Dating and Stratigraphy of Middle to Late Holocene Eolian Sand Deposits in the San Luis Basin, East of Alamosa, Colorado

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CHAPTER E

Abstract

The Baca Lane pit (field-trip stop A9, this volume) exposes four depositional units within an eolian sand dune. As part of his reconnaissance mapping of the Alamosa 1:100,000-scale sheet during the summer of 2005, the senior author made a quick description of this sand sequence, sampled charcoal and other organic matter from three buried soils, and noted archeological materials associated with a prehistoric hearth site. Charcoal samples were separated from three of the four buried soils that mark depositional hiatuses in the sequence of eolian sands. The charcoal samples, which were radiocarbon dated at about 2800 cal yr, 3900 cal yr, and 5560 cal yr, record a much longer sequence than is normally exposed in the basin (see various field trip stops in chapter A, this volume). Faunal and floral remains in these samples reveal paleovegetation that is consistent with that of the present, and archeological evidence indicates prehistoric occupation of this site between 2.8 ka and 5.6 ka.

Introduction

The Baca Lane pit is one of the few places in the Alamosa area where we can see a sequence of stratified Holocene eolian sand deposits separated by well-formed, organic-rich soils (buried A horizons). This area, and in particular the southeast corner of County Road 6S and Road S116 (Baca Lane, see fig. A9–1, chapter A, this volume), is characterized by largely stabilized sand dunes and interspersed blowouts that expose playa-like organic rich sediment. The presence of charcoal, locally abundant, and a hearth site on one of the buried soils indicates that the organic-rich horizons were at the surface and occupied by prehistoric man.

Local Geology

The Baca Lane pit is located north of U.S. Highway 160, which is the main highway across the San Luis Valley. From east to west, it connects the cities of Fort Garland, Alamosa on the Rio Grande, Monte Vista, and Del Norte. The pit is about 0.9 mi (1.5 km) north of the highway and about 6.5 mi (10 km) east of Alamosa, on the southwest side of a northwest-southeast-trending string of eolian sand dunes (fig. A9–1, chapter A, this volume). A low escarpment to the east separates eolian sand and underlying upper Pleistocene to Holocene fluvial sediment (at and west of site) from a gentle west-sloping piedmont covered by eolian-dune and cover sands (Holocene to upper Pleistocene). The piedmont is largely a relict basin floor of ancient Lake Alamosa (chapter G, this volume) of middle Pleistocene age. The escarpment is fluvial (see field trip stop A8) and, to the south, its height increases to about 25 m where it is known as Hansen Bluff (see field trip stop B7, chapter B, this volume). The lacustrine and interbedded fluvial sediment that underlie the piedmont are part of the Alamosa Formation, which is considered to be an informal, upper member of the Santa Fe Group (middle Pleistocene to late Oligocene, Michael Machette and Ren Thompson, unpub. mapping, 2007).

Baca Lane Pit

During the summers of 2004 and 2005, the senior author made a quick description of the sand sequence, photographed the site, sampled organic materials and charcoal from buried soils, and noted archeological materials associated with a prehistoric hearth site. Four samples of organic-rich sand were submitted to Paleo Research Institute, Inc., Golden, Colo., and processed

by Kathy Puseman (table E–1). Charcoal, bones and bone fragments, and plant fragments were separated from three of the four sampled soils, and one sample contained archeological materials (small rock flakes, burned bone fragments, and fish bones).

Flotation of bulk soil material (R1, R2, R3, and R4) from the Baca Lane pit (site BA–MM04–25) resulted in recovery of charcoal and other charred botanic remains suitable for radiocarbon dating. All of the dating was performed by the Woods Hole Oceanographic Institute (WHOI) National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS; see http://nosams.whoi.edu/index.html). Rabbitbrush charcoal in samples R2 and R4, saltbush charcoal in sample R2, greasewood charcoal in samples R2 and R4, and *Chenopodiaceae* (Goosefoot family) charcoal in samples R1, R2, and R4 all were present in sufficient quantities (>0.007 g) for accelerator mass spectrometry (AMS) radiocarbon analysis. Only sample R3 yielded insufficient charcoal or other organic materials for dating.

Stratigraphic Units

Unit 1

In the borrow-pit wall, which is crescent shaped and faces south, the sand sheets lap over one another in a southeasterly direction, which likely reflects the predominant wind and sand-transport direction at this site during middle and late Holocene time (figs. E–1 and E–2). The upper surface of the excavated dune is covered with modern eolian sand (unit 1) that is sparsely vegetated but anchored by woody shrubs (such as *Artemisia sp*., *Atriplex sp*., and *Sarcobatus sp.*). This unit contained no obvious datable materials (charcoal, fossils, or organic matter) and thus was not sampled or described in any detail.

Unit 2

The uppermost sampled A horizon is formed in the top of unit 2 of the dune sequence. This sample, R1 (BA–MM04–25R1, fig. E–1 and tables E–2, E–3), was collected from an interval 85 to 90 cm below the modern land surface. Sample R1 is from a weakly consolidated light-brown eolian sand (weak A horizon with abundant charcoal in the top of unit 2) that is about 1.2 m thick here (fig. E–1*B*). Unit 2 thickens to the southeast where it fills an intradune low. Conversely, unit 2 is not present on the crest of the dune; instead, older sand (unit 3) forms the northwestern core of this dune (fig. E–1*B*).

Unit 3

The buried soil formed in the top of unit 3 (and buried by unit 2) is characterized by a moderately well developed, light gray A horizon. The soil is best exposed in the northeast part of the pit, below and to right of the sample locality (R1, 2.8 ka A horizon on unit 2). Unit 2 is about 1.2 cm thick at the locality where we sampled for charcoal (between R1 and R2, fig. E–2 and fig. A9–1, chapter A, this volume). The A horizon in the top of unit 3 has been disturbed by a prehistoric fire pit (hearth) that is buried by sand of unit 2.

Charcoal separated from the hearth in the basal part of unit 2 (R2, fig. E–1B) has an AMS radiocarbon age of 3,590±55 ^{14}C yr B.P. (NOSAMS no. OS–52750, table E–2. The radiocarbon ages were calendar corrected using the radiocarbon calibration program (CALIB REV. 5.1, 2005 of Stuiver and Reimer; see also Stuiver and Reimer, 1993). Using a 2-sigma error, sample R2 yielded calendar-corrected age ranges as follows:

1. 3720–3804 cal yr B.P. (13 percent of calibration curve),
2. 3807–4002 cal yr B.P. (80 percent of calibration curve; age reported herein), and
3. 4034–4080 cal yr B.P. (6 percent of calibration curve).

The second range (3807–4002 cal yr B.P.) is most likely to be correct, so we use an age of 3905±98 cal yr B.P. for the age of charcoal in the hearth pit in the A horizon in the top of unit 3 or the base of unit 2 (buried hearth). For the purposes of further discussion, this age range will be treated as 3.9±0.1 ka. This age brackets unit 3 as older than 3.9 ka and unit 2 as 3.9 ka and younger (fig. E–2).). The charcoal submitted for analysis was *Atriplex* (saltbush or shadscale; table E–4), although a variety of other floral and faunal remains were also identified.

A second portion (R3) of the A horizon formed in the top of unit 3 was sampled in the northern part of the pit. Here, unit 3 is overlain by an eroded section of unit 2 (no soil), and sand of unit 1. Separation of organic components of sample R3 yielded rootlets (probably modern), fragments of unidentified hardwood charcoal too small to date (<0.001g), as well as a fragment of bone, an ostracode shell (wind transported), and insect remains (table E–5). Therefore, we were not able to recover datable materials from this soil (unit 3, fig. E–2).

The minimum age of eolian sand unit 3 is limited by the 3905±98 cal yr B.P. age of charcoal in the hearth pit that rests on the A horizon of unit 3. For the purposes of further discussion, this age range will be treated as 3.9±0.1 ka.

Unit 4

The oldest and stratigraphically lowest eolian sand deposit (herein referred to as unit 4) is exposed in the west half of the pit (left-hand side of figs. E–1 and E–2). Unit 4 has a thick, dark silty to clayey A horizon with abundant charcoal. The high silt and clay contents of the A horizon and the

Table E-1. Basic information for samples collected at stop A9, this volume.

[Paleo Research, Inc. is a for-profit company that specializes in the separation and identification of materials for radiocarbon dating, archaeology, and environmental studies]

Paleo Research Institute, Inc. Total Number of Samples: Four
2675 Youngfield Street Delivered: August 12, 2005
Golden CO 80401 Complete: September 19, 2005
Phone: 303–277–9848; Fax: 303–462–2700 Analyst: Kathy Puseman
Client: Michael N. Machette, U.S. Geological Survey, *machette@usgs.gov*

SITE INFORMATION
Site Name: Baca Lane Pit Site No. BA–MM04–25
Location: Baldy 7.5' quadrangle, south central Colorado. UTM coordinates (NAD 27): UTM Zone 13, 433910m E, 4148955 m N. NW¼ NW¼ Sec. 2, T. 37 N., R. 11 E. Alamosa County, Colo. East side of Rd. S116 (Baca Lane), about 2.0 mi north of Colorado State Highway 160, 6.5 mi east of Alamosa, Colo. Elevation: 7,530 ft. Feature description: Eolian sand dune complex, multiple buried A (soil) horizons. About 4 m of section exposed in abandoned borrow (sand) pit.
Environment/vegetation: Semiarid (est. 9 inch MAP), sagebrush, four-wing saltbush is dominant vegetation.
Cultural affiliation: Cultural (Holocene) artifacts are associated with several of the land surfaces (A horizons) that are buried, including a small hearth with flakes and burned bones.
Provenience for samples: Sand-dune complex derived from older floodplain deposits of the Rio Grande, San Luis Basin.
Site description: All four samples are from the same location (pit).
R1 (BA–MM04–25R1) is the highest sample from the section. Charcoal and plant fragments collected from interval 85–90 cm below the modern land surface. The sample is weakly consolidated light-brown eolian sand (unit 2) with abundant charcoal. Weak soil (A horizon) development; not rich in organic matter. Unit 2 is 1.2 m thick here.
R2 (BA–MM04–25R2) is the second highest sample from the section. Abundant, large pieces of charcoal in a pocket (hearth) in A horizon of unit 3, buried by unit 2.
R3 (BA–MM04–25R3) is the third highest sample in the section. Sampled thick, very organic rich A horizon of unit 3, which is overlain by loose eolian and well-stratified sandy silt (unit 2). Sample from interval 15–20 cm below top of unit 3. Can't trace west to R4, but believe that R3 is stratigraphically higher than R4.
R4 (BA–MM04–25R3) is the lowest sample in the section. Sampled a 10–15 cm thick A horizon (near top of unit 4) that is composed of silty sand with very fine medium blocky peds with soft, 2–3 mm diameter carbonate nodules. Contains sparse charcoal below sampled position. Top of unit 4; well stratified sand (unit 3) overlies this sample.
Dates: None known
Maps: Baldy 7.5' topographic quadrangle map
Photos: Available from collector

WORK REQUESTED: Separate charcoal for radiocarbon analysis. Identify plant type when possible.

Table E–2. Radiocarbon age determinations from charcoal samples at stop A9.

[Reported radiocarbon ages have 1-sigma errors; calendar-corrected ages have 2-sigma errors. The radiocarbon ages were calendar corrected using the radiocarbon calibration program (CALIB REV. 5.1, 2005 of Stuiver and Reimer; see also Stuiver and Reimer, 1993)]

USGS sample number	Date reported	NOSAMS accession number	$\delta^{13}C$	Fraction modern	FM error	Radiocarbon ages and errors (^{14}C yr B.P.)	Calendar ages and errors (cal yr B.P.)
BA–MM04–25R1 (soil on unit 2)	2/27/2006	OS–52749	–23.38	0.7148	0.0032	2700±35	2804±54
BA–MM04–25R2 (hearth, base of unit 2)	2/27/2006	OS–52750	–11.21	0.6393	0.0045	3590±55	3905±98
BA–MM04–25R4 (soil on unit 4)	2/27/2006	OS–52751	–25.62	0.549	0.0030	4820±45	5560±90

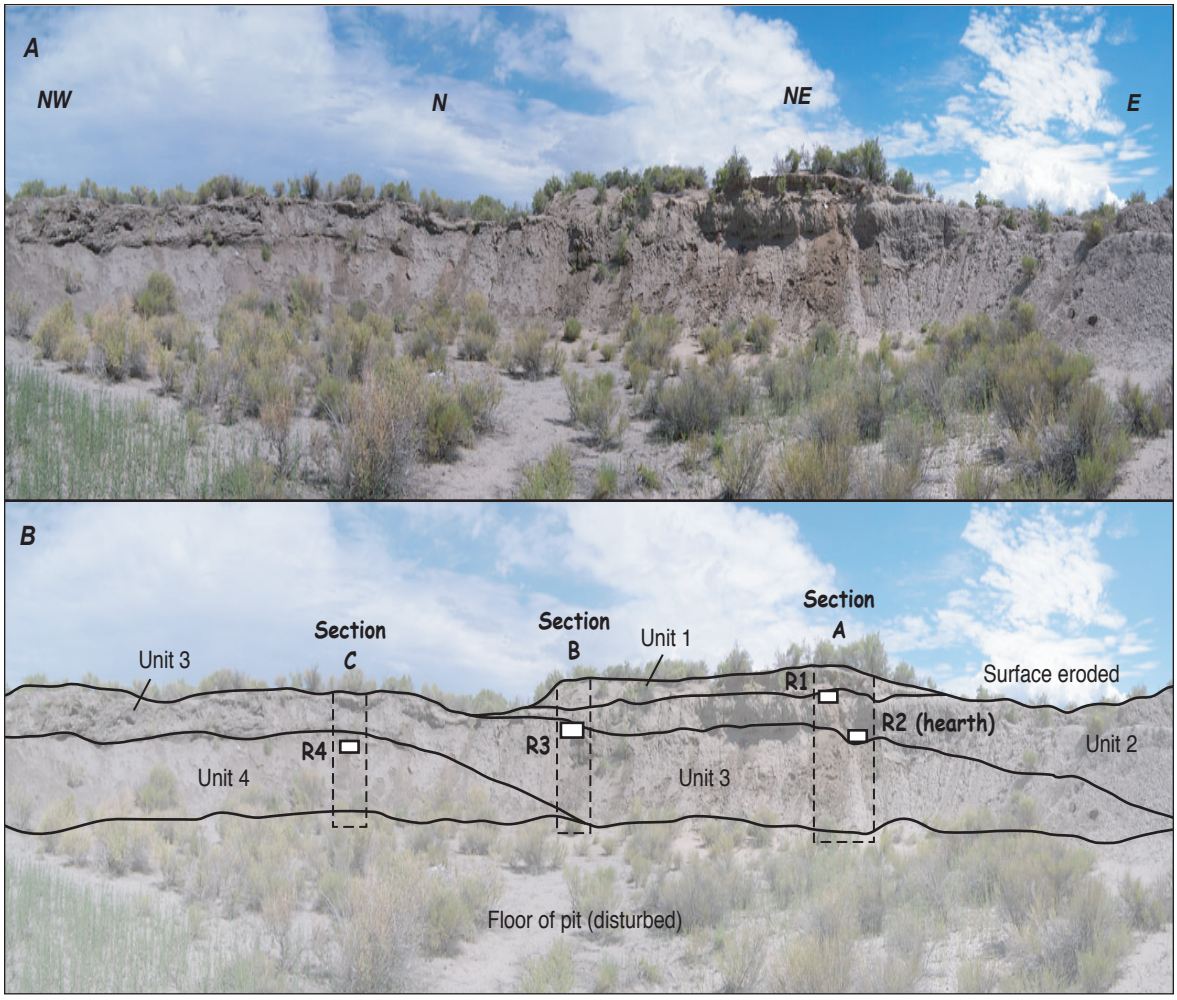

Figure E–1. South-facing wall of the Baca Lane pit (sand borrow pit). *A*, Panoramic view toward the northwest (on left) sweeping to the east (on right). *B*, Overlay showing stratigraphic units (dark lines) exposed in the Baca Lane pit. Soil samples R1 through R4 (white boxes) collected from eolian sand units 2, 3, and 4. Total vertical exposure in the pit is about 4 m below the top of the modern dune surface. Vertical exaggeration of image, 1.5x.

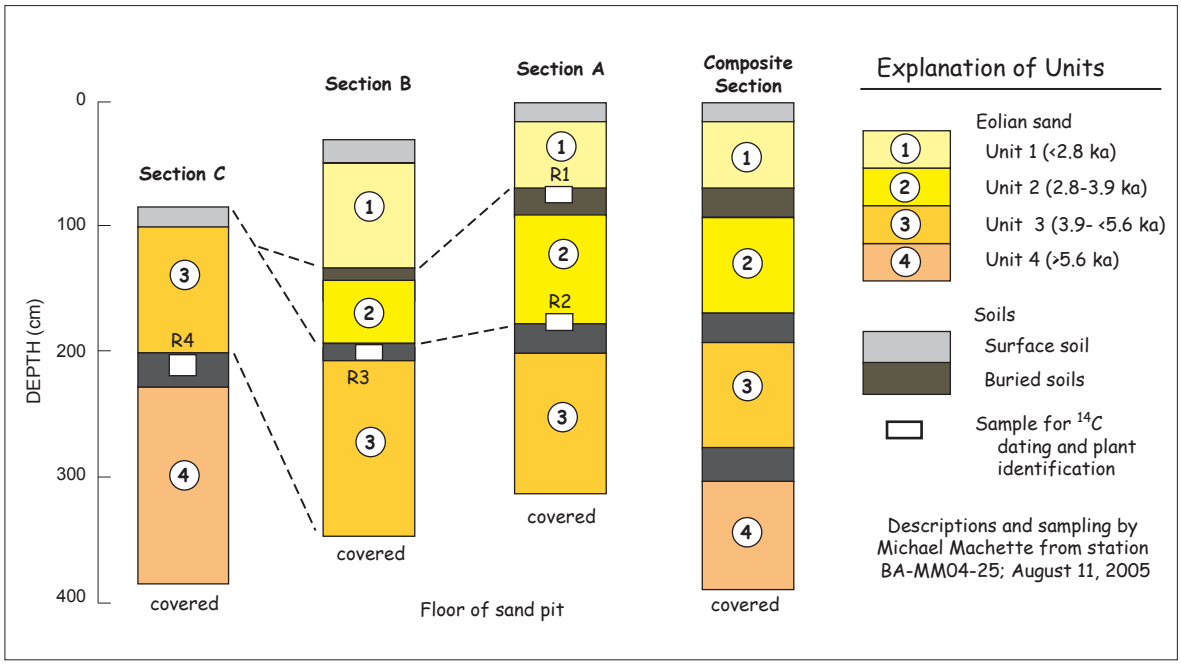

Figure E–2. Stratigraphic sections and sample localities at the Baca Lane pit, east of Alamosa, Colo.

Table E–3. Materials identified from sample R1 (BA–MM04–25R1).

[Analyses by Kathy Puseman and Jamie Dexter of Paleo Research Institute, Inc. Abbreviations: W, whole; F, fragment; X, presence noted in sample; *, indicates number recovered. Material shown in bold was submitted for dating]

Identification	Material	Charred		Uncharred		Material weight or abundance
		W	F	W	F	
Floral remains						
Chenopodium (goosefoot)	Seed	1	17			
Rootlets					X	Moderate
Charcoal or wood						
Chenopodiaceae (Goosefoot family)	**Charcoal**		**20**			**0.025 g**
Nonfloral remains						
Bone ≥2 mm - mostly fish bone			53		6	
Bone <2 mm - mostly fish bone			X		X	Numerous
Fish vertebrae ≥1 mm		35	38			0.311 g
Fish vertebrae <1 mm			X			Moderate
Fish scale					42*	
Flake					5	
Insect	Chitin				5	
Shell					X	Few

Table E–4. Materials identified from sample R2 (BA–MM04–25R2).

[Analyses by Kathy Puseman and Jamie Dexter of Paleo Research Institute, Inc. Abbreviations: W, whole; F, fragment; X, presence noted in sample; *, indicates number recovered. Material shown in bold was submitted for dating]

Identification	Material	Charred		Uncharred		Material weight or abundance
		W	F	W	F	
Floral remains						
Chenopodium (goosefoot)	Seed	7	80			
Oxalis (wood sorrel)	Seed	1	1			
Portulaca (purslane)	Seed	3	1			
Sporobolus (dropseed grass)	Caryopsis	3				
Rootlets					X	Moderate
Charcoal or wood						
Chenopodiaceae (Goosefoot family)	Charcoal		40			0.784 g
***Atriplex* (saltbush or shadscale)**	**Charcoal**		**3**			**0.038 g**
*Sarcobatus vermiculatus (*greasewood)	Charcoal		13			0.140 g
Chrysothamnus (rabbitbush)	Charcoal		19			0.098 g
Unidentified ≥2 mm	Charcoal		X			0.215 g
Nonfloral remains						
Bone ≥2 mm			6			0.467 g
Bone <2 mm			X		X	Few
Snail shell				4	1	

Table E–5. Materials identified from sample R3 (BA–MM04–25R3).

[Analyses by Kathy Puseman and Jamie Dexter of Paleo Research Institute, Inc. Abbreviations: W, whole; F, fragment; X, presence noted in sample; *, indicates number recovered. Material shown in bold was submitted for dating]

Identification	Material	Charred		Uncharred		Material weight or abundance
		W	F	W	F	
Floral remains						
Rootlets					X	Few
Charcoal or wood						
Unidentified hardwood, small	Charcoal		2			<0.001 g
Nonfloral remains						
Bone			1			
Insect	Chitin				5	
Ostracode shell					1	
Sand					X	

upward fining of unit 4 suggests that this sediment is a result of deflation of dry lake sediment (playa sediment) from an upwind source. The lower, sandier parts of unit 4 must have been deposited when older sands (earlier than unit 4) became unstable (less vegetated), but the lakes still remained moist enough to preclude erosion.

Charcoal separated from the upper part of unit 4 (R4, fig. E–1*B*) has an AMS radiocarbon age of 4,820±45 ^{14}C yr B.P. (NOSAMS no. OS–52751, table E–2). Using a 2-sigma error, this date yielded a unique calendar-corrected age range of 5470–5650 yr B.P. (i.e., 5560±90 cal yr B.P.). We submitted a large piece of unidentified hardwood charcoal for analysis (table E–6), although a variety of floral remains, charred wood and fragments of bone and snails were also identified. For the purposes of further discussion, this age range will be treated as 5.6±0.1 ka. Therefore, unit 4—the oldest eolian sand exposed in the Baca Lane pit—is older than about 5.6 ka. The deeper (exposed) parts of unit 4 could be dated by optical stimulation luminescence (OSL) techniques.

Environments During the Late and Middle Holocene

Climatic and environmental conditions at the Baca Lane site appear to have fluctuated from moist (shallow lakes or ponds) and stabilized (vegetated) landscapes to dry and unstable (poorly vegetated) landscapes at least four times (we recorded four sand units) during the past 6,000 years. During moister conditions, the sand was stable and soil organic matter accumulated at or near the surface of the dunes. Without OSL dating of the eolian sand, we cannot estimate how long it took each unit to accumulate (intervals of instability and sand transport) or the duration of soil formation (intervals of stability and minimal sand transport). Nevertheless, it appears that, on average, these sand dunes persisted for periods of about 1–2 k.y. before becoming unstable.

Table E–6. Materials identified from sample R4 (BA–MM04–25R4).

[Analyses by Kathy Puseman and Jamie Dexter of Paleo Research Institute, Inc. Abbreviations: W, whole; F, fragment; X, presence noted in sample; *, indicates number recovered. Material shown in bold was submitted for dating]

Identification	Material	Charred		Uncharred		Material weight or abundance
		W	F	W	F	
Floral remains						
Chenopodium	Seed		1			
Portulaca	Seed	1				
Sporobolus	Caryopsis	1				
Rootlets					X	Few
Charcoal or wood						
Chenopodiaceae - friable, with pits and fissures	Charcoal		7			0.053 g
Sarcobatus vermiculatus	Charcoal		1			0.006 g
Chrysothamnus	Charcoal		10			0.030 g
Unidentified hardwood >2 m	**Charcoal**		**X**			0.015 g
Unidentified <2 mm	Charcoal		X			
Nonfloral remains						
Bone ≥1 mm			2		1	
Bone <1 mm			X		X	Few
Insect	Chitin				6	
Snail shell			3	1	2	

Paleovegetation During Stable Intervals

The recovered charcoal came from local shrubs (*Chenopodiaceae, Atriplex, Sarcobatus,* and *Chrysothamaus*) that likely were burned as fuel sources by the prehistoric occupants of the site. Charred seeds of *Chenopodium* (goosefoot), *Portulaca* (purslane), *Sporobolus* (dropseed) and *Oxalis* (wood sorrel) were found in the samples that were processed. During prehistoric times, humans appear to have occupied this area during the late summer or fall season when these seed resources are available for harvesting. Charred bone fragments in all four samples most likely reflect the processing of meat and fish (sample R1). Samples R1, R2, and R4 encompass a time span of 2.8 ka to about 5.56 ka, which equates to late and middle Holocene time.

Acknowledgments

We appreciate the constructive and helpful comments of Ralph Shroba (USGS) and Laura Strickland (USGS) who reviewed a preliminary version of this manuscript. However, any errors that may remain are the responsibility of the authors.

References Cited

Stuiver, M., and Reimer, P.J., 1993, Extended ^{14}C database and revised CALIB 3.0 ^{14}C age calibration program: Radiocarbon, v. 35, no. 1, p. 215–230.