS Laboratory (AA#s), the Beta Analytic, Inc. laboratory (Beta #s), Pennsylvania State University (PSU-#s), and the International Chemical Analysis laboratory (16OS/ and 16B/#s). Radiocarbon ages were corrected for isotopic fractionation and are presented as uncalibrated radiocarbon years before present (¹⁴C yr BP) in the text and in Table 2. Calibrated ages and statistical means were

determined using the CALIB 7.0.4 program (Stuiver and Reimer 1993) and the IntCal 13.14c database.

Dating by optically stimulated luminescence (OSL) was carried out on sediment samples by the University of Nebraska – Lincoln (UNL- #s; Goble 2014, 2015) and Utah State University (USU- #s; Rittenour 2011) (Tables 2, S1, S2). OSL ages are given simply as calendar years (yr) in the text. Calibrated radiocarbon years are considered to be equivalent to OSL calendar years-

3 RESULTS OF GEOLOGICAL STUDIES

The landforms and strata at the Water Canyon site can be grouped into two categories defined by age: those created during the older Pleistocene (defined here as Last Glacial Maximum [LGM] and older), including Strata 1, 2, 3, and 4; and landforms and more localized strata created in the terminal Pleistocene and early Holocene (TPEH) and later Holocene epochs (<18,000 yr), consisting of Strata 5, 6, 7 and 8, which are inset against the older strata.

3.1 Older Deposits and Landforms

3.1.1 Strata 1, 2, and 3

The topographic setting in the immediate area of the Water Canyon site is directly or indirectly related to geomorphic processes that created and modified the large, prominent Water Canyon bajada that characterizes the landscape of the southern La Jencia Basin (Figures 1, 3A). As noted, the arroyos that dissect the site are parts of drainages incised into the lower

end, or toe, of the Water Canyon bajada. The uplands north of Big Wash and Locus 3, those southwest of Locus 4, west of Locus 1, and the surface of Locus 6, represent the surface of the toe of the Water Canyon bajada (Figure 4A). The bajada sediments (Stratum 1) consist of “poorly to moderately sorted, bouldery to cobbly, volcanic-rich gravel, gravelly sand and muddy silts. [They are] generally reddish orange to reddish brown, locally light brown to tan in color [and are] mostly non-indurated, however, the uppermost beds beneath its graded surfaces are variably cemented by pedogenic carbonate horizons approximately 0.6 m to 0.1 m thick” (Chamberlin 2005:6). The surface sediments have undergone some modification in the immediate site area where they are characterized by carbonate-engulfed gravel. Less than a kilometer to the west, the Water Canyon bajada surface is covered by sandy fines that display an exceptionally well-developed soil (Bt horizon with red color almost 2.5YR, pervasive illuvial clay, strong structure, and a Bk horizon with Stage III carbonate development). Because the carbonate forms beneath the Bt horizon (Machette 1988), the areas of exposed carbonate on the fan surface (e.g., the surface of Locus 6) are indicative of erosion of the less resistant Bt horizon.

The age of the Water Canyon bajada is estimated at >500,000 to 25,000 years old based on the degree of development of surface and buried soils nearby and radiometric age control elsewhere (Machette 1988). Bajada construction probably ended when drainages in the La Jencia Basin began to erode the Rio Grande shield in the La Jencia Basin (Machette 1988). The Rio Grande shield is a large, flat, low-relief area that covers the entire La Jencia Basin (Machette 1988). The Rio Grande shield is a large, flat, low-relief area that covers the entire La Jencia Basin (Machette 1988).

broader bajada surfaces to the north, west and south (Figures 2, 3A). The archaeological materials at Locus 2 are emplaced on this younger surface which is expressed as a narrow, flat ridge roughly two to three meters below the local bajada surface. This surface was created when the upper portions of the older bajada deposits were eroded. The sediments underlying this ridge represent an early episode of filling (Stratum 2) following incision of the bajada surface sometime before 42,000 years ago (Figure 4B; see OSL discussion below). Backhoe trench 5 (BHT-5; Figure 2B) exposed a paleochannel in the Stratum 2 fill below this surface (Figure 4C). Designated as Stratum 3, the fill in this paleochannel includes sandy, loamy and slightly gravelly alluvium inset into the older, coarse, well-sorted and well-rounded gravel of Stratum 2. Minimal soil development on this surface suggests that Locus 2 has been undergoing continued erosion.

Two OSL ages on the sand indicate that both strata below the Locus 2 surface are pre-LGM in age. The age of Stratum 2 alluvium ranges between ~32,000 and 41,000 yr and the age of the inset Stratum 3 sediment is between ~29,100 and 37,500 yr (Table 2). The ages appear to be reasonable given the estimated age of the stratigraphically older bajada surface (Middle Pleistocene) and the dating of the younger terminal Pleistocene fill (discussed below).

3.1.2 Stratum 4

Stratum 4 is topographically lower than Strata 1, 2, and 3, inset against the eroded toe of the bajada (Figures 4E). It consists of sandy and pebbly alluvium with more local clayey

1
2
3 facies. A strongly developed soil (Bt horizon with 7.5YR hues and thick, continuous clay films,
4
5 and pervasive carbonate coatings on ped faces) formed through most of the stratum. Stratum 4
6
7 is most obvious on the south side of the site. It is found along the southwest margin of Locus 1
8
9 (Locus 1 South), at the foot of the scarp that leads up to the old bajada surface, exposed in
10
11 BHT-6 (Figure 5) and in cores through the area (Figure S1). It is inferred to be present to the
12
13 south in Locus 4 based on an exposure in the unnamed arroyo that separates Locus 1 from
14
15 Locus 4.
16
17
18
19

20 In Locus 1 South the top of Stratum 4 forms a bench, likely an alluvial terrace, almost
21
22 imperceptible topographically (Figure 5). This bench was initially recognized because of the
23
24 dense concentration of coarse gravel at the surface along with a high concentration of lithic
25
26 artifacts, including conjoining fragments of a probable Paleoindian projectile point and related
27
28 artifacts. The layer of gravel with the artifacts rests on Stratum 4 and its associated soil.
29
30
31

32 The dating of Strata 2 and 3 suggests that Stratum 4 is <30k years old, assuming that the
33
34 OSL dating in Locus 2 is accurate. Unweathered alluvium at the base of Stratum 4 (below the
35
36 Stratum 4 soil) in BHT-6 yielded an OSL date of ~18,000 yr (Table 2). This date could be accurate
37
38 or it is a minimum age. The degree of development of the soil formed in Stratum 4 suggests
39
40 that the surface stabilized and then underwent pedogenesis for at least a few tens of
41
42 thousands of years, based on dating of soils in similar settings across the Southwestern U.S.
43
44 (Gile et al. 1981; Machette 1988; Birkeland 1999; Holliday 2004). Stratum 4 is also present near
45
46 the north end of the site in Locus 3 and was exposed in BHT-4. At the base of the sequence in
47
48 BHT-4 is a reddish sandy layer that yielded another OSL date of ~18,000 yr (Table 2). Soil
49
50 development in
51
52
53
54
55
56

1
2
3 this deposit and the OSL dating at the base of the deposit indicate that this layer is equivalent
4
5 to Stratum 4 in Locus 1 South. These dates suggest that there must have been an additional
6
7 phase of local (if not regional) deep incision between ~30,800 and ~18,000 yr.
8
9

10 The gravel layer on the bench in Locus 1 South and resting on the Stratum 4 soil may be
11
12 entirely redeposited from the adjacent scarp and bajada surface, but more likely the gravel was
13
14 in place on the bench. The artifacts on that bench probably represent in situ occupation
15
16 because the archaeological debris is continuous from Locus 1 South to and across Locus 1
17
18 North. Artifacts within the gravel may have been mixed in via bioturbation and soil shrink-
19
20 swell.
21
22
23
24
25
26

27 **3.2 Terminal Pleistocene and Holocene Deposits**

28
29
30 The TPEH deposits at the Water Canyon site are the focus of our research. They contain
31
32 the *in situ* archaeological record at the site. The deposits are divided into five stratigraphic
33
34 units: four lithostratigraphic units (5, 6, 7, and 8) and one soil-stratigraphic unit (the La Jencia
35
36 Soil). Facies of the strata are defined on the basis of lithological characteristics or color or both.
37
38 Color variation includes post-depositional alteration, primarily by groundwater modification.
39
40
41
42
43
44

45 **3.2.1 Stratum 5**

46
47 Stratum 5 is a pebbly to gravelly to cobbly and locally sandy deposit that underlies
48
49 Stratum 6 throughout much of the site. Data from Locus 1 suggest that Stratum 5 deposits are
50
51 inset against Stratum 4 in a channel cut below Stratum 4 (Figure 4G). Exposures of Stratum 5
52
53
54

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

were limited to Unit 1-6 in Locus 1 and adjacent No Name Arroyo walls (Figure 3B), and in Unit 5-1 of the Locus 5 excavation block (Figure 6B). The coring rig rarely penetrated deeply into the gravel and, therefore, we could not determine the thickness of the deposit in most cores nor the character of it or its underlying deposits.

Stratum 5 is complex topographically, stratigraphically, and geochronologically. For example, where initially observed along No Name Arroyo (Units 1-6 and 1-5 in Locus 1 North), the top of Stratum 5 gravel is at 47.00 m and 47.03 m grid elevation, respectively. But 10 meters to the northeast, in the southwest corner of the deep Locus 5 excavation block (Unit 5-1), the top of the gravel is at 45.39 m grid elevation (Figures 6B, 7). Similarly, running from Locus 1 North to the east-southeast (based on coring) elevations for the contact between the top of Stratum 5 and the base of overlying Stratum 6 show a dramatic change in elevation of almost 4 meters (Figure 8). The mud of Stratum 6 engulfs the Stratum 5 gravel in some areas of the site (Locus 1: Cores 9-2, -6, -7, -10, -15, -18; Locus 3: Cores 10-15, -17; Locus 5: southwest corner of main pit and Core 10-10). In contrast, in BHT-4, cut across Locus 3, a time-stratigraphic valley-margin equivalent is composed of gravelly sand that is likely from slope wash based on thickening and facies changes toward the old bajada uplands (Figure 9).

The age and sequence of Stratum 5 deposition is difficult to interpret, limiting our understanding of the site formation processes. The estimated age range of the deposit can only be based on dates from above and below. As noted previously, the two OSL ages from the older (pre-TPEH) Stratum 4 deposits in Locus 1 (BHT-6; Figure 5; UNL-3856) and Locus 3 (BHT-4;

Figure 9; UNL-3859) provide an approximate minimum age for the base of Stratum 5 at ~18,000 yr (Table 2). The oldest radiocarbon age for overlying Stratum 6 is ~11,310 ¹⁴C yr BP (~13,170 cal yr BP).

As a whole, the paleo-topographic expression of Stratum 5 is that of an alluvial fan (Figure 4G). Elevations on top of Stratum 5 in and near Locus 1 and Locus 5 show that, at the mouth of the No Name Swale, Stratum 5 slopes down by several meters to the northeast across Locus 5 and to the southeast away from Locus 1; i.e., it has the shape of a fan with apex at the mouth of No Name Swale. The layer varies in content of sand, pebbles, and gravel, and degree of sorting from exposure to exposure. Alluvial fans are characterized by cut-and-fill cycles and that could account for the dramatic variability in lithology. Big Swale has a larger drainage area than No Name and likely contributed to deposition and erosion of Stratum 5. But very little of our stratigraphic or geochronological data can be directly linked to alluvial processes in Big Wash because very little late Quaternary fill is preserved there.

3.2.2 Stratum 6

Stratum 6 contains most of the archaeological remains recovered *in situ* at the Water Canyon site, primarily in Locus 1 North and Locus 5. It is up to ~200 cm thick and is primarily a dark gray to black mud, but there are several facies. Lighter gray and olive green facies are locally common as is an upland soil facies. In some areas of the site the mud encases underlying gravel, producing a mix (vertical facies) of Strata 5 and 6. Along the margins of the site there is

also an upland soil facies. Stratum 6 in at least one of its facies was found everywhere across the site except at the far east central portion of the site, east of Locus 1 and north of Locus 4 (Cores 10-23 to 29), due to erosion. One of the thickest and most complete sections of Stratum 6 is located in and just east of Locus 5. Stratum 6 rests unconformably on Stratum 5 and is locally inset against it or Stratum 4. Along No Name Arroyo and south across Locus 1, Stratum 6 is both atop and inset into Strata 4 and 5 (Figures 3B, 5, 7).

The dark gray-to-black mud facies of Stratum 6 with its distinctive color and presence of bone, is the most ubiquitous stratigraphic marker at the site (Figure 10). The dark color, fine-grained lithology, based on field texture and micromorphology (below and Supporting Information), and dating suggest slow aggradation of fines under conditions of high biological activity. The dark, subdued coloration and apparent biological activity tends to inhibit evidence for physical weathering such as root casts or cracking.

The olive green facies is a local biochemical alteration of Stratum 6. Where observed, the olive green facies is always below the black/dark gray facies and just above the gravel of Stratum 5 (Figure 10). The colors (gleyed or low chroma) are typical of reducing conditions in the presence of a high water table and abundant organic matter (Schaetzl and Thompson 2015: 483). The absence of mottled redoximorphic features (i.e., colors of both reduced and oxidized iron) are indicative of year-round saturation rather than seasonal water table fluctuation (Schaetzl and Thompson 2015: 356-358, 484). The gleyed facies is common only in the area of Locus 1 and to the southeast of Locus 1, but also minimally present far to the northeast along

1
2
3 Big Wash (section 12-9) and in an abandoned pit by an old windmill (Windmill Pit, Figure 2A).

4
5 This patterning puts the gleyed facies in proximity to the older pre-TPH gravels and the bajada
6
7
8 gravels, which, along with flow down the local drainages, could have been a source of seep or
9
10 spring water that kept Stratum 6 saturated along the site margins.
11

12
13 The micromorphological analyses of thin sections collected in the Locus 1 excavation
14
15 block provide some clues to the origin of Stratum 6 (Supporting Information). The thin sections
16
17 (Figures S4-S11) show that there are subtle differences in the lithology of Stratum 6 in Locus 1,
18
19 thus we subdivide it in Locality 1 into 6A and 6B. The lower part of the layer (6A) is finer (silt
20
21 and clay), weakly laminated and pervasively gleyed. This suggests very low energy alluvial
22
23 aggradation and perhaps additions of dust followed by reduction. Upper Stratum 6 (6B) is
24
25 likewise dominated by fines and exhibits some weak bedding, but it contains some fine to
26
27 medium gravel. The coarser particles are sub-rounded to angular, suggestive of short-distance
28
29 transport.
30
31
32
33

34
35 Stratum 6B is mostly dark gray to black, but the micromorphology shows that the
36
37 gleying characteristic of 6A also crossed the boundary between 6A and 6B and modified the
38
39 lowermost portion of Stratum 6B. This discovery highlights the importance of differentiating
40
41 facies based on sedimentological characteristics from those based on post-depositional
42
43 characteristics. Stratum 6B exhibits localized gleying and some redoximorphic features,
44
45 indicative of short-term saturation. The incomplete gleying and persistence of darker
46
47 coloration is suggestive of either high original organic matter content or rapid burial shortly
48
49 after
50
51
52
53
54

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

deposition of 6B. However, development of soil structure and coatings of illuvial clay in 6B demonstrate a period of subaerial weathering of 6B prior to burial. All thin sections also provide evidence of syndepositional or post-depositional bioturbation.

The gray facies is a deposit locally above and disconformably on the black/dark gray facies. It is common in the east-central area of the site, in and around Locus 5. The gray facies of Stratum 6 are sandy and locally pebbly near the site margins, probably picking up coarser clastics as slope wash. The upper gray mud also tends to be generally sandier. Influxes of sand (probably by both eolian and slope wash processes) would dilute the organic matter content and make the color lighter. The presence of oxidized iron staining (redoximorphic features) in the exposures of upper gray muds upstream of Locus 1 in the No Name Arroyo cut banks suggests the occurrence of seasonal water table fluctuations during the early Holocene.

A well-drained upland soil facies of Stratum 6 is located on topographically slightly higher settings in the north-central portion of the site (along the northeast edge of Locus 3) and on the bench along the southeast margin of Locus 1 South (Figures 9 and 5, respectively). This upland facies is a dark gray to black soil A-horizon. The sub-horizons of this soil (formed in Stratum 4; discussed above) vary from Bk horizons in sand to a clayey, well developed Bt horizon (Table 1; Figures 5 and 9). The topographic and stratigraphic facies relationships between the black mud facies and the soil facies show well at the south end of BHT-6 in Locus 1 where the soil is formed on two levels of the bench (Figure 5). Soil formation was on stable, slightly elevated landscapes roughly contemporaneous with aggradation of the other facies in

1
2
3 lower settings.
4

5
6 Stratum 6 apparently was subjected to several phases of erosion. This interpretation is
7
8 based on the variable thickness of the layer, the abrupt and locally irregular contacts between
9
10 Stratum 6 and overlying Stratum 7, the local presence of gravel lenses within Stratum 6 and on
11
12 the Strata 6/7 contact, and radiocarbon dating. Otherwise, erosional contacts within Stratum 6
13
14 are difficult to identify due to the uniformly dark coloration which, as noted, obscures contacts
15
16 such as erosional surfaces. In the exposure along the north side of No Name Arroyo, in the area
17
18 of Locus 1 North and in the Locus 5 deep excavation block, at least one disconformity was
19
20 observed within the gray facies of Stratum 6. More prominent is a disconformity at the top of
21
22 Stratum 6 in Loci 1 and 5 and a disconformity cross-cutting Stratum 6 in the south and west
23
24 walls of Locus 5. The latter erosion is due to the action of a re-routed paleo-arroyo (an earlier
25
26 version of No Name Arroyo, discussed more fully below) that cut down through Stratum 6 and
27
28 subsequently filled with Stratum 8.
29
30
31
32
33

34
35 The radiocarbon age estimates for the base of the Stratum 6 muds, either resting on top
36
37 of the Stratum 5 gravel or encasing it, tend to be in the range of ~10,000 to ~9500 ^{14}C yr BP
38
39 (~11,450 to ~10,800 cal yr BP) across much of the site (Table 2). There are several significant
40
41 exceptions to this trend, however. In Locus 1, on top of the Stratum 5 fan, the base of Stratum
42
43 6 yielded dates of 11,310 and 11,030 ^{14}C yr BP (~13,170 and ~12,895 cal yr BP). Just northeast
44
45 in the Locus 5 excavation block, lower Stratum 6 is dated 10,280 to 10,000 ^{14}C yr BP (~12,005
46
47 and ~11,450 cal yr BP). Along the northeast margin of the site in or near Big Wash the base of
48
49
50
51

Stratum 6 dates to ~8810 ¹⁴C yr BP (~9820 cal yr BP). Further, dating and distribution of bone and lithic artifacts in Locus 1 North suggest an unconformity in the range of ~9200 to ~8300 ¹⁴C yr BP (~10,390 to ~9100 cal yr BP) (Figure 11). All of these ranges in radiocarbon ages suggest several episodes of significant erosion and incision. The earliest phase of erosion isolated, and left in place, a small pocket of Clovis-age muds in Locus 1 just beyond the mouth of No Name Swale and on top of the Stratum 5 fan. This erosion may have been between ~11,000 and ~10,360 ¹⁴C yr BP (~12,890 and ~12,240 cal yr BP) given the absence of dates in this age span across the remainder of site. Another cycle of erosion apparently was relatively widespread, given the extent of basal dates in the range of ~10,000 to ~9500 ¹⁴C yr BP (~11,450 to ~10,800 cal yr BP) across the site. The degree of erosion is highlighted by the topographically lowest component of Stratum 6 in Core 10-26, downstream (~130 meters) far to the east of Locus 1 and at grid elevation 41.8 m (compared to 47.0 m in Locus 1 and 46.2 m in core 9-10) (Figure 8). The base of Stratum 6 in that core dates to ~9745 ¹⁴C yr BP (~11,170 cal yr BP). Sedimentation resumed, and then another phase of erosion ensued along Big Wash >8810 ¹⁴C yr BP (~9820 cal yr BP) and then along paleo-No Name Arroyo >8300 ¹⁴C yr BP (>9100 cal yr BP).

In Locus 5, the Stratum 6 black facies began to develop by ~10,280 ¹⁴C yr BP (~12,005 cal yr BP), which is older than some of the dating of the gleyed facies in Locus 1. The gleyed facies of Stratum 6 in Locus 1 and elsewhere in the site likely started as the black facies (the presence of abundant organic matter would help drive the gleying, as noted above). The process of gleying, therefore may have begun after ~10,280 ¹⁴C yr BP, but it is not isochronous across the

1
2
3 site. The gleyed facies at the base of Stratum 6 in Section 12-9 along Big Wash is dated to
4 ~8810 ^{14}C yr BP (~9820 cal yr BP), but the gleying could post-date the carbon that was dated.
5
6
7

8 The transition of the black facies to the gray facies is not well dated, but numerical age
9 estimates in Loci 1 and 5, and in Core 10-7 (Figures 2A, S1; Table 2), provide some clues. In
10 Locus 1, Unit 1-9, the upper black facies is dated to ~9310 ^{14}C yr BP (~10,535 cal yr BP). A
11 concentration of charcoal fragments in the upper part of the gray facies, interpreted as hearth
12 Feature 1 (Unit 1-11), produced a mean date of ~8321 ^{14}C yr BP (~9365 cal yr BP). In Locus 5,
13 charcoal from the upper black facies dated ~8775 ^{14}C yr BP (~9755 cal yr BP) and charcoal from
14 the gray facies dated ~8395 ^{14}C yr BP (~9400 cal yr BP). Similarly, just east of Locus 5 in Core
15 10-7, the transition occurred between ~8630 ^{14}C yr BP (black facies) (~9660 cal yr BP) and
16 ~8305 ^{14}C yr BP (gray facies) (~9280 cal yr BP).
17
18
19
20
21
22
23
24
25
26
27
28
29

30 This transition from black to gray is usually indicated by an abrupt contact and locally
31 accompanied by gravel, thus denoting some erosion. This likely explains some of the variable
32 dating among the three areas of the site. Erosion across the top of the black facies clearly
33 provides some variability. The timing of the black-to-gray transition could also be locally
34 variable across the site depending on influx of coarse clastics. The much younger ages for the
35 two facies on Core 10-7 may also be due to unknown contaminants.
36
37
38
39
40
41
42
43
44

45 The upper gray facies of Stratum 6 yielded broadly similar dates in Loci 1 and 5 and in
46 Core 10-7: ~8395 ^{14}C yr BP (~9400 cal yr BP) in Locus 5; ~8321 ^{14}C yr BP (~9365 cal yr BP) in
47 Locus 1; and ~8050 ^{14}C yr BP (~8940 cal yr BP) in Core 10-7.
48
49
50
51
52
53
54
55
56
57
58
59
60

The age of the upland soil facies of Stratum 6 is, in part, a function of localized upland geomorphic processes. On the northeast side of Big Wash, in the Windmill Pit (Figure 2A), the upland soil facies yielded two dates of ~5600 ¹⁴C yr BP (~6385 cal yr BP) (upper) and ~6500 ¹⁴C yr BP (~7395 cal yr BP) (lower). Downstream from the Windmill Pit, approximately 320 meters along Big Wash (section 15-20, a black mud facies produced a date of ~6125 ¹⁴C yr BP (~7050 yr BP). This could indicate that the black, upland soil on the north side of Locus 3 is a facies of a younger version of the Stratum 6 black muds. Deposition of Stratum 6 spanned ~11,310 to ~8000 ¹⁴C yr BP (~13,170 to ~8900 cal yr BP). Breaks in the geochronology are indicative of erosion, in particular between ~11,030 and ~10,360 ¹⁴C yr BP (~12,895 and ~12,240 cal yr BP) and between ~9900 to ~9500 ¹⁴C yr BP (~11,310 and ~10,800 cal yr BP). These breaks and even erosion could also be due to drying conditions that precluded formation of a wetland.

3.2.3 *Strata 7 and 8*

Strata 7 and 8 are discussed together because of their similar lithologies and depositional environments. They are distinct stratigraphic entities, however. This inference is based on the presence of a mappable erosional disconformity between the two (Figure 6A). Both layers are sandy and gravelly, but fines are more common than in Strata 4 or 5 (Table 1). The exposures in the excavation block in Locus 5 show that Stratum 7 was deposited on top of the Stratum 6 gray facies following a phase of east-dipping erosion and gravel deposition across Stratum 6 (Figure 6A). A moderately well-developed soil formed in upper Stratum 7 where it is

1
2
3 unburied and in upper Stratum 8. The soil varies in thickness from 30 to >100 cm, depending on
4
5 the thickness of the parent material (i.e., the thickness of Stratum 8 or unburied Stratum 7). It
6
7 is usually a red Bt horizon that forms a distinct soil stratigraphic unit, here referred to as the La
8
9 Jencia Soil. The degree of development of this soil was one of the stratigraphic characteristics
10
11 that led to the realization that the black muds (Stratum 6) underlying Stratum 7 are of some
12
13 antiquity.
14
15
16

17
18 The thickness of the combined Strata 7 and 8 decreases to the northeast, east, and
19
20 southeast away and downstream from both Locus 1 and the mouth of No Name Arroyo
21
22 (Figures 4I, 7). Similarly, the surface of these deposits (i.e., the present-day surface of the
23
24 Water Canyon site) slopes down in the same directions, following the topography trending
25
26 downslope with the present-day No Name Arroyo. These characteristics, together with the
27
28 coarse nature of the sediments and the cut-and-fill stratigraphy, provide further indications
29
30 that these strata comprise the upper portions of an alluvial fan at the mouth of No Name
31
32 Swale.
33
34
35
36

37
38 Some cores revealed evidence of a buried soil (in the form of a Bw horizon or weakly
39
40 expressed Bt horizon) in alluvium resting on Stratum 6 and, in turn, buried by younger alluvium,
41
42 although this buried soil is not continuous across the site. In Locus 3 and Locus 1 South, the
43
44 upland facies of Stratum 6 is locally, but not completely, buried by a layer of cobbles or by finer
45
46 sediments with an A-Bt soil. The relative ubiquity and similar morphology of this covering soil,
47
48 distributed discontinuously across the site, suggests that it is the same soil in each instance. As
49
50 such, the alluvium in Loci 3 and 1 South most likely represents an eroded remnant of early
51
52
53
54

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Strata 7/8. Further, the presence of at least one buried soil shows that Strata 7/8 aggraded episodically, at least in local settings.

An ancient channel of No Name Arroyo (referred to in this paper as paleo-No Name Arroyo) cut across the middle of the Water Canyon site, down through Stratum 7 and deep into Stratum 6. It was subsequently filled with Stratum 8. This paleo-arroyo was exposed in the southwest corner of the Locus 5 excavation block (Figures 6A, 6B) and can be traced upstream to the north wall of the present-day No Name Arroyo. The north wall of the paleo-arroyo was relatively steep (i.e., as exposed on the Locus 5 block) as was the lower half of the south wall of the paleo-arroyo as exposed in the modern No Name arroyo. But on the south side of the modern arroyo and in BHT-3, erosion by the upper half of the paleo-arroyo was more nearly horizontal, cutting across the top of the Stratum 6 black facies. Where it fills the paleo-arroyo, and prior to subsequent erosion, Stratum 8 is >3 m thick. Deposition of Stratum 8 was in at least two cycles, as indicated in the Locus 5 exposure (Figure 6A). The upper deposit of Stratum 8 thins to the south and is ~1 m thick as exposed in No Name Arroyo in Locus 1 (Figure 3B) and thins to less than 1 m further to the south (Figure 5).

There are no reliable dates directly from Stratum 7 in the areas of Locus 1 or Locus 5. It is younger than the Stratum 6 gray facies (<8050 ¹⁴C yr BP; ~8940 cal yr BP) and older than Stratum 8, which is inset against it. The sheet of alluvium across the surface of Locus 3 produced an OSL age of ~8070 yr (Figure 9), further suggesting that it is a facies of Stratum 7. Stratum 8 produced a wide range of OSL dates and no radiocarbon dates. The OSL age

estimates range from ~9210 to ~8540 to ~6560 yr among the five dates from Locus 5 and one date of ~9770 yr from BHT-3 in Locus 1 (Table 2). The sequence from Locus 5 comes from the fill in the paleo-arroyo (precursor to No Name Arroyo) and also contains several reversals. Given the upper radiocarbon age of <8050 ¹⁴C yr BP from upper Stratum 6, the three OSL dates in the range of ~9770 to ~9020 yr (with large standard deviations) likely do not date the deposition of Stratum 8. Given the short transport distances of sediments in the fan and potential problems of OSL dating of alluvium (Walker 2005: 99; Bradley 2015: 97), partial bleaching is a likely problem. The same problem could also apply to the date of ~8540 yr (R. Goble, personal communication, Feb. 3, 2017). The two youngest OSL dates from the sequence, ~6480 yr from the lower paleo-arroyo fill, and ~6560 yr from the top of Stratum 8, appear to provide the best age estimates and suggest no significant break in time between deposition of lower and upper Stratum 8.

4 ARCHAEOLOGICAL SUMMARY

After the site's initial discovery, The Water Canyon site has been subjected to both archaeological survey and excavation. The artifact assemblages in surface contexts at Loci 1, 2, 3, 4, and 6 were mapped and analyzed in the field. These assemblages included hundreds of core flakes, biface thinning flakes, other debitage, projectile points, and tools. Fourteen diagnostic projectile points and point fragments were collected from the surface and one diagnostic projectile point was recovered from an *in situ* buried provenience (Table 3).

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

The faunal assemblage retrieved thus far from Locus 1 consists primarily of ~177 *Bison* *sp.* bone elements and bone fragments (of which 60 are identifiable to element), and tooth enamel pieces representing at least one bull, one to two cows, and three juveniles (Akins 2012; Dello-Russo et al. 2017). The horizontal extent of the Locus 1 faunal deposit is currently not completely defined and, although it may continue a little further to the east, no faunal remains were encountered in BHT-3, so it is likely that the majority of the assemblage has been recovered. Collagen samples from six elements have been radiocarbon dated and have returned ages ranging from ~9240 to ~8200 ¹⁴C yr BP (~10,390 to ~9150 cal yr BP) (Figure 11; Table 2), suggesting that the bone bed might represent the remains of at least two, and possibly three, chronologically separate events (Dello-Russo et al. in press).

Given these possibilities, a further exploration of the chronometrics in Locus 1 N is warranted. Three of the bone collagen radiocarbon dates from Locus 1 N (~9180 ¹⁴C yr BP, PSU-3564; ~9240, PSU-3565; ~ 9185; PSU-3566; Table 2) are from the lower bone cluster and they are statistically the same (Figure 11). These three collagen samples were subjected to ultra-filtration during pretreatment and their C/N ratios were each 2.8, indicating that the collagen in each sample was of sufficient quality to provide a reliable date. Their mean radiocarbon date (~9204 ¹⁴C yr BP ±30) is statistically different than that of the dated collagen sample in the upper portion of the bone bed (~8200, Beta 292053) (Figure 11). This suggests that the upper portion of the bone bed represents a later depositional event than the lower portion of the bone bed. It also suggests that the upper bone bed is similar, although statistically different, in

age to the Feature 1 hearth at a mean date of ~ 8321 (Figure 11). No C/N value is available for this upper bone collagen date, nor was the sample subjected to ultra-filtration during pretreatment, so it is likely that the date for this collagen sample is a little too young.

In addition, there are two other bone collagen dates in Locus 1 N (~8810, PSU-3567; ~8640, 16B/0713; Table 2) which, being only slightly different themselves ($t=4.446$), suggest a third possible bone cluster whose mean radiocarbon age (8682 ± 35) is statistically different in age than both the lower bone bed and the upper bone bed (Figure 11). The collagen sample for the ~8810 date was subjected to ultra-filtration during pretreatment, while the collagen sample for the ~8640 date was not, so the latter date is probably a little too young. The three groupings of bone, artifacts, and charcoal illustrated in a back plot (Figure 11) present hypothesized temporal relationships of cultural materials and highlight the location of 1) the disconformities that we infer to exist between the upper and lower *Bison sp.* bone beds in Stratum 6 and 2) a possible disconformity between the western *Bison sp.* bone bed and the eastern *Bison sp.* bone cluster. Given the known potential for erosional unconformities in Locus 1 N, therefore, these dates and artifact groupings may reflect the processes involved in creating the cultural deposit.

Feature 1 in Locus 1 North (Figure 11) produced a dense concentration of charcoal fragments. Ten were identified as oak, pine, Ponderosa pine, juniper, and an unknown hardwood species (McBride 2012; Davis 2012). These 10 samples returned radiocarbon ages that are statistically similar ($t=5.079$) with a pooled mean ranging from ~8307 to ~8339 ^{14}C yr BP (~9113 to ~9525 cal yr BP). Only two of the charcoal dates fall within the range of ages

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

provided by the dated bone (~8160 to ~8240 ¹⁴C yr BP) in the upper portion of the bone bed. These charcoal fragments were also directly associated with burned and calcined bone fragments, and carbonized amaranth and goosefoot seeds. From these data, we infer the past presence of a small thermal feature or hearth (Buenger 2003; c.f. Surovell et al. 2016:83) spatially associated with the uppermost portion of the Locus 1 bone bed.

The lithic artifact assemblage recovered from Locus 1 North includes 141 unutilized debitage flakes, three retouched or utilized flakes, four bifaces, and four multipurpose tools, five scrapers, and two projectile point or hafted knife fragments, as well as a small, slab grinding / anvil implement. The types of artifacts in the assemblage, together with hearth charcoal, burned/calcined bone and a number of long bones that exhibited percussion marks, bone flakes and green-bone fracture edges comprise what we infer to be the remains of one, and possibly two, open-air activity areas utilized for bison processing during the Late Paleoindian (Allen-Frederick?) and the Cody (Eden) periods (Dello-Russo et al. in press). The affiliation of the upper open-air activity area with a possible Allen-Frederick occupation and the lower activity area with a possible Cody (Eden) era occupation are based on the probable dates of the bone beds themselves, at ~8200 ¹⁴C yr BP and ~9200 ¹⁴C yr BP, respectively. No temporally diagnostic artifacts were found in direct association with either of the bone beds. The Locus 1 N Allen-Frederick era date conforms well with the 9350-7900 ¹⁴C yr BP range suggested by Pitblado (2003:112) for Allen-Frederick in the southern Rocky Mountains and the Locus 1 N Cody (Eden) date conforms well with the ~9800-8800 ¹⁴C yr BP range suggested by

Knell and Muñiz (2013:11) for Eden on the High Plains.

An additional *Bison sp.* bone bed was discovered by mechanical coring in Locus 5, at approximately 3.5 m below the present-day ground surface in the black facies of Stratum 6. Directly associated with this deposit and recovered *in situ* in hand-excavated Unit 5-1, was the resharpened Eden projectile point. This is the only diagnostic artifact recovered from Locus 5, to date. Only 10 other lithic artifacts have been recovered from Stratum 6 in Locus 5 so far. We have also recovered, to date, more than 91 faunal elements, fragments, and tooth enamel pieces from the Locus 5 *Bison sp.* bone bed. These faunal elements recovered from Locus 5 represent an unknown number of individuals and their analyses are continuing. The bone bed is thought to cover more than 50 square meters and hand excavations in this area, thus far have only opened 10 one-by-one m units.

Determining the age of the *Bison sp.* bone bed and the associated Eden point in Locus 5 has proven problematic. Samples of bison bone and teeth yielded no collagen, thus far precluding the possibility of direct dating. When the feature was first encountered in core 10-1, Stratum 6 encased the bone. Two samples were collected and the SOM was dated (Figure 12; Table 2). The samples produced two dates between ~9887 and 9640 ¹⁴C yr BP (~11,305 and ~10,975 cal yr BP), from below and above the bone, respectively. These dates are stratigraphically correct and statistically different and could, thus, be accurate. Accordingly, the age of the encased bone could be the mean of these two dates, or ~9718 ¹⁴C yr BP. However, the difference in the dating could also be in part a matter of inter-laboratory variation (Taylor

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

and Bar-Yosef 2014:147). Elsewhere in Locus 5, a similar SOM date of ~9750 ¹⁴C yr BP (~11,180 cal yr BP) from a sample taken just below the bone bed in Unit 5-1 provided confirming evidence that the bone bed was no older than this and in the range of ~9718 to ~9750 ¹⁴C yr BP. This falls at the older end of the age range for Eden points as currently known for western North America (Knell and Muñiz, 2013:11-12).

Alternatively, the Locus 5 bone bed age might be indicated by an SOM date of ~8955 ¹⁴C yr BP (~10,070 cal yr BP) determined on a sample collected near the Eden point found in the uppermost portion of the bone bed (Table 1) (Dello-Russo et al. in press). This date is well within the age range for Eden points on the northern and central Great Plains (Knell and Muñiz 2013:11-12) and within the range for Firstview points on the southern Great Plains (Holliday 2000). This leaves two scenarios for the age of the bone bed: the older dates could be due to mixing (from bison and human trampling during the kill and initial butchering and/or via bioturbation as the paleo-wetland evolved) or Eden occupations may be older in the Southwest than on the Great Plains.

5 DISCUSSION and CONCLUSIONS

The Water Canyon site is notable in the Southwest for its multiple Paleoindian occupations in an intact, stratified context (the only such documented Paleoindian site in New Mexico west of the Pecos River), its multiple *Bison sp.* bone beds, and its extensive paleo-wetland with abundant paleoclimatic and paleoenvironmental proxy data. The Water Canyon

1
2
3 site is also unusual in being one of the few Paleoindian sites preserved in an alluvial fan. The
4
5 site formed at the mouths of several swales cut into the distal toe of the old bajada flanking
6
7 the Magdalena Mountains and emptying into the Water Canyon drainage (Figure 4).
8
9

10 Archaeological materials are found at the surface on older, stable coalesced fan surfaces and
11
12 on stable surfaces formed on Late Pleistocene sediments inset against those older fan surfaces.
13
14

15 Buried, *in situ* cultural deposits are found in a paludal deposit that formed in the fans of
16
17 intermittent drainages, here identified as No Name Arroyo and Big Wash.
18
19

20 **5.1 Soils and Geomorphology**

21

22 Incision of the main Water Canyon bajada (Stratum 1) likely began sometime before
23
24 42,000 years ago and the initial formation of the site landscape (cutting and filling associated
25
26 with deposition of Strata 2 and 3) probably took place ~30,000 years ago (Figure 4). Deep
27
28 incision then followed and there was at least one phase of alluvial deposition (Stratum 4) inset
29
30 against the original Water Canyon bajada. This deposit is dated to ~18,000 yr, but soil
31
32 development suggests that it could be older. It was incised and left as remnant benches in
33
34 Locus 1 South and in Locus 3 (Figure 4). Stratum 5 alluvium is inset against Stratum 4.
35
36
37
38
39

40 Buried, *in situ* archaeological deposits are found in paludal mud (Stratum 6). The most
41
42 common facies is black to very dark gray, but an underlying olive green or gleyed facies is
43
44 present atop Stratum 5 gravels, and a lighter gray facies is on top of the black facies. The
45
46 darker colors and fine-grained nature of much of Stratum 6 suggest the slow aggradation of
47
48 fines, including alluvium and perhaps dust, under wetland conditions. The green coloration
49
50
51
52 seen
53
54

locally in Stratum 6 is due to iron reduction (gleying) under conditions of a high water table and abundant organic matter. The gleying is likely post-depositional and, in at least Locus 1, was superimposed over at least one older disconformity within Stratum 6. The gleying is apparent along the southern flank and, to an extremely limited extent, along the northern flank of the site in proximity to the eroded margins of the bajada. The grayer facies is somewhat sandier than the black and green facies and likely represents a period of aggradation with more coarse alluvial and possibly eolian clastics, diluting the input of organic remains.

Stratum 6 does not represent uninterrupted sedimentation. Several disconformities are apparent. The oldest muds, dated $\sim 11,310$ to $\sim 11,030$ ^{14}C yr BP ($\sim 13,170$ to $\sim 12,895$ cal yr BP) and $< \sim 10,365$ ^{14}C yr BP ($\sim 12,240$ cal yr BP), are in Locus 1, on a high bench of Stratum 5 gravel, and suggest several cycles of erosion just before and during the Younger Dryas Chronozone of the Terminal Pleistocene. Above those deposits are more Stratum 6 muds and sandy muds dated ~ 9750 to ~ 9200 ^{14}C yr BP ($\sim 11,180$ to $\sim 10,390$ cal yr BP) and to $< \sim 8321$ ^{14}C yr BP (~ 9365 cal yr BP). Elsewhere in the site, the oldest Stratum 6 deposits are slightly older than $\sim 10,280$ ^{14}C yr BP ($\sim 12,005$ cal yr BP) (Locus 5) and are on topographically lower Stratum 5 gravel. Thus, the oldest Stratum 6 deposits were removed from much of the site by erosion. In particular, Folsom-age (i.e., dating to the Younger Dryas Chronozone) and older deposits are largely missing with the exception of those on the high bench of Stratum 5 gravel. Mud deposition in Locus 5 then resumed after $\sim 10,280$ ^{14}C yr BP ($\sim 12,005$ cal yr BP) and continued until $< \sim 8395$ ^{14}C yr BP (~ 9400 cal yr BP). Away from Loci 1 and 5, another cycle of erosion was relatively

widespread, given the extent of basal dates in the range of ~9900 to ~9500 ¹⁴C yr BP (~11,310 and ~10,800 cal yr BP) across the site, i.e., there was erosion just prior to that time. The youngest deposit of Stratum 6 is the younger sandy gray facies, dated ~8395 to ~8050 ¹⁴C yr BP (~9400 to ~8940 cal yr BP). The top of Stratum 6 was heavily eroded <~8050 ¹⁴C yr BP, based on obvious disconformities in stratigraphic exposures and variable dating. The relatively long and continuous suite of dates for Stratum 6 from the Locus 5 area, beginning at ~10,280 ¹⁴C yr BP (~12,005 cal yr BP), suggests that this area of the site was spared significant early Holocene erosion, perhaps because of its position on a divide between No Name and Big Wash Arroyos.

The age range of Stratum 6 along Big Wash is significantly younger than it is on the fan emanating from the mouth of No Name arroyo. In section 12-9 on the south side of Big Wash, a base date is ~8810 ¹⁴C yr BP (~9820 cal yr BP). An upper black facies is dated <~8655 and >~7230 ¹⁴C yr BP (<9620 and >8065 cal yr BP). Above is a layer of dark gray mud dated to ~7230 ¹⁴C yr BP. Wetland conditions apparently persisted much longer (or are better preserved) along Big Wash. North of the wash in the Windmill Pit is an upland soil facies of Stratum 6 (with some gleying) dating from ~6500 to ~5600 ¹⁴C yr BP (~7395 to 6385 cal yr BP). The limited dating suggests that the paleo-wetland shifted north away from the No Name fan in the early Holocene. There are few dates along Big Wash because there are limited exposures. Moreover, there are no stratigraphic or geomorphic indicators of significant fan construction. This seems unusual given the much larger drainage area for Big Wash. But the swale that defines the wash (as opposed to the channel or arroyo) is also much wider (~82 m) just above the point at which

1
2
3 it widens at the site, compared to No Name Swale (~22 m) just above where it opens up. No
4
5 Name Arroyo is in a position to create a fan, with flow confined to a relatively narrow swale
6
7 until it reaches the end of the swale and water is no longer confined (a classic setting for a
8
9 fan). The swale with Big Wash is wider and, as it gets into the site area, it becomes
10
11 progressively wider. This geomorphic characteristic may have gradually dissipated discharge,
12
13 rather than changing abruptly (as in the case of No Name Swale).
14
15
16

17
18 The characteristics of Stratum 6, as delineated previously, are indicative of a wetland
19
20 and this interpretation is strongly supported by paleoenvironmental reconstructions based on
21
22 proxy data recovered from Stratum 6 (Dello-Russo et al. 2016a, 2016b). These proxy data
23
24 included stable carbon isotopes and other data derived from pollen (Smith 2010, 2012, 2015),
25
26 land snails and snail eggs (Hall 2015), phytoliths (Yost 2016) and diatoms (Winsborough 2016).
27
28 The Stratum 6 muds represent the remains of a TPEH wetland environment, characterized by
29
30 wet meadows bordering a creek or interconnected pools and interspersed with marshy areas,
31
32 similar to modern cienega ecosystems in the region. Taken as a whole, the record at the Water
33
34 Canyon site indicates a landscape mosaic of different vegetation communities that, along with
35
36 the presence of fresh water, would have provided a variety of shrubs, grasses and herbs
37
38 strongly attractive to browsing bison and other game and non-game animals (Dello-Russo et
39
40 al. 2016a).
41
42
43
44
45
46

47 The paleoenvironmental reconstruction suggests the presence of at least local shallow
48
49 standing water. How this standing water was maintained is unclear. Today the site drainage
50
51

1
2
3 drops almost 20 meters over a distance of less than 1 kilometer to the confluence with the
4
5 main channel of the Water Canyon channel itself. Stream flow is easy to maintain after rains.
6
7 The coarse character of Stratum 5 and some of Strata 7 and 8 suggest flashy discharges from
8
9 the No Name drainage and likely from Big Wash in the late Pleistocene and in the middle
10
11 Holocene. Except for the evidence of erosion, Stratum 6, in striking contrast, is indicative of a
12
13 high water table supporting a long-lasting wetland habitat.
14
15
16

17
18 Even with a high water table some sort of impoundment downstream from the Water
19
20 Canyon site seems likely. The lower Big Wash drainage and, at its mouth, Water Canyon are
21
22 both incised into either coarse gravel or bedrock so there are no clues to the terminal
23
24 Pleistocene history of either drainage at their confluence. There is some evidence for mass
25
26 movement along a bedrock slope failure on the south side of Water Canyon just downstream
27
28 of its confluence with Big Wash (David Love, personal communication, 2009). Such a mass
29
30 movement could have blocked the drainage and impounded stream flow, but that geologic
31
32 record has not been investigated and, in any case, the mass movement is not dated.
33
34
35
36

37
38 Another possible mechanism for impounding the Big Wash drainage is the Water
39
40 Canyon system itself. Aggradation of the drainage above, below, and at the confluence with Big
41
42 Wash could have impounded flow in Big Wash and also could raise the local water table. Some
43
44 fluctuations in the flow along Water Canyon could also account for the evidence of erosion in
45
46 Stratum 6.
47
48

49
50 The Terminal Pleistocene stratigraphic record at Water Canyon contrasts with that from
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

other localities in the Southwest. The Mockingbird Gap site to the east-southeast (Holliday et al. 2009) and the Scholle site to the northeast (Hall et al. 2012) as well as Murray Springs and other Clovis sites in the upper San Pedro Valley of southeast Arizona (Haynes 2008; Haynes and Huckell 2007) all exhibit conformable stratigraphic sequences for the period ~13,500 to ~10,000 cal years. In particular, the Stratum 6 wetland mud is broadly similar lithologically and chronologically to that proposed for the “black mats” of the San Pedro Valley, the “wet meadow” zone at the Scholle site, and the palustrine muds (stratum 2) at the Mockingbird Gap site. But in detail, Stratum 6 is characterized by several cycles of erosion. Sediments of Younger Dryas age are largely missing and later phases of erosion are indicated between >~9500 ¹⁴C yr BP (>~10,800 cal yr BP) and >~8320 ¹⁴C yr BP (>~9365 cal yr BP). The Younger Dryas erosion may just represent local instability or may be indicative of regional variability at that time (e.g., Meltzer and Holliday 2010). Likewise, the early Holocene cycles of erosion have no direct correlates in the area (Onken 2015).

Strata 7 and 8 represent a return to more energetic cycles of fan deposition and erosion. They are sandier than Stratum 6 and both have common pockets and lenses of gravel. Stratum 7 rests unconformably on Stratum 6 and was truncated by erosion in the middle Holocene (Figure 4). Inset against Stratum 7 (on the north) and burying the eroded surface of Stratum 6 is more sand and gravel (Stratum 8). The erosion that truncated Stratum 7 also produced a deep paleo-arroyo (Figure 6A) that cut down through Stratum 7 and into Stratum 6 in a west-to-east direction across the middle of the site. Stratum 8, which filled the lower portion of the paleo-

gully, is dated to ~6500 yr. A well-expressed soil (A-Bt morphology; the La Jencia Soil) formed across the surface of the site in Strata 7 and 8.

The cutting and filling cycles of Strata 7 and 8 broadly mirror trends in the evolution of arroyos across the Southwest. Incision, fan construction, and another phase of incision are documented at Water Canyon between 6800 and 6200 yr. Localized and episodic but not necessarily synchronous incision is documented from ~8000 to ~5600 ¹⁴C yr BP (~8900 to ~6400 cal yr BP) across the Southwest (e.g., Waters and Haynes 2001; Mann and Meltzer 2007; Onken 2015) and attributed to the evolving Holocene climate, but the specific drivers are debated.

The gross sedimentological evolution of the landforms on which the Water Canyon site is located began with deposition of coarse, high energy, pre-LGM and LGM, Pleistocene gravel in an alluvial fan followed by erosion and then formation of a terminal Pleistocene/early Holocene wetland. Following another phase of erosion, thick sand and gravel deposits accumulated during cut and fill cycles as another fan formed. This stratigraphic trend is roughly similar to stratigraphic sequences across the Southwest and parts of the Great Plains (e.g., Holliday and Mandel 2006; Holliday and Miller 2013).

5.2 Archaeology

The Water Canyon archaeological site encompasses five different surface loci (1 South, 2, 3, 4 and 6) and two, possibly more, significant subsurface loci (1 North and 5). The subsurface cultural deposits are in fan sediments and consist of intact, buried Paleoindian materials in a stratified context. The fan contains several significant cultural deposits, including a bed of

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

poorly preserved *Bison sp.* bone with an associated Eden projectile point (Locus 5); and a possible palimpsest of two additional, but very well-preserved, *Bison sp.* bone beds with associated activity areas consisting of butchered bison bones, flaked and ground stone artifacts and the remains of an ephemeral hearth (Locus 1 North). The bone bed in Locus 5, associated with the Eden point, could be dated between ~9887 and ~9640 ¹⁴C yr (~11,305 and ~10,975 cal yr BP), although the projectile point itself is more closely associated with a date of ~8955 ¹⁴C yr BP (~10,070 cal yr). The upper portion of the bone processing area in Locus 1 North has a mean age estimate of ~8321 ¹⁴C yr BP (~9365 cal yr BP) (based on dated charcoal in the Feature 1 hearth), while the lower portion of that bone processing area is dated ~9240 ¹⁴C yr BP (based on dated bone collagen). The Locus 1 North bone bed is upslope of, and stratigraphically above, the Locus 5 bone bed. Clovis and Folsom occupations at the site are evidenced by diagnostic projectile point fragments documented in Loci 6 and 3, together with a suite of broken blade fragments repurposed into small, spurred end scrapers (Collins 1999) documented in Locus 6. Subsurface cultural deposits associated with these artifact types have not yet been identified at the site, although sediments dated to those respective time periods have been identified in Locus 1 North.

Buried, stratified Paleoindian sites are rare in southwestern North America west of the Pecos River. Between the Great Plains (northwest Texas/eastern New Mexico) to the east and the San Pedro Valley (Arizona) to the west, only two others are reasonably well-documented and both are in New Mexico: Boles Wells, a Folsom occupation in the Tularosa Basin just south

of Alamogordo (Mauldin and O'Leary 1994; Amick et al. 1996, 1998), and LA111429, a Folsom camp site in the Jornada del Muerto, southeast of the town of Truth or Consequences (Figure 1) (Akins and Moore 2012: 82-98; Moore and Akins 2014). Sandia Cave (Figure 1) probably had intact and stratified Paleoindian deposits, but they were obscured by animal burrowing (Haynes and Agogino 1986) and the archaeological record was further mired in controversy (Preston 1995). A buried Cody occupation may be preserved at the R-6 site near Las Vegas, New Mexico (Figure 1) (Stanford and Patten 1984). None of the aforementioned sites west of the Great Plains are securely dated nor are the stratigraphic contexts clear, however. So, the lack of dateable Paleoindian deposits from buried, multi-component stratified contexts makes the discoveries at the Water Canyon site all the more significant.

The Water Canyon site contains two Paleoindian bison bone beds (one of which is a possible palimpsest of two distinct processing events and the second which is the remains of a kill), another rarity west of the southern Great Plains in New Mexico and Arizona. Bison kills are stereotypical characteristics of Paleoindian sites on the Southern Great Plains and across the Southwest, expressed both as buried bone beds (Hester 1972; Johnson 1987; Jodry 1999; Meltzer 2006; Haynes and Huckell 2007; Holliday et al. 2017) and surface assemblages of bison tooth enamel or highly fragmented and desiccated bison skeletal elements (Beckett 1980; Holliday et al. 2006, 2009; Huckell et al. 2008). The Water Canyon site is thus unique west of the Pecos River in New Mexico for the reasons cited above and because it contains rare, intact, open air processing areas.

6 SUMMARY

The Water Canyon site is a buried, multi-component, stratified Paleoindian site in the Southwestern United States. The archaeological materials are within an alluvial fan at the toe of a large bajada. It contains three late Paleoindian occupation features in ancient paludal deposits on and beneath coarser, higher energy deposits more typical of an alluvial fan. The oldest, well-dated occupation zone, at ~9240 ¹⁴C yr BP (~10,390 cal yr BP), is a bed of *Bison sp.* bones on the margin of the ancient wetland, interpreted as an open-air processing station. A nearby *Bison sp.* bone bed, farther out in the paleo-wetland and downslope from the processing station, and a probable kill site with an *in situ* Eden projectile point, currently dates to ~8955 ¹⁴C yr BP (~10,070 cal yr), but it may be older. It may be functionally related to the older processing area. The youngest, well-dated occupation level, at ~8321 ¹⁴C yr BP (~9365 cal yr BP), is also along the margins of the paleo-wetland and may also contain processed *Bison sp.* bone and a hearth. Both Clovis and Folsom artifacts have been found on the surface of the site, and remnants of both Clovis- and Folsom-aged paludal strata are preserved in the site but may be of limited extent. Nevertheless, the data show that the palustrine environment that interrupted fan construction attracted ancient foragers since at least ~11,000 ¹⁴C yr BP (late Clovis time) through the early Holocene.

FUNDING SOURCES

Funding for this research was provided by the Argonaut Archaeological Research Fund (VTH Executive Director; University of Arizona Foundation), the UNM Office of Contract Archeology, the NM Office of Archaeological Studies, the Curtiss T. and Mary G. Brennan Foundation, the UNM College of Arts and Sciences, the NM Historic Preservation Division, and numerous private donors.

ACKNOWLEDGMENTS

This research was conducted through several field permits issued to RDR since 2008 by the New Mexico State Historic Preservation Division and the Energetic Materials Research and Testing Center of the New Mexico Institute of Mining and Technology. Geoarchaeological field assistance was provided by William T. Reitze and Andrew J. Richard. The authors jointly thank the following people for their helpful advice or collaboration, without which our current understanding of the Water Canyon site would not have been possible: Patrice Walker Dello-Russo, Ron Goble, Paul Goldberg, C. Vance Haynes, and Jill Onken. VTH thanks Bruce Huckell and Greg Hodgins, and RDR thanks Mike Collins, Russell Greaves, Stephen Hall, David Love, Les McFadden, Keith Prufer, David Rachal, and Christian Solfisburg. Figures 1, 5, 8, and 9 were created by Jim Abbott; Figures 3A, 3B, 6A, and 6B were jointly created by RDR and VTH; Figures 2, 4, 7, and S1 were created by RDR; Figure 10 was jointly created by RDR and Scott Gunn; and Figure 11 was jointly created by RDR, Alex Kurota and Scott Gunn. The manuscript was

improved by a review from Lee Nordt and two anonymous reviewers.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

FIGURE CAPTIONS

Figure 1. Geographic setting of the Water Canyon site west of the Rio Grande in central New Mexico illustrating the general geomorphic features of the area (based on Machette 1988: figure 1). Inset shows the location of the figure area (dashed rectangle) in New Mexico along with archaeological sites mentioned in the text: BW = Boles Wells; C = Clovis (Blackwater Draw Locality 1); F = Folsom; LA = LA111429; R6 = R-6 site; S = Sandia Cave; SJ = San Jon; WM = Williamson-Plainview and Milnesand.

Figure 2. Topographic map of the Water Canyon site showing locations of: (A) Loci, soil sections, and lines of sections A-A' (Figure 7) and B-B' (Figure 8) and (B) excavation blocks and backhoe trenches (BHT). See Figure S1 for locations of all cores.

Figure 3. Views overlooking the Water Canyon site. (A) View to the north with excavations

under way in Locus 1. The area from the foreground north to Big Wash is the surface of the Terminal Pleistocene/Holocene fan encasing the buried archaeological materials, inset well below the surface of the Pleistocene bajada where Locus 6 is situated. (B) View east down No Name Arroyo at the head of the Terminal Pleistocene/Holocene fan showing the exposure of Strata 4, 6, and 8 (with 6 pinching out against 4) at section 10-30 with Locus 1N immediately beyond and the north end of BHT 6 (Figure 2B) visible at right center. Exposure of Unit 1-47 in Locus 1N (Figure 2B) is on the opposite arroyo wall.

Figure 4. Late Pleistocene and early Holocene landscape evolution sequence. (A) Original Magdalena fan (bajada) surface on Stratum 1 at > 100 kya. (B) Paleo-channel incises Stratum 1 at >42.0k yr BP; Stratum 2 sediments fill paleo-channel at ~40.0k years BP. (C) Paleo-channel incises Stratum 2 at <40.0 kya; Stratum 3 sediments fill paleo-channel at ~30.0 kya. (D) Initial incision of Big Wash between ~30.8k and ~18.0k years BP. (E) Initial incision of No Name Arroyo at <18k years BP; Deposition of Stratum 4 at or <18.0k years BP. (F) Shallow bench cut on Stratum 4 then deep incision of Stratum 4 at <18.0k years BP. (G) Construction of Stratum 5 fan at <18.0k to >13.0k cal years BP. H) Paludal deposition of Stratum 6 at ~13.1k through ~ 8.0k cal years BP. (I) Deposition and erosion of Strata 7 and 8 from ~8.0k cal years BP to present.

Figure 5. Lithostratigraphy and soil stratigraphy exposed in a segment of Backhoe Trench 6 in Locus 1 (Figures 2B, 3B) illustrating position of OSL sample, erosion on Stratum 4, inset

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

relationship of Stratum 6 against Stratum 4, and facies relationship of Stratum 6 and its soil facies. Secondary calcium carbonate is common throughout Strata 4 and 6 as films and threads.

Figure 6. (A) The west wall of the Locus 5 excavation block (Figure 2B) illustrating the stratigraphic relationships of Strata 6 (black and gray facies), 7, and 8, and paleo-arroyo. (B) Close-up of the excavations (Units 5-1, 5-6 and 5-8) and profile in the southwest corner of the Locality 5 excavations (keyed to Figure 6A), illustrating the bottom of paleo-arroyo infilled with laminated sediments of Stratum 8 and inset into Stratum 6, a portion of the *Bison sp.* bone bed (Unit 5-8), and Stratum 5 cobbles beneath the black facies of Stratum 6.

Figure 7. Generalized stratigraphic sequence of the Water Canyon site along section A-A' (Figure 2A) running northeast from Locus 1 South.

Figure 8. Generalized stratigraphic sequence of the Water Canyon site along section B-B' running east-southeast from Locus 1 North (Figure 2A), illustrating the change in elevation across the top of Strata 5 and 6. Radiocarbon means are provided for the base of Stratum 6 in cores 9-10, 9-11, and 10-26 (Table 2).

Figure 9. Lithostratigraphy and soil stratigraphy exposed in Backhoe Trench 4 east of Locus 3 (Figure 2B) illustrating position of OSL samples, erosion on Stratum 4, and sloping fan-like

character and facies of Stratum 5. Secondary calcium carbonate is common throughout Stratum 5 and 6 as films and threads.

Figure 10. An example of the black and olive green (gleyed) facies of Stratum 6 along the North wall of Unit 1-47 on the north side of No Name Arroyo in Locus 1 North (Figures 2B, 3B). Cobbly Stratum 5 is overlain by the olive facies of Stratum 6 (6A) and, above, the black facies (6B). The dot on the aluminum can is the location for radiocarbon sample A-15021 (Table 2). It and the other sampling locations (dots) are labeled with their respective mean dates (Table 2).

Figure 11. West-to-east backplot of dated and undated bones, artifacts, and charcoal in Locus 1 North. Dates for bone collagen and Feature 1 hearth are in ^{14}C yr BP (Table 2). Shaded areas illustrate inferred groupings of different age bone beds (upper and lower) and eastern-most bone cluster. Unshaded areas between bone beds/cluster represent inferred disconformities. The three bone collagen dates in the lower bone bed (bone cluster 2) are statistically the same ($t=0.823$) and their mean radiocarbon date is statistically different ($t=26.765$) than that of the bone collagen sample in the upper bone bed Bone cluster 1). The bone collagen date in the upper bone bed is statistically different than ($t=7.466$), but only slightly younger than, the Feature 1 hearth in the same bone bed. The third potential bone cluster, on the eastern side of Figure 11 (Bone cluster 3), has two dated bone collagen samples that are only slightly different in age ($t=4.446$) but whose mean date is very different than both the upper ($t=82.239$) and

lower (t=128.228) bone beds.

Figure 12. Bison bone found within the black facies of Stratum 6 in core 10-1 (Figure S1). The mud that encased the bone produced radiocarbon samples AA-95610 and Beta-317339 (Table 2).

REFERENCES

Abbot, M.B., & Stafford Jr., T.W. (1996). Radiocarbon geochemistry of modern and ancient Arctic Lake Systems, Baffin Island, Canada. *Quaternary Research*, 45, 300–311.

AGI (1982). *AGI data sheets*. Falls Church, VA: American Geological Institute, 157 p.

Akins, N. (2012). Analysis of Water Canyon faunal recovery for 2009 and 2010 field seasons. In R. Dello-Russo (Ed.), *Continued interdisciplinary research at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim Report for the 2010 Field Season and Data Recovery Plan for the 2012 Season* (pp. 166-170). OAS PR 42. Santa F: Office of Archaeological Studies, Museum of New Mexico.

Akins, N.J., & Moore, J.L. (2012). *Test excavations at eight sites at the Spaceport America Facility, Sierra County, New Mexico*. Archaeology Notes 435. Santa Fe: Museum of New Mexico,

Office of Archaeological Studies.

Amick, D.S., Mauldin, R.P., & O'Leary, B.L. (1996). The Boles Wells Folsom locality in the Tularosa Basin, New Mexico. *Current Research in the Pleistocene*, 13, 1-3.

Amick, D.S., Mauldin, R.P., & Tagg, M.D. (1998). Paleoindian archaeology at Holloman Air Force Base, New Mexico. *Current Research in the Pleistocene*, 15, 1-4.

Beckett, P.H. (1980). *The Ake site: Collection and excavation of LA 13423, Catron County, New Mexico*. Report 357 prepared for the National Radio Astronomy Observatory. Las Cruces: Department of Sociology and Anthropology, Cultural Resources Management Division.

Birkeland, P.W. (1999). *Soils and geomorphology* (3rd ed.). New York: Oxford University Press, 430 p.

Bradley, R.S. (2015). *Paleoclimatology: Reconstructing climates of the Quaternary* (3rd ed.). New York: Academic Press.

Buenger, B.A. (2003). *The impact of wildland and prescribed fire on archaeological resources* (unpublished PhD Dissertation). Department of Anthropology, University of Kansas, Lawrence.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Chamberlin, R.M., & Osburn, G.R. (2006). Geologic map of the eastern half of the Water Canyon 7.5 Minute Quadrangle, Socorro County, New Mexico, New Mexico Bureau of Geology and Mineral Resources Open-file Geologic Map Series, 1:24,000, OF-GM-118.

Chapin, C.E., McIntosh, W.C., & Chamberlin, R.M. (2004). The late Eocene-Oligocene peak of Cenozoic volcanism in southwestern New Mexico. In G.H. Mack & K.A. Giles (Eds.), *The Geology of New Mexico: A Geologic History* (pp. 271-293). Socorro: New Mexico Geologic Society Special Publication 11.

Collins, M.B. (1999). *Clovis blade technology: A comparative study of the Keven Davis cache, Texas*. Austin: University of Texas Press.

Davis, O.K. (2012). Charcoal species identifications for Water Canyon samples. In R.D. Dello-Russo (Ed.), *Archaeological excavations at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim Report for the 2012 and 2013 Field Seasons* (pp. 47-51). OCA Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New Mexico.

1
2
3 Dello-Russo, R.D. (2001). *A cultural resources inventory of 472 acres in Socorro County, New*
4
5 *Mexico. The Archaeology of the EMRTC / GLINT Project Area*. Report No. 2001-03 for Energetic
6
7
8 Materials Research and Testing Center, New Mexico Institute of Mining and Technology.
9
10 Socorro, NM: Escondida Research Group.

11
12
13
14
15 Dello-Russo, R.D. (2010). *Archaeological testing at the Water Canyon site (LA134764), Socorro*
16
17 *County, New Mexico – Interim report for the 2008 and 2009 field seasons*. ERG Report No.
18
19
20 2009-09 for New Mexico Historic Preservation Division, Department of Cultural Affairs. Socorro,
21
22 NM: Escondida Research Group, LLC.

23
24
25
26
27 Dello-Russo, R.D. (2012). *Continued interdisciplinary research at the Water Canyon Paleoindian*
28
29 *site (LA 134764), Socorro County, New Mexico – Interim report for the 2010 field season and*
30
31 *data recovery plan for the 2012 Season*. OAS PR 42. Santa Fe: Office of Archaeological Studies,
32
33
34 Museum of New Mexico.

35
36
37
38
39 Dello-Russo, R.D. (2015). *Archaeological excavations at the Water Canyon Paleoindian site (LA*
40
41 *134764), Socorro County, New Mexico – Interim report for the 2012 and 2013 field seasons*.
42
43
44 OCA Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New
45
46
47 Mexico.

48
49
50
51 Dello-Russo, R.D., Walker, P.A., & Holliday, V.T. (2010). Recent research results from the Water
52
53
54

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Canyon site, a Clovis and late Paleoindian locale in west-central New Mexico. *Current Research in the Pleistocene*, 27, 72-75.

Dello-Russo, R.D., Smith, S.J., Yost, C., Winsborough, B., Hall, S.A., McBride, P. & Davis, O.K. (2016a). The Black Mat at the Water Canyon Paleoindian site and a new paleoenvironmental record for the Pleistocene-Holocene transition in west-central New Mexico. Poster presentation at the American Quaternary Association Conference, Retooling the Quaternary to Manage the Anthropocene. Santa Fe. https://www.academia.edu/26962887/Poster_Presentation

Dello-Russo, R.D., Smith, S.J., & Walker, P.A. (2016b). The Black Mat at the Water Canyon Paleoindian site near Socorro, New Mexico: A paleoenvironmental proxy data archive for the Pleistocene-Holocene transition. *New Mexico Geological Society Guidebook*, 67th Field Conference, Geology of the Belen Area (pp. 491-500). Socorro: New Mexico Geological Society.

Dello-Russo, R.D., Cordero, R., & Leonard, B., in review. Analytical and interpretive challenges posed by late Paleoindian activity areas at the Water Canyon site, west-central New Mexico. In K. Carlson & L. Bement (Eds.), *Open air camps of the Terminal Pleistocene and early Holocene: Intra-camp spatial organization, activity areas, and technology*. Boulder: University of Colorado Press.

1
2
3 Figgins, J.D. (1927). The antiquity of man in America. *Natural History*, 27, 229-239.
4
5

6
7
8 Gile, L.H., Hawley, J.W., & Grossman, R.B. (1981). *Soils and geomorphology in the Basin and*
9
10 *Range area of southern New Mexico - Guidebook to the Desert Project*. Socorro: New Mexico
11
12 Bureau of Mines and Mineral Resources, Memoir 39.
13
14
15

16
17
18 Goble, R.J. (2014). *OSL analysis and sample preparation*. Report submitted by Luminescence
19
20 Geochronology Laboratory, University of Nebraska, Lincoln.
21
22
23

24
25 Goble, R.J. (2015). *OSL analysis and sample preparation*. Report submitted by Luminescence
26
27 Geochronology Laboratory, University of Nebraska, Lincoln.
28
29
30

31
32 Haas, H., Holliday, V.T., & Stuckenrath, R. (1986). Dating of Holocene stratigraphy with soluble
33
34 and insoluble organic fractions at the Lubbock Lake archaeological site, Texas: An ideal case
35
36 study. *Radiocarbon*, 28, 473-485.
37
38
39

40
41
42 Hall, S.A. (2015). Fossil Snails from the Water Canyon Site, Preliminary Analysis. In R.D. Dello-
43
44 Russo (Ed.), *Archaeological excavations at the Water Canyon Paleoindian site (LA 134764),*
45
46 *Socorro County, New Mexico – Interim report for the 2012 and 2013 field seasons* (pp. 47-51).
47
48
49 OCA Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Mexico.

Hall, S.A., Penner, W.L., Palacios-Fest, M.R., Metcalf, A.L., & Smith, S.J. (2012). Cool, wet conditions late in the Younger Dryas in semi-arid New Mexico. *Quaternary Research*, 77, 87-95.

Haynes, C.V., Jr. (1975). Pleistocene and Recent Stratigraphy. In F. Wendorf and J. J. Hester (Eds.). *Late Pleistocene environments of the Southern High Plains* (pp. 57-96. Taos, New Mexico: Publication of the Fort Burgwin Research Center 9.

Haynes, C.V., Jr. (2008). Younger Dryas “black mats” and the Rancholabrean termination in North America. *Proceedings of the National Academy of Science, U.S.A.*, 105, 6520–6525.

Haynes, C.V., Jr., & Agogino, G.A. (1986). *Geochronology of Sandia Cave*. Smithsonian Institution Press, Smithsonian Contributions to Anthropology 32.

Haynes, C.V., Jr., & Huckell, B.B. (Eds.) (2007). *Murray Springs: A Clovis site with multiple activity areas in the San Pedro Valley, Arizona*. Tucson: University of Arizona Press.

Haynes, C.V., Jr., and Warnica, J.M. (2012). *Geology, Archaeology and Climate Change in Blackwater Draw, New Mexico: F. Earl Green and the Geoarchaeology of the Clovis Type Site*.

Contributions in Anthropology, volume 15. Portales: Eastern New Mexico University.

Hester, J.J. (1972). *Blackwater Locality No. 1 – A stratified Early Man site in eastern New Mexico*. Fort Burgwin Research Center Publication 8, Southern Methodist University, Dallas.

Holliday, V.T. (2000). The evolution of Paleoindian geochronology and typology on the Great Plains. *Geoarchaeology*, 15, 227-290.

Holliday, V.T. (2004). *Soils in archaeological research*. New York: Oxford University Press.

Holliday, V.T., & Miller, D.S. (2013). The Clovis landscape. In K. E. Graf, C. V. Ketron, & M.R. Waters (Eds.). *Paleoamerican odyssey* (pp. 221-245). College Station: Texas A&M University Press.

Holliday, V.T., & Mandel, R.D. (2006). Paleoindian geoarchaeology of the Great Plains, Central Lowlands, and Southwestern U.S. In D.H. Ubelaker (Ed.), *Environment, origins, and populations, Volume 3, Handbook of North American Indians* (pp. 23-46). Washington, D.C.: Smithsonian Institution Press.

Holliday, V.T., Haynes, C.V., Hofman, J.L., & Meltzer, D.J. (1994). *Geoarchaeology and*

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

geochronology of the Miami (Clovis) site, Southern High Plains of Texas. *Quaternary Research*, 41, 234-244.

Holliday, V.T., Gustavson, T.C., & Hovorka, S.D. (1996). Stratigraphy and geochronology of playa fills on the Southern High Plains. *Geological Society of America Bulletin*, 108, 953-965.

Holliday, V.T., Huckell, B.B., Mayer, J.M., & Forman, S.L. (2006). Geoarchaeology of the Boca Negra Wash Area, Albuquerque Basin, New Mexico. *Geoarchaeology*, 21, 765-802.

Holliday, V.T., Huckell, B.B., Hamilton, M., Weber, R.H., Reitze, W.T., & Mayer, J.H. (2009). Geoarchaeology of the Mockingbird Gap (Clovis) site, Jornada del Muerto, New Mexico. *Geoarchaeology*, 24, 438-370.

Holliday, V.T., Johnson, E., Warnica, J., & Haynes, C.V., Jr. (2017). The Williamson-Plainview and type Milnesand sites on the Southern High Plains, New Mexico. *PaleoAmerica*, 3, 122-149.

Howard, E.B. (1933). Association of artifacts with mammoth and bison in eastern New Mexico. Paper presented at the National Academy of Sciences Meeting, Boston.

Howard, E.B. (1935). Evidence of Early Man in North America. *The Museum Journal, University Museum, University of Pennsylvania*, 24 (2-3), Philadelphia.

Huckell, B.B., Holliday, V.T., Hamilton, M.J., Sinkovec, C., Merriman, C., Shackley, M.S., & Weber, R.H. (2008). The Mockingbird Gap Clovis site: 2007 investigations. *Current Research in the Pleistocene*, 25, 95-97.

Jodry, M.A.B. (1999). *Folsom technological and socioeconomic strategies: Views from Stewart's Cattle Guard and the upper Rio Grande basin, Colorado* (unpublished PhD dissertation). Department of Anthropology, American University, Washington, D.C.

Johnson, E. (Ed.) (1987). *Lubbock Lake: Late Quaternary studies on the Southern High Plains*. College Station: Texas A&M University Press.

Knell, E.J., & Muñiz, M.P. (2013). Introducing the Cody Complex. In E.J. Knell & M.P. Muñiz (Eds.), *Paleoindian lifeways of the Cody Complex* (pp. 3-28). Salt Lake City: University of Utah Press.

Machette, M.N. (1988). *Quaternary movement along the La Jencia fault, central New Mexico*. U.S. Geological Survey Professional Paper 1440. U.S. Government Printing.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Mann, D.H., & Meltzer, D.J. (2007). Millennial-scale dynamics of valley fills over the past 12,000 ¹⁴C yr in northeastern New Mexico, USA. *Geological Society of America Bulletin*, 119, 1433–1448. doi:10.1130/B26034.1

Martin, C.W., & Johnson, W.C. (1995). Variation in radiocarbon ages of soil organic matter fractions from late Quaternary buried soils. *Quaternary Research*, 43, 232-237.

Mauldin, R.P., & O’Leary, B.L. (1994). *HAR-074 (LA104, 267), The Boles Wells Paleoindian site, data collection and test excavations, Holloman Air Force Base, Otero County, New Mexico*. HAFB Report No. 1994-021 (HSR 9349E) for Holloman Air Force Base, White Sands Missile Range, Contract No. DAAD07-89-D-0050, delivery order No. 0062. Tularosa, NM: Human Systems Research.

Mayer, J.H., & Mahan, S.A. (2004). Late Quaternary stratigraphy and geochronology of the Western Killpecker Dunes, Wyoming, USA. *Quaternary Research*, 62, 72-84.

McBride, P.J. (2012). Analysis of flotation and wood charcoal samples from Water Canyon (LA 134764), In R.D. Dello-Russo (Ed.), *Continued interdisciplinary research at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2010 field*

season and data recovery plan for the 2012 season (pp. 38-40). OAS PR 42. Santa Fe: Office of Archaeological Studies, Museum of New Mexico.

McGeehin, J., Burr, G.S., Jull, A.J.T., Reines, D., Gosse, J., Davis, P.T., Muhs, D., & Southon, J.R. (2001). Stepped-combustion ^{14}C dating of sediment: A comparison with established techniques. *Radiocarbon*, 43, 255-261.

Meltzer, D.J. (2006). *Folsom: New archaeological investigations of a classic Paleoindian bison kill*. Berkeley: University of California Press.

Meltzer, D.J., & Holliday, V.T. (2010). Would North American Paleoindians have noticed Younger Dryas age climate changes? *Journal of World Prehistory*, 23, 1-41.

Moore, J.L., & Akins, N.J. (2014). *10,000 years of transient occupation in the Jornada del Muerto: Excavations at eight sites at the Spaceport America Facility, Sierra County, New Mexico*. Archaeology Notes 453 for the Federal Aviation Administration and the New Mexico Spaceport Authority. Santa Fe: Museum of New Mexico, Office of Archaeological Studies.

Onken, J. (2015). *Late Quaternary climatic geomorphology, volcanism, and geoarchaeology of Carrizo Wash, Little Colorado River headwaters, USA* (unpublished PhD Dissertation),

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Department of Geosciences, University of Arizona, Tucson.

Pitblado, B.L. (2003). *Late Paleoindian occupation of the Southern Rocky Mountains – early Holocene projectile points and land use in the High Country*. Boulder: University Press of Colorado.

Preston, D. (1995). The mystery of Sandia Cave. *The New Yorker* (June 12, p. 66-83).

Quade, J., Forester, R.M., Pratt, W.L., & Carter, C. (1998). Black mats, spring-fed streams, and late-glacial-age recharge in the southern Great Basin. *Quaternary Research*, 49, 129-148.

Rawling, J.E., 3rd, Fredlund, G.G., & Mahan, S. (2003). Aeolian cliff-top deposits and buried soils in the White River Badlands, South Dakota, USA. *The Holocene*, 13, 121-129.

Reed, E.K., 1964. The greater Southwest. In: Jennings, D., Norbeck, E. (Eds.), *Prehistoric man in the Southwest*. University of Chicago Press, Chicago, pp. 175-191.

Rittenour, T. (2011). *Final age report for Project 093*. Report submitted to Office of Archaeological Studies by Utah State University Luminescence Laboratory, North Logan, Utah.

Sanchez, G., Holliday, V.T., Gaines, E.P., Arroyo-Cabral, J., Martinez-Tagüña, N., Kowler, A., Lange, T., Hodgins, G.W.L., Mentzer, S.M., & Sanchez-Morales, I. (2014). Human (Clovis) – gomphothere (*Cuvieronius* sp.) association ~13,390 calibrated yBP in Sonora, Mexico.

Proceedings of the National Academy of Sciences, U.S.A. 111, 10972-10977.

Schaetzl, R.J., & Thompson, M.L. (2015). *Soils: Genesis and geomorphology* (2nd ed.). New York: Cambridge University Press.

Smith, S.J. (2010). Water Canyon pilot pollen study In R.D. Dello-Russo (Ed.), *Archaeological testing at the Water Canyon site (LA134764), Socorro County, New Mexico – Interim report for the 2008 and 2009 field seasons* (pp. 31-32). ERG Report No. 2009-09 for the New Mexico Historic Preservation Division, Department of Cultural Affairs. Santa Fe: Escondida Research Group, LLC.

Smith, S.J. (2012). Pollen results from LA 134764. In R.D. Dello-Russo (Ed.), *Continued interdisciplinary research at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2010 field season and data recovery plan for the 2012 season* (pp. 41-59). OAS PR 42. Santa Fe: Office of Archaeological Studies, Museum of New Mexico.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Smith, S.J. (2015). Pollen results from the 2012 Water Canyon Field Season, In R.D. Dello-Russo (Ed.), *Archaeological excavations at the Water Canyon Paleoindian site (LA 134764), Socorro County, New Mexico – Interim report for the 2012 and 2013 field seasons* (pp. 34-47). OCA Report No. 185-1174. Albuquerque: Office of Contract Archeology, University of New Mexico.

Stanford, D., & Patten, R. (1984). R-6, a preliminary report on a Cody site in north central New Mexico. *Proceedings of the New Mexico Archeological Council*, 6(1), 198-199.

Stuiver, M., & Reimer, P.J. (1993). Extended ¹⁴C database and revised CALIB radiocarbon calibration program. *Radiocarbon*, 35, 215-230.

Taylor, R.E., & Bar-Yosef, O. (2014). *Radiocarbon dating: An archaeological perspective* (2nd ed.). Walnut Creek, CA: Left Coast Press.

Surovell, T.A., Boyd, J.R., Haynes, C.V., Jr., & Hodgins, G.W.L. (2016). On the dating of the Folsom complex and its correlation with the Younger Dryas, the end of Clovis, and megafaunal extinction. *PaleoAmerica*, 2(2):81-89.

Walker, M. (2005). *Quaternary dating methods*. Chichester, UK: John Wiley & Sons.

1
2
3 Waters, M.R., & Haynes, C.V. (2001). Late Quaternary arroyo formation and climate change in
4 the American Southwest. *Geology*, 29, 399–402.
5
6
7
8
9

10 Winsborough, B. (2016). *Diatom paleoenvironmental analysis of sediments from the Water*
11 *Canyon Paleoindian site (LA134764)*. Report prepared by Winsborough Consulting for Office
12 of Contract Archeology, University of New Mexico, Albuquerque.
13
14
15
16
17
18
19

20 Yost, C.L. (2016). *Phytolith analysis of late Pleistocene and early Holocene sediments from the*
21 *Water Canyon Paleoindian site, LA134764, New Mexico*. Technical Report 16003 for Office of
22 Contract Archeology, University of New Mexico. Tucson, AZ: Paleoscapes Archaeobotanical
23 Services Team, LLC.
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 7. Generalized stratigraphic sequence of the Water Canyon site along section A-A' (Figure 2A) running northeast from Locus 1 South.

Figure 10. An example of the black and olive green (gleyed) facies of Stratum 6 along the North wall of Unit 1-47 on the north side of No Name Arroyo in Locus 1 North (Figures 2B, 3B). Cobbly Stratum 5 is overlain by the olive facies of Stratum 6 (6A) and, above, the black facies (6B). The dot on the aluminum can is the location for radiocarbon sample A-15021 (Table 2). It and the other sampling locations (dots) are labeled with their respective mean dates (Table 2).

Figure 11. West-to-east backplot of dated and undated bones, artifacts, and charcoal in Locus 1 North. Dates for bone collagen and Feature 1 hearth are in 14C yr BP (Table 2). Shaded areas illustrate inferred groupings of different age bone beds (upper and lower) and eastern-most bone cluster. Unshaded areas between bone beds/cluster represent inferred disconformities. The three bone collagen dates in the lower bone bed (bone cluster 2) are statistically the same ($t=0.823$) and their mean radiocarbon date is statistically different ($t=26.765$) than that of the bone collagen sample in the upper bone bed Bone cluster 1). The bone collagen date in the upper bone bed is statistically different than ($t=7.466$), but only slightly younger than, the Feature 1 hearth in the same bone bed. The third potential bone cluster, on the eastern side of Figure 11 (Bone cluster 3), has two dated bone collagen samples that are only slightly different in age ($t=4.446$) but whose mean date is very different than both the upper ($t=82.239$) and lower ($t=128.228$) bone beds.

249x158mm (200 x 200 DPI)

Figure 12. Bison bone found within the black facies of Stratum 6 in core 10-1 (Figure S1). The mud that encased the bone produced radiocarbon samples AA-95610 and Beta-317339 (Table 2).