Geoarchaeology of the Boca Negra Wash Area, Albuquerque Basin, New Mexico, USA

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Dozens of Paleoindian sites, including the Boca Negra Wash (BNW) Folsom site (LA 124474), are scattered across a basalt plateau (the West Mesa) on the western side of the Albuquerque Basin, and adjacent uplands. The BNW site, like many others in the area, is located near a small (~60 × 90 m) playa basin that formed in a depression on the basalt surface and was subsequently covered by an eolian sand sheet (Unit 1) dated by OSL to ~23,000 yr B.P. Most of the basin fill is ~2 m of playa mud (Units 2 and 3) dating ~13,970 ^{14}C yr B.P. (17,160–16,140 cal yr B.P.) at the sand–mud interface to ~2810 ^{14}C yr B.P. (~2960–2860 cal yr B.P.) at the top. C/N ratios suggest that the BNW playa basin probably held water more often during the Folsom occupation; stable carbon isotope values indicate C3 vegetation was more common as well, but C4 grasses became dominant in the Holocene. Cores extracted from four playa basins nearby revealed a similar stratigraphy and geochronology, documenting presence of wetlands on playa floors during the Paleoindian occupation of the area. © 2006 Wiley Periodicals, Inc.

INTRODUCTION

The Albuquerque Basin in the central Rio Grande Valley (Figure 1) has long been known to archaeologists for its rich Paleoindian record (e.g., Hibben, 1941; Dawson and Judge, 1969; Judge and Dawson, 1972; Judge, 1973). The area has one of the highest concentrations of reported Paleoindian sites in the Southwest. Most of these are on terraces or other uplands in proximity to the Rio Grande. Very little is known of the stratigraphic or paleoenvironmental context of these Paleoindian localities,

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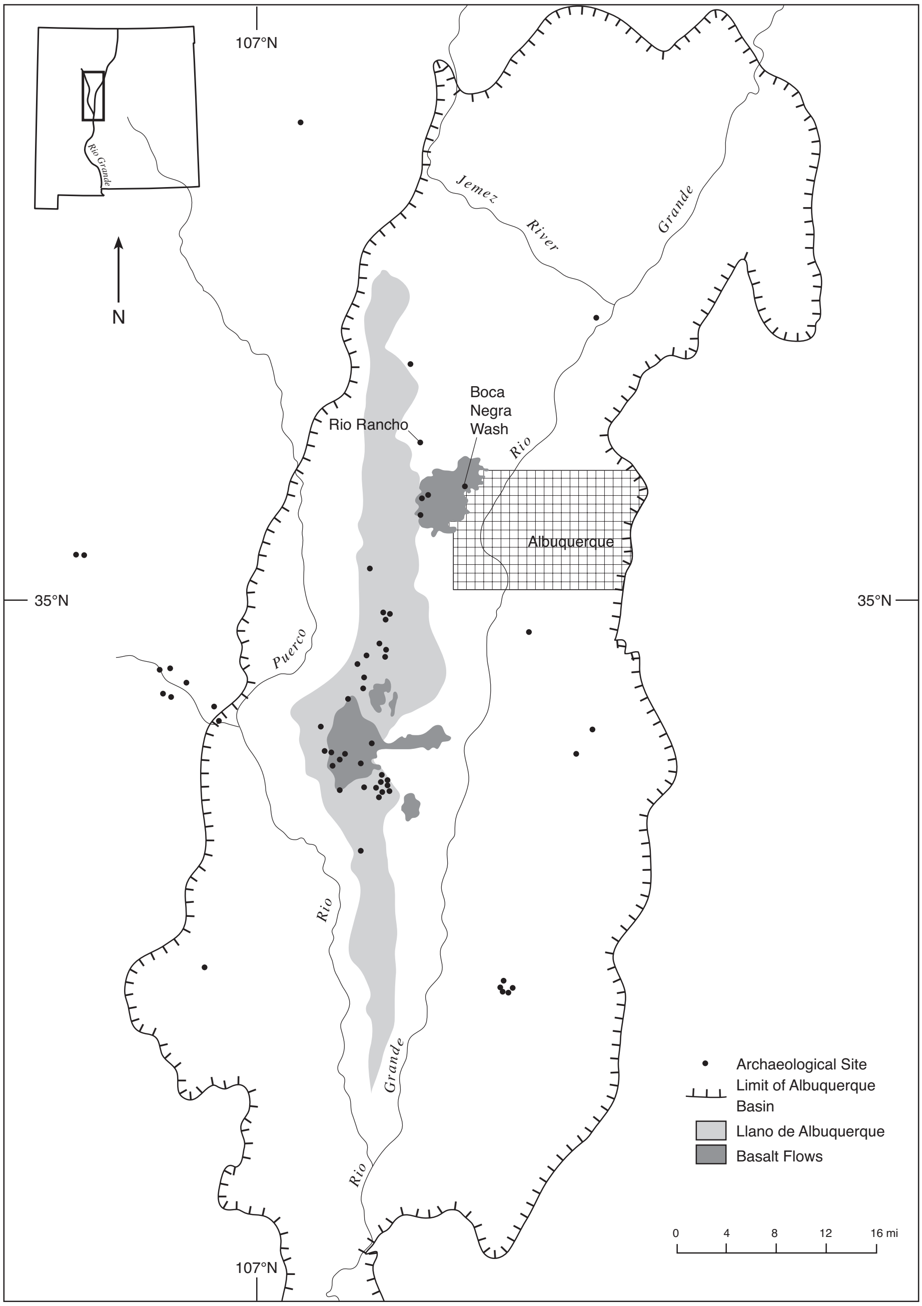

Figure 1. The Albuquerque Basin showing the location of the Boca Negra Wash site, archaeological sites reported by Judge (1973, Figure 4), and key physiographic features (based on Kelley and Kudo, 1978, Figure 1, sheet 1; Connell 2004, Figure 2). Inset shows the location of the figure area relative to New Mexico and the Rio Grande.

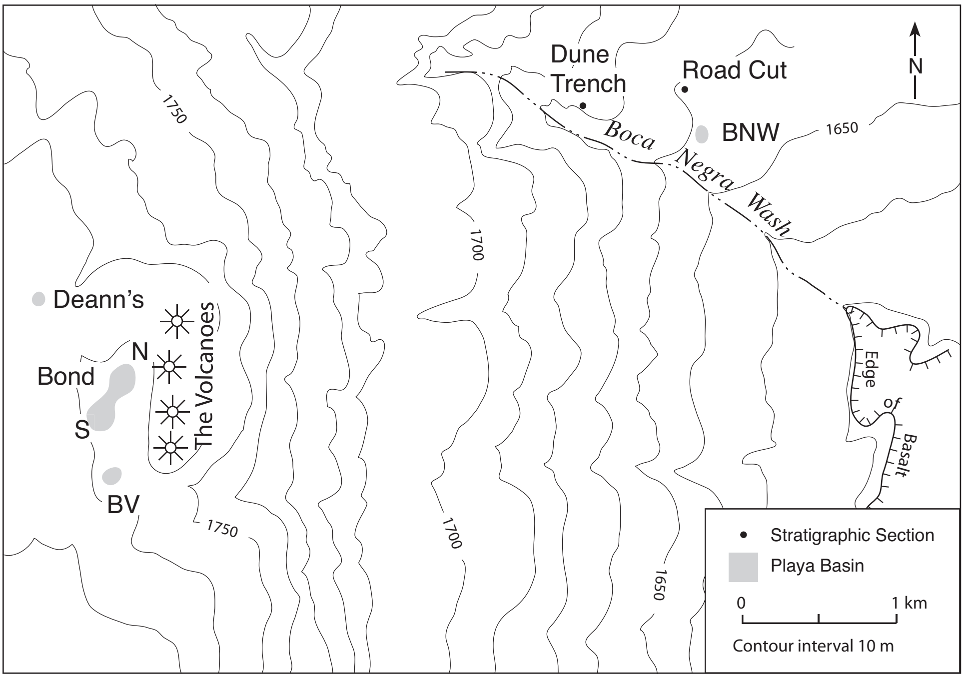

Figure 2. Topographic map of a portion of the West Mesa area showing locations of study sites discussed in the text and selected physiographic features.

however. Indeed, except for the Southern High Plains of eastern New Mexico (Haynes, 1975, 1995; Holliday, 1997), the Folsom site in northeastern New Mexico (Meltzer, 2006), the San Luis Valley of south-central Colorado (Jodry, 1999), and the upper San Pedro Valley of southeastern Arizona (Haynes, 1987), the geoarchaeology of Paleoindian occupations in the Southwest is largely unknown. Prior to 1998, only a single Folsom site—Rio Rancho—in the middle Rio Grande had been excavated (Dawson and Judge, 1969; Huckell and Kilby, 2002).

From 1999 to 2004, systematic archaeological and geoarchaeological investigations were conducted at Boca Negra Wash (LA 124474), a Folsom site on the West Mesa of Albuquerque in the Albuquerque Basin (Figure 2; Huckell and Kilby, 2000; Huckell et al., 2002, 2003). This work expanded to include the archaeological survey and geoarchaeological exploration of other Paleoindian localities in the area, as well as analysis of collections from earlier work on the West Mesa (Huckell, 2002; Huckell and Kilby, 2002; Huckell and Ruth, 2004). In this article, we present the results of our geoarchaeological investigations on the West Mesa, focusing on, but not limited to, the record at Boca Negra Wash (BNW). This is the first review of the stratigraphic and paleoenvironmental context of Paleoindian sites in the area based on subsurface exploration.

Our data provide insights into the evolution of the landscape prior to and throughout the Paleoindian occupation, complementing both the initial archaeological interpretations (e.g., Judge, 1973) and the more recent work (Huckell and Kilby, 2000). A particular focus of this work has been on small playa basins that dot the West Mesa and neighboring uplands on the west side of the Rio Grande. The BNW site and many others are adjacent to or near these basins. These landforms are roughly similar to the better-known playas of the Southern High Plains to the east that have associated Paleoindian sites, contain fills up to 8 m thick, and hold paleoenvironmental records spanning the late Quaternary (Gustavson et al., 1995; Holliday et al., 1996; Holliday, 1997; Fredlund et al., 2003; Litwinionek et al., 2003). Two of the authors (Vance T. Holliday and James H. Mayer) have been investigating the High Plains playas as well as those on the West Mesa. Our observations and data from the High Plains provoke several specific questions addressed in our research on the West Mesa. What was the relationship of Paleoindian occupations to the playa basins (building on the work of Judge and Dawson, 1972; Judge, 1973)? What is the character of the basin fill? What is the stratigraphic relation of the basin fill to the sediments and soils in the archaeological excavations, and what does the stratigraphic record tell us about the evolution of the landscape? Finally, what sort of paleoenvironmental record is preserved in the basin fill?

SETTING AND RESEARCH BACKGROUND

The Albuquerque Basin is a structural depression in central New Mexico ~160 km (north–south) by 40–65 km (east–west) and covering ~11,000 km^2 (Figure 1; Kelley, 1977; Connell, 2004). It is bordered on the east by the Sandia and Manzano Mountains and on the west by the mesas and low hills that feed runoff and sediment to the Rio Grande and Rio Puerco. Its northern limit is approximately the Rio Jemez–Rio Grande confluence, and its southern limit is the Rio Puerco–Rio Grande confluence. The Rio Grande and the lower Rio Puerco dissect the basin (Figure 1). Most of the basin fill consists of sandstone, mudstone, and gravel of the Miocene–Pliocene Santa Fe Group (up to 3700 m thick). Surficial deposits of the basin include Pleistocene and Holocene alluvial, eolian, and palustrine sediments, and localized Pleistocene and Holocene volcanic deposits. The alluvium includes early and middle Pleistocene stream deposits at the top of the Santa Fe Group, and Pleistocene and Holocene terrace and floodplain deposits inset against the Santa Fe Group. The Tertiary–Quaternary volcanic deposits include those derived from basaltic volcanic fields and cinder cones within the basin. The eolian deposits are relatively thin layers of sand draped across much of the basin floor.

The study area is west of the Rio Grande, on the Llano del Albuquerque west of the city of Albuquerque (Figure 1). The following discussion of the Albuquerque Basin focuses on the geomorphic evolution of the greater study area. The end of basin filling (and Santa Fe deposition) was marked by incision of the Rio Grande Valley in the middle Pleistocene (Maldonado et al., 1999; Connell, 2004; Connell et al., 2005). In the study area, this incision and related downcutting by the Rio Puerco drainage isolated the Llano de Albuquerque (the Ceja Mesa discussed in Kelley, 1977), a long, prominent geomorphic surface on the west side of the basin between the Rio Grande and Rio Puerco (Figure 1). This surface was once part of the "basin–plain constructional surface" of the Albuquerque Basin, marking the top of the Santa Fe Group (Maldonado et al., 1999:175). Incision and deposition by the Rio Grande produced a series of alluvial fills and terraces below the Llano de Albuquerque. Along the western margin of the Rio Grande valley, these deposits and surfaces include (oldest to youngest): the Lomatas Negras Formation and *tercero alta* surface; the Los Duranes Formation and *tercero segundo* surface; discontinuous younger deposits and terraces; and the modern floodplain (Lambert, 1968; Machette, 1985; Maldonado et al., 1999; Connell and Love, 2001).

Volcanic eruptions emplaced basalt and andesite in the Albuquerque Basin throughout deposition of the Santa Fe Group and subsequently across the middle and late Pleistocene landscape. Most of these deposits are on the west side of the basin. Surficial volcanic deposits are associated with the Los Lunas, Albuquerque, and Cat Hills eruptions (Figure 1; Kelley and Kudo, 1978; Crumpler, 1999; Smith et al., 1999). Los Lunas is an andesitic volcano southwest of Albuquerque. Its eruption postdates incision by the Rio Grande. The Albuquerque Volcanic Field, due west of the city, include the volcanoes prominent on the western skyline of the city (Figure 2). Eruptions of these volcanoes date to ~156 ka and locally bury the Lomatas Negras Formation and the tercero alto surface (Maldonado et al., 1999; Connell and Love, 2001). The Cat Hills Volcanoes comprise an extensive area of basalt flows just north of Los Lunas. Cat Hills basalt dated to 98–110 ka locally buries the segundo alto surface and the Los Duranes Formation (Maldonado et al., 1999; Connell and Love, 2001). Deposits correlated to the Lomatas Negras Formation contain a tephra geochemically identical to the ~600 ka Lava Creek B tephra (Connell and Love, 2001).

Eolian deposits, in the form of sand sheets and dunes, are common throughout the basin, particularly downwind of the Rio Grande and Rio Puerco (Kelley, 1977). In and near the study area eolian deposits are extensive on the Llano de Albuquerque and across the Albuquerque Volcanic Field (however, Kelley, 1977, did not map the later eolian sands). As discussed below, these deposits are late Pleistocene and Holocene in age.

The Boca Negra Wash site and nearby playa basins are near the Albuquerque Volcanoes (Figures 1 and 2) and on the landscape created by the associated basalt flows. The eastern edge of the basalt forms a distinct escarpment that was eroded by the Rio Grande during the late Quaternary, and gives rise to the local term *West Mesa* to refer to the immediate area of the Albuquerque Volcanoes. The BNW archaeological site is ~100 m from Boca Negra Wash, a small reentrant incised into the basalt and draining southeast toward the Rio Grande (Figure 2). Across the surface of the West Mesa are shallow depressions typically < 100 m in diameter. They are covered by thin sand sheets draped throughout the area. These depressions were recognized and briefly described by Judge and Dawson (Dawson and Judge, 1969; Judge and Dawson, 1972; Judge, 1973) and interpreted as playas or seasonally dry lake basins. They were believed to play a central, although temporally variable, role in structuring Paleoindian settlement. Otherwise, they were never investigated or described geologically.

Most of the reported or known Paleoindian sites in the Albuquerque Basin were discovered in the 1960s by local artifact collectors (Judge, 1973). Judge investigated the settings and artifact assemblages of 59 Paleoindian sites in the area (Figure 1). Approximately half of the sites contained Folsom occupations. Most of the rest yielded Belen/Plainview and Cody/Firstview assemblages. One Clovis site was reported. Many of the sites are in proximity to the enigmatic playa basins; this is particularly true for Folsom sites (94% are within 1 km of a playa), but the percentage declines for Belen/Plainview (67%) and Cody (20%). Thirty-six of the sites are on the Llano de Albuquerque/West Mesa (Figure 1), including the Rio Rancho Folsom site, the only one of the group to be tested or excavated (Dawson and Judge, 1969; Judge and Dawson, 1972). Since the survey reported by Judge (1973), additional Paleoindian sites have become known, including BNW (Huckell and Kilby, 2000).

This study deals primarily with the Boca Negra Wash site, which was discovered by Huckell in 1998 (Huckell and Kilby, 2000). It is a small Folsom camp and the subject of archaeological and geoarchaeological investigations since 1999. The site consists of two spatially discrete short-term camp and processing areas around the margins of a small playa (~60 × 90 m; Figure 3). We focus largely on the geoarchaeology of the site, but the archaeology will also be addressed, to some degree, to place it in local and regional context. To understand more fully the record of late Quaternary landscape evolution and paleoenvironments, stratigraphic and geochronologic studies were also conducted at four playas (Deann's, Bond North, Bond South, and BV) that are west of the volcanoes (Figure 2) and at several exposures of eolian deposits in and near the BNW site. Archaeological debris was found near some of the playas and these finds are also summarized.

METHOD

Research in and near the BNW site included both archaeological and geological methods. Archaeological work concentrated in two areas on the east and south sides of the playa—designated Locus A and Locus B, respectively (Figure 3). The surface artifact distributions helped define the extents of the both loci but revealed no obvious patterning. Following the creation of a 1-m grid system, the general excavation approach was, therefore, to use random (Locus A) and systematic (Locus B) sampling to obtain representative samples of each locus and to search for artifact concentrations. Sampling within Locus A was conducted by randomly choosing a 5% sample of 1-m units within a 20-m east–west by 30-m north–south block that encompassed the limited area of the surface artifact scatter. A systematic approach was employed at Locus B, which entailed the excavation of 1-m units separated from one another by 2-m intervals within a 4-m north–south by 20-m east–west strip through the center of the artifact scatter (a 16% sample). The sampling revealed that the densest part of the locus extended 5 m farther west, south, and over 15 m farther north, so the systematic sampling approach was ultimately employed over a square 25 m on each side. At both loci, judgmentally selected 1-m units were excavated to explore areas where sample squares suggested the presence of subsurface concentrations of artifacts. Excavations were carried out by trowel within the 1 × 1 m grid squares in arbitrary 5-cm levels. All excavated sediments were passed through 1/4-in. and 1/16-in. mesh screens. All artifacts were piece-plotted and given individual

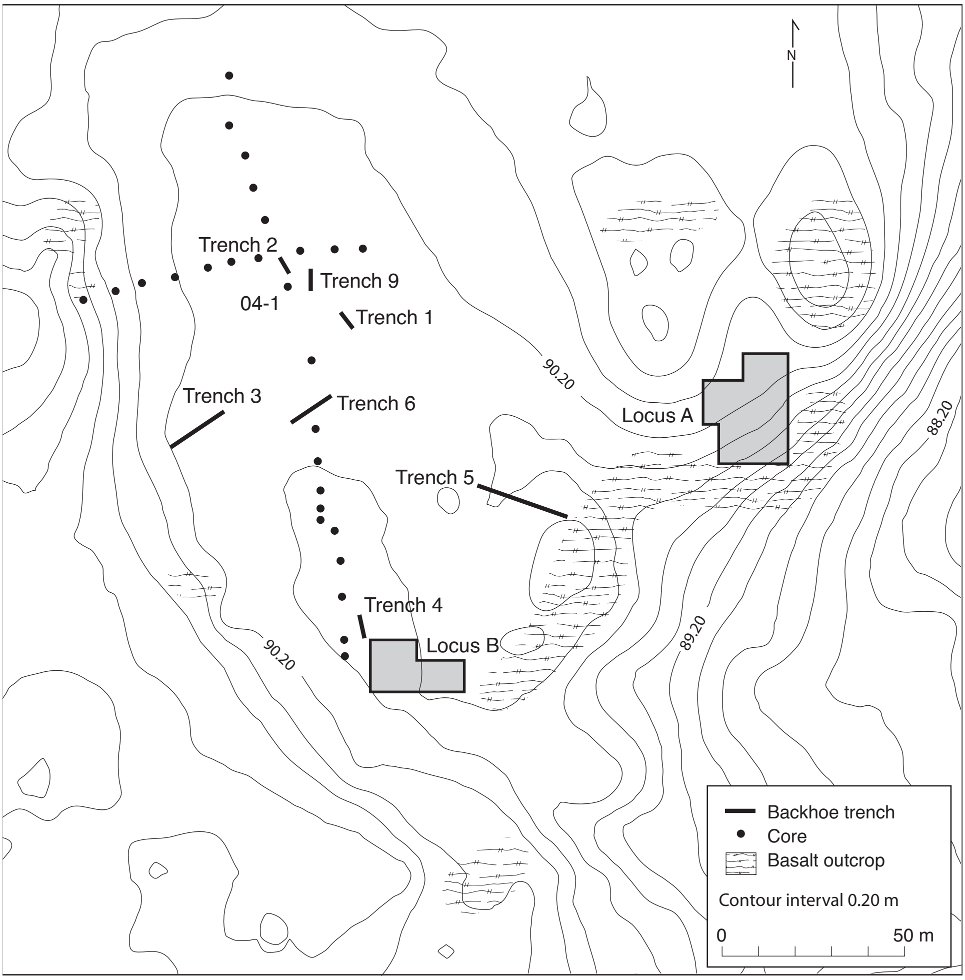

Figure 3. Topographic map of the Boca Negra Wash site, associated playa, and basalt outcrops showing locations of archaeological loci A and B, trenches, and cores (Trenches 7 and 8 are off the map to the east of Locus A). Elevations are relative to an arbitrary site datum plane.

specimen numbers. Topographic mapping of the site was conducted with a SOKKIA Total Station Set 4A (SOKKIA Co., Ltd., Kanagawa, Japan).

Several approaches were taken for the subsurface geologic exploration of the BNW site, the surrounding eolian deposits, and the nearby playa basins. A series of nine trenches was dug by backhoe near the main excavation area and across the playa (Figure 3). This was followed by coring, using a Giddings soil probe (Giddings Machine Co., Windsor, CO) and recovery of 17 6.35 cm cores at 5- or 10-m spacing (Figure 3) on a line beginning in Locus B and extending north–northwest across the playa. An additional nine cores were recovered along an east–west transect (Figure

3). Coring was also carried out in the four playa basins on the west side of the volcanoes. Nine cores were recovered at Deann's playa (most at 10-m intervals, but one pair 5-m apart) on an east–west line across the basin. In the Bond playas, 14 cores were taken at 20-m intervals on a line from the center of Bond North to the center of Bond South, including cores across a shallow sill separating the two basins. One core was recovered from BV playa. All cores were 6.35 cm in diameter. However, the depth of cores varied depending on the depth of refusal, usually determined by presence of basalt fragments, but none penetrated below 3 m and most were less than 2 m deep. The stratigraphy of the upland eolian deposits was exposed in the archaeological excavations, in backhoe trench 4, in a trench hand dug into a dune west–northwest of BNW (Figure 2), and in cuts along a north–south dirt road that runs past the east side of BNW playa (and separates Locus A and B; Figure 2). Most cores and other exposures were described using standard soil-stratigraphic nomenclature (American Geological Institute [AGI], 1982; Birkeland, 1999; Holliday, 2004). Samples were collected from several cores and exposures for laboratory analyses.

Laboratory analyses for standard soil and sediment characterization were carried out on samples from selected cores and trenches. The samples were placed in sealed plastic bags and brought to the Geoarchaeology Laboratory in the Department of Geosciences, University of Arizona, Tuscon. All samples were air-dried, then crushed with a ceramic mortar and pestle and sieved through a 2-mm sieve. Particle-size analysis was based on sieving for sand fractionation and by pipette for silt and clay content (Janitzky, 1986a) on a carbonate-free and organic-matter-free basis. Organic carbon content was measured by wet combustion (Walkley–Black method) (Janitzky, 1986b). Calcium carbonate content was determined by gasometry with a Chittick apparatus (Machette, 1986).

Dating the geomorphic evolution of BNW and other localities on the West Mesa was accomplished using radiocarbon dating and optically stimulated luminescence (OSL) dating. Radiocarbon ages were determined for soil organic matter (SOM) from buried soil horizons and organic-rich sediments, as well as charcoal (Table I). Although radiocarbon dating of organic-rich sediments is somewhat problematic (Martin and Johnson, 1995; Abbot and Stafford, 1996; McGeehin et al., 2001), studies have shown that with proper care in sampling and interpretation, these materials can provide good 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 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 (sodium hydroxide [NaOH] insoluble) and humic acid (NaOH soluble) fractions using the liquid scintillation method at the University of Arizona Isotope Geochemistry Laboratory (A-#s) and the NSF-Arizona Accelerator Mass Spectrometry (AMS) Laboratory (AA#s). We consider the ages derived from the residue fractions to be more reliable than ages of humic acids for two reasons: The residue ages are stratigraphically consistent, and they are consistent with OSL ages. One radiocarbon age was determined on bulk decalcified sediment (AA46155). Another radiocarbon age (AA46156) was determined for burned grass fragments, pretreated for carbonate and humate removal.

Table I. Radiocarbon ages from sites on the West Mesa.

Site	Laboratory number	Trench/core: depth (cm)	Material dated	Uncalibrated age years B.P.	Calibrated age	$\delta^{13}C$
Boca Negra Wash	AA46156	Tr 1-U4: 40	Burned grass	560 ± 35	629–601 B.P.	–18.0
	AA46155	Tr 1-U2b: 120	Decalcified sediment	9540 ± 580	11825–10155 B.P.	–15.9
	A-13033	Tr. 9: 47–52	Residue	2025 ± 60	2052–1918 B.P.	–14.3
	A-13033.1 (AA57673)	Tr. 9: 47–52	Humic acids	2810 ± 40	2957–2862 B.P.	–14.2
	AA56690	Tr. 9: 87–97	Residue	6030 ± 59	6947–6793 B.P.	–17.6
	A-13034	Tr. 9: 131–136	Residue	10,200 +270/–260	12242–11399 B.P.	–18.5
	A-13034.1 (AA57674)	Tr. 9: 131–136	Humic acids	7250 ± 40	8057–8011 B.P.	–17.0
	AA56993	Tr. 9: 146–151	Residue	10,490 ± 110	12676–12346 B.P.	–21.0
	A-13035	Tr. 9: 161–166	Residue	10,450 +300/–290	12414–12224 B.P.	–19.5
	A-13035.1 (AA57675)	Tr. 9: 161–166	Humic acids	6765 ± 40	7626–7586 B.P.	–17.0
	AA56694	Tr. 9: 176–181	Residue	12,700 ± 150	15217–14667 B.P.	–21.5
	A-13036	Tr. 9: 191–196	Residue	13,970 +330/–315	17160–16140 B.P.	–18.6
BV	AA64532	04-1: 80–85	Residue	7650 ± 55	8463–8392 B.P.	–18.6
	AA64533	04-1: 145–150	Residue	10,145 ± 55	11843–11707 B.P.	–21.0
	AA64534	04-1: 280–290	Residue	17,780 ± 110	21207–20775 B.P.	–23.3
Bond	AA64528	04-2: 20–25	Residue	2770 ± 55	2896–2791 B.P.	–15.9
	AA64529	04-2: 100–105	Residue	7510 ± 55	8389–8304 B.P.	–18.8
	AA64530	04-2: 170–175	Residue	9120 ± 70	10387–10315 B.P.	–21.8
	AA64531	04-2: 215–220	Residue	11,235 ± 85	13222–13063 B.P.	–22.0
Deann	A-13030	03-3: 66–75	Residue	5990 +155/–150	7016–6644 B.P.	–15.9
	A-13030.1	03-3: 66–75	Humic acids	5075 ± 35	5827–5752 B.P.	–16.3
	A-13031	03-3: 92–104	Residue	7335 +230/–225	8377–7691 B.P.	–16.5
	A-13032	03-3: 120–131	Residue	9130 ± 40	10297–10230 B.P.	–15.9
	A-13032.1	03-3: 120–131	Humic acids	7315 ± 35	8094–8051 B.P.	–18.2

Radiocarbon ages were corrected for isotopic fractionation and are presented in uncalibrated radiocarbon years before present (^{14}C yr B.P.) and calibrated years before present (cal yr B.P.).

Four OSL ages were determined on eolian sand collected in and around BNW (Table II). A sample collected previously was also recalculated (Table II). Single-aliquot regenerative (SAR) dating procedures were used to date medium–fine eolian sand (Murray and Wintle, 2000; 2003), similar to recent efforts to date eolian sand on the Great Plains, U.S. (Rich and Stokes, 2001; Forman et al., 2005; Goble et al., 2004; Mason et al., 2004; Feathers, 2003). SAR dating resolves a mean equivalent dose by averaging 20–40 separate equivalent doses (D_e) from respective aliquots of quartz grains following procedures in Forman et al. (2005, Table 2). The quartz fraction (100–150 μm) was isolated by density separations using Na-polytungstate and a 40-minute immersion in hydroflouric acid (HF) applied to etch the outer ~10 μm of grains, which are affected by alpha radiation (Mejdahl and Christiansen, 1994). The purity of the quartz separate was evaluated by petrographic inspection and point counting of a representative aliquot. Samples that showed $>$ 1% of nonquartz minerals were retreated with HF and checked further petrographically. Eolian sands from Boca Negra Wash contain $>$ 85% quartz and obtaining a pure quartz separate was straightforward. The SAR ages reported for UIC914Q,F supersede a previous published age for UIC914 (Huckell et al., 2003), reflecting a purer quartz extract and measurement of over 30 aliquots, yielding improved accuracy and precision.

The environmental dose rate is another analysis required to calculate a SAR age and is derived from the potassium, uranium, and thorium (assuming secular equilibrium) content, as determined by inductively coupled plasma mass spectrometry (Table II). A small cosmic ray component is included in the estimated dose rate (Prescott and Hutton, 1994). A moisture content (by weight) of 5 $\pm$ 2% or 10 $\pm$ 3% is assumed in the dose-rate calculations, which reflects collection conditions and hygroscopic limit for sandy soils (Brady, 1974:192). The errors associated with SAR analyses are usually ~5% or less, which usually yields ages with uncertainties $<$ 10%. The SAR ages are reported in years before A.D. 2000 $\pm$ 1 σ.

The fine-grained polymineral fraction was analyzed for one sample (UIC914F) under infrared excitation (Forman and Pierson, 2002). This fine fraction yielded an OSL age of 26,430 $\pm$ 1740 years, well within 1 σ of the corresponding age of 23,830 $\pm$ 1860 years (UIC914Q) by SAR on the coarse-grain quartz fraction. All OSL ages overlap at 2 σ, indicating the dated eolian sediments were deposited ~26–20 ka.

Isotopic and elemental measures of soils and sediments can yield information on the sources of organic matter, and are valuable paleoenvironmental proxies (e.g., Nordt, 2001; Meyers, 2003; Leng and Marshall, 2004). Algae are protein-rich and cellulose-poor, with carbon/nitrogen (C/N) ratios usually between ~4 and 10, whereas vascular land plants are protein-poor and cellulose-rich, with C/N ratios usually $\geq$ 20 (Meyers, 1994). Measured C/N ratios of playa sediments can thus provide insights regarding the dominant source of organic matter (SOM). Some modification of C/N ratios apparently occurs in soil organic matter because of microbial decomposition (e.g., Sollins et al., 1984; Krull and Skjemstad, 2003). Nevertheless, changes in C/N ratios through time can be interpreted as representing varying importance of ter-

Table II. Optically stimulated luminescence (OSL) ages on eolian sediments from Boca Negra Wash Archaeological Site, New Mexico. Recalculation of UIC914 was published by Huckell et al. (2003). All ages calculated prior to 2005 A.D., and all errors are at 1 sigma.

Field number	Depth (cm)	Laboratory number	Aliquots[a]	Equivalent dose (Gray)	U[b] (ppm)	Th[b] (ppm)	K_2O[b] (%)	Cosmic dose[c] (Gray/1000 yr)	Moisture content (%)	Dose rate (Gray/1000 yr)	OSL age (yr)
BNW Road Cut	75	UIC1509	30	17.97 ± 0.77	1.6 ± 0.1	5.1 ± 0.1	2.22 ± 0.02	0.19 ± 0.017	5 ± 2	2.93 ± 0.14	6130 ± 460[e]
BNW Tr-4	165	UIC1511	28	74.18 ± 3.53	2.0 ± 0.1	6.8 ± 0.1	2.35 ± 0.02	0.17 ± 0.017	10 ± 3	3.07 ± 0.15	24,170 ± 1940[e]
BNW Dune Trench	75	UIC1508	30	56.73 ± 2.23	2.0 ± 0.1	6.7 ± 0.1	1.53 ± 0.02	0.19 ± 0.019	5 ± 2	2.51 ± 0.13	22,570 ± 1540[e]
BNW Dune Trench	140	UIC1510	30	57.37 ± 2.08	1.7 ± 0.1	5.2 ± 0.1	2.31 ± 0.02	0.17 ± 0.017	10 ± 3	2.86 ± 0.14	20,060 ± 1530[e]
Unit 1A		UIC914Q	29	65.72 ± 2.88	0.9 ± 0.1	4.0 ± 0.1	2.27 ± 0.02	0.15 ± 0.015	5 ± 2	2.75 ± 0.14	23,830 ± 1860[e]
Unit 1A		UIC914F	NA	80.88 ± 0.49[e]	0.9 ± 0.1	4.0 ± 0.1	2.27 ± 0.02	0.15 ± 0.015	5 ± 2	3.06 ± 0.15[d]	26,430 ± 1740[f]

[a] Quartz grains with 100–150 μm diameters analyzed.
[b] U, Th, and K_2O content determined by ICP-MS by Activation Laboratories Inc., Ontario, Canada.
[c] Includes a contribution from cosmic and galactic sources calculated from Prescott and Hutton (1994).
[d] Includes an alpha efficiency value of 0.041 ± 0.001.
[e] Single-aliquot regeneration ages (SAR) ages calculated before 2005 A.D. for UIC1508-1511 and UIC914Q under blue stimulation (470 ± 20 nm).
[f] Equivalent dose on fine-grained polymineral fraction by the multiple-aliquot additive dose method, under infrared stimulation (880 ± 80 nm).

restrial and aquatic sources of organic matter, providing insights into the character of playas during the late Quaternary.

Carbon isotope ratios of SOM are a direct measure of the relative contributions of C3 and C4 vegetation (Nordt, 2001). During photosynthesis, C4 plants, consisting mainly of warm-season grasses, discriminate to a lesser extent against $^{13}CO_2$ than C3 plants (trees, some shrubs, forbs, and most cool-season grasses; Park and Epstein, 1960; O'Leary, 1980). Consequently, $\delta^{13}C$ values of C4 plants range between about –19 and –10‰, with a mean around –13‰, while $\delta^{13}C$ values of C3 plants range between –30 and –20‰, with a mean around –27‰ (Smith and Epstein, 1971). In the central United States, the distribution of C4 grass cover is best explained by temperature (Teeri and Stowe, 1976; Ehleringer et al., 1997), a relationship that extends to $\delta^{13}C$ values of soil organic matter (Fredlund and Tieszen, 1997; Tieszen et al., 1997). Although some studies have shown that minor fractionation (~±1–2‰) may occur during decomposition of organic matter (Nissenbaum and Shallinger, 1974; Melillo et al., 1989; Wedin et al., 1995), $\delta^{13}C$ values from SOM over timescales of thousands to tens of thousands of years (Kelly et al., 1993), and even millions of years (Cerling et al., 1989, 1993; Quade et al., 1989), are likely to yield fairly accurate records of vegetation change.

Carbon isotope values, %C, and C/N ratios were measured on soil organic matter at the University of Arizona Isotope Geochemistry Laboratory, Tucson. Samples were passed through a 125-µm sieve to isolate the finer fraction, as well as to remove rootlets. Secondary carbonates were removed by digestion in 3N HCl at ~60°C until effervescence stopped, but pH remained < 3, and then washed with distilled H_2O until slightly acid. The %C and C/N ratios were measured by placing oven-dried samples in tin capsules and combusted at 1030°C in a Costech Elemental Analyzer (ISO-MASS Scientific, Inc., Calgary, Alberta, Canada). Stable carbon isotopic values were measured using a Finnigan Delta Plus XL mass spectrometer connected via a Finnigan MAT Conflo III split interface (Finnegan MAT, GmbH, Bremen, Germany). Results are presented in ‰ notation as per mil (‰) deviation of the sample CO_2 carbon isotopic value from the Vienna PeeDee Belemnite (VPDB) standard, where $\delta^{13}C = (^{13}C/^{12}C_{sample}/^{13}C/^{12}C_{standard} - 1) \times 1000$. Calibration of $\delta^{13}C$ values was done using USGS-24 and NBS-22, for which the precision is better than ± 0.1‰ ($1\ \sigma$). We use the $\delta^{13}C$ values of SOM to estimate the proportion of C3 and C4 plant biomass contributing to the total organic matter pool using the formula (after Ludlow et al., 1976):

$$\%C4\ \text{component} = ((\delta^{13}C_{SOM} - \delta^{13}C_{100\%C3})/(\delta^{13}C_{100\%C4} - \delta^{13}C_{100\%C3})) \times 100$$

We assume values of –27 and –13 for 100% C3 and C4 end-members, respectively.

THE ARCHAEOLOGY OF BOCA NEGRA WASH

The Boca Negra Wash (BNW) Folsom site was discovered in 1998, and was determined to consist of two spatially discrete localities. An eastern locus (Locus A) is separated from the more westerly (Locus B) by 60 m (Figure 3). Investigations of BNW began with testing in 1999–2000, and was followed by four seasons (2001–2004) of intensive excavations (Huckell and Kilby, 2000; Huckell et al., 2002, 2003). The basic research goals were to investigate Folsom land use through (a) reconstruction of technological organization, (b) definition of intrasite spatial patterning of task areas, and (c) reconstruction of paleoenvironmental conditions.

Excavations yielded flaked-stone debitage, broken or discarded tools, pieces of tooth enamel, and rare pieces of weathered bone scrap. These archaeological materials had a fairly consistent vertical distribution through a suite of soil horizons representing at least two periods of pedogenesis separated by erosion (more fully described below). The upper soil (A/B and Bw) extended to a depth of some 10–15 cm; below it was the older soil, featuring well-developed Bt, Btk, Bk, and K horizons. In Locus A, both soils were developed in a thin sand deposit atop a basalt flow; in Locus B, the soils reached greater depths because sand had accumulated in what seems to be a very deep swale. Archaeological materials were typically recovered over 10–30 cm below the present ground surface, but tended to be concentrated in the Bw and underlying Btkb horizons in both loci (15–25 cm below present ground surface).

Locus A

Locus A occupies the crest and south-facing slope of a low ridge where a shallow deposit of sand had accumulated over portions of an eroded basalt flow. Aerial photographs revealed that since at least 1935, the western portion of the locus had been impacted by a dirt road and by the construction of two natural gas lines east of, and parallel to, it in the 1950s. The excavated part of the locus lay northeast of the road and gas lines, but a tiny portion of it was preserved on the west side of the road. A single area of high artifact density was detected in the southeastern part of the locus and explored with a series of nonrandom units. Covering an area some 5×5 m, it was explored with 22 contiguous units. At its center were four units that produced between 15 and 32 artifacts each; surrounding units yielded no more than 4–8 artifacts each. Small biface and probable uniface retouch flakes comprised this concentration. Adjacent units contained a broken unifacially retouched flake tool, an endscraper, and a graver. The area seems to have been the location of a work area where several tools were used and resharpened.

At Locus A we excavated 95 1-m^2 units over an area measuring roughly 32 m north–south by 20 m east–west. From them and from surface collection, we recovered approximately 450 pieces of flaked stone, 5 pieces of tooth enamel, and several pieces of (probably recent) small-mammal bone. Among the flaked stone artifacts were two fragments of Folsom points, a Folsom point preform fragment, two endscrapers, three gravers, and 13 fragments of retouched flake tools. The tooth enamel is morphologically consistent with bison, and we interpret it to represent the weathered vestiges of bison killed at the site. Traces of later use of the locus included eight sherds, seven from a single vessel, and a few pieces of fire-cracked rocks.

Locus B

Approximately 60 m southwest of Locus A, a second archaeological locality containing Folsom material was discovered in 1999. It is positioned in a relatively level, sandy area just west of the western terminus of the basalt flow on which Locus A was situated. No Folsom diagnostic artifacts were present on the surface, but the same suite of lithic materials seen at Locus A was present.

All or portions of 104 1-m^2 units (103.5 m^2) were excavated at Locus B between 2001 and 2004, covering an area of approximately 30 m east–west by 23 m north–south. The assemblage from this locus included some 1250 flaked stone artifacts, 2 large cobble tools, 281 pieces of bison tooth enamel, and some 45 weathered fragments of large-mammal bone. Among the flaked stone artifacts were 4 Folsom point fragments, a fragment of a miniature, "pseudo-fluted" point, 4 Folsom preform fragments, and 37 channel flake fragments; clearly, weaponry repair and replacement were important activities in Locus B. Other implements included a biface fragment, 2 endscrapers, 3 gravers, 13 miscellaneous unifacially retouched flake tool fragments, 7 utilized flakes or fragments thereof, and a single core. The pair of cobble tools are both unmodified pieces of volcanic rock—one a cobble derived from the Santa Fe formation and the other a piece of the local basalt flows. The large number of pieces of bison tooth enamel and occurrences of weathered bone fragments suggest that Locus B also functioned as a processing area, as well as a place where weaponry was repaired.

Approximately 30–50 m west of the main portion of Locus B, on a low ridge sloping eastward, seven 1-m units were excavated in an area where parts of two finished Folsom points and debitage occurred on the surface. Excavations at Locus B West, as it was called, produced 24 additional flaked stone artifacts (including a Folsom point preform), as well as small quantity of younger, probably Puebloan, artifacts stratigraphically above the Folsom material. These units displayed Bw and Bk horizons resting unconformably on an erosionally truncated K horizon, suggesting that this area was eroded and then reburied after the Folsom occupation. The diagnostic Folsom artifacts were deep in the Bw or within the Bk horizons, and the Puebloan artifacts in the upper part of the Bw.

The lithic artifacts from both loci reflect activities consistent with a campsite occupied after one or more successful bison hunts. Whether Locus A and B were created by the dispersal of activities across the landscape after one kill or whether they reflect two or more occupations is difficult to ascertain. The two areas may represent occupations separated in time by a few years, decades, or even centuries. Both camps were likely set up after successful bison kills around the playa, and were occupied for a few days while the Folsom people processed the animals they had killed, repaired their weaponry, and conducted routine domestic tasks. In the 12,000 or so calendar years since the site was abandoned, it was slowly and shallowly buried by blowing sand. The raw materials for artifact manufacture at both loci are virtually the same, and represent a suite of sources that occur west and north of the site. Two materials—Pedernal chert and Jemez (Valle Grande and possibly Bear Springs) obsidian—make up the bulk of the assemblage. Following a distant third is Chuska chert (also known as Washington or Narbona Pass chert or "paleo-pink"), followed by Zuni spotted chert, petrified wood, quartzite, and a few cherts and quartzites likely derived from cobbles in the Santa Fe formation. Pedernal, Chuska, and other cherts were identified using macroscopic properties, such as color, translucence, type and size of inclusions, and luster. Source assignments were aided by reference to comparative samples. The obsidian was identified through X-ray fluoresence. Of eight samples analyzed thus far, seven are derived from the Valle Grande member and the other (rather small) is possibly from the Bear Springs source (M.S. Shackley, personal communication to B. B. Huckell, 2002). These sources permit tracing a general path of travel taken by the Folsom people to reach Boca Negra Wash, if one assumes that the most distant materials were obtained prior to visits to closer sources and that the relative quantities of each source material are indicative of how much was on hand when the BNW site was reached. Beginning in the Chuska Mountain area on the Arizona–New Mexico border, they proceeded east or southeast across the San Juan Basin, probably acquiring Zuni spotted chert in the process. A slight turn to the northeast seems to have taken them to the northern Jemez Mountains, where they acquired a large supply of Pedernal chert. They then traveled south, through the Valle Grande, obtaining another large supply of obsidian. These two sources are some 70–80 km north of the site. Continued southward movement brought them into the Rio Grande Valley and ultimately to Boca Negra Wash.

Investigation of the intrasite organization relies on discovering the spatial distribution of tools, waste flakes, features, and animal bone concentrations to understand how the Folsom people chose to separate activities within the area where their camps were located. Investigating the impact of postoccupational geomorphic processes is critical to understanding the original patterning of cultural debris. Because the site was slowly buried to a very shallow depth (less than 25 cm below present ground surface) and reexposed, to some extent, by erosion, neither animal bone nor features, such as hearths, are well preserved. However, numerous small fragments of tooth enamel—consistent in morphology and thickness with bison teeth—were recovered from Locus B, and may mark the general locations of highly weathered skulls and mandibles. In turn, this may signal the positions of the carcasses of bison killed by the hunters. The east–central part of Locus B produced finished, but badly damaged, point fragments, as well as preform fragments and channel flake fragments, suggesting a general area where weaponry repair took place. In addition, one area of highly concentrated waste flakes from tool manufacture and discarded unifacially retouched flake tools was discovered in Locus A, and probably marks a work area. Ultimately, we hope that these spatial distributions will inform us of group size, organization of domestic space within the camp, and locales where particular tasks were undertaken.

BOCA NEGRA WASH STRATIGRAPHY

The stratigraphy of the BNW area can be divided into four basic lithostratigraphic units in three landscape settings. The strata include the upper Pleistocene basalt, an older eolian sheet sand, a younger eolian sheet sand, and muddy basin fill. The landscape settings include the playa basin, the uplands immediately adjacent to the playa (containing the archaeological site proper), and the uplands farther removed from the playa. The following discussion begins with the stratigraphy on the uplands adjacent to the playa, followed by the playa itself, and finally the uplands removed from the playa.

Figure 4. The area of the Boca Negra Wash site and playa, looking southeast. The BNW playa is in front of the truck at left center. The playa basin is highlighted by the lighter vegetation (*Scleropogon* or burro grass) pattern running left–right (north–south). Locus B is just right of the right end of the vegetation patter, to the right of the large, isolated juniper in the middle foreground. Locus A is to the right of the two larger and closely spaced junipers directly behind and above the truck. The east margin of the West Mesa (and the volcanoes basalt flow) is apparent in the middle distance. The city of Albuquerque is in the basin beyond and the Sandia Mountains form the left skyline.

The landscape in the immediate vicinity of the BNW site is undulating, representing the surface of the basalt, though some depressions are filled with eolian sand. Relief is provided by "buckles" in the surface of the basalt flows, drainages such as Boca Negra Wash, and the eroded margin of the basalt where it faces the Rio Grande (Figures 2–4).

Around the playa basin, in and near the two occupation loci, the basalt is exposed at the surface (Figure 3). Immediately north and east of Locus A are two low mounds of exposed basalt, and on the west side of the basin is a prominent low ridge of exposed basalt (Figure 3). In the area of Locus B, however, the basalt is buried by up to 3 m of sand comprising the older sand sheet (Figure 5). The older sand sheet is fine sand to loamy–fine sand. Basalt fragments are scattered throughout the lower few decimeters of the sand. The upper 75–100 cm of the older sand in the area of Locus B is strongly modified by pedogenesis, exhibiting a Bt–Btk–Bk soil profile with common clay films and Stage II carbonate morphology (after Gile et al., 1981; e.g., Btkb2–Bwkb2 in Trench 4; see Table III and Figure 5). A large percentage of the Folsom occupation debris is on, or in the upper few centimeters of, this Bt horizon (Figure 5). The undersides of many artifacts contained thin, discontinuous coats of calcium carbonate $<$ 1-mm thick. An OSL age of ~24.1 $\pm$ 1.9 ka (UIC1151; Table II) was determined on the unweathered sand below the Btkb2 soil (in Trench 4; Table III). This is in good agreement with age control on Bt and Btk horizons in other parts of the Rio Grande Valley (e.g., Gile et al., 1981).

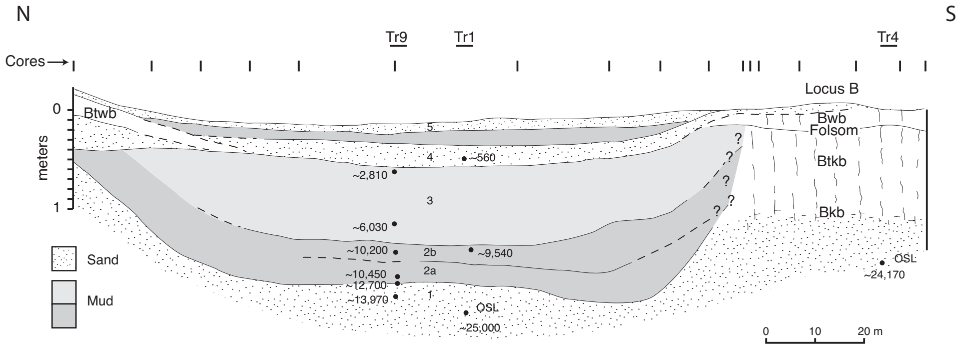

Figure 5. Stratigraphic cross section of the Boca Negra Wash site, based on data from the line of cores running from just west of Locus B north across the basin as well as Trenches 4 and 9 (Figure 3). All dates shown are uncalibrated radiocarbon means in years B.P. unless otherwise indicated as optically stimulated luminescence (OSL) ages (see Tables I and II).

Above the older sand sheet and associated soil is the younger sand sheet. In the area of Locus B, this eolian drape varies in thickness from as little as 5 cm (within the excavated area) to 23 cm in Trench 4 near Locus B (Figure 3). The sand sheet locally includes several layers of sand (e.g., 0–19 cm and 19–23 cm in Trench 4; Table III), but in most exposures, there is at least one layer, usually modified by weak pedogenesis (e.g., Bwb1 horizon in Trench 4; Table III; Figure 5). This pedogenic development modified the entire sand sheet in the area of Locus B such that (a) no unweathered sand was observed between the older and younger sand sheets, and (b) pedogenic processes in the younger sand sheet welded the Bw to the Btkb. As noted, the Folsom occupation is concentrated in the lower Bw and upper Btkb horizons.

The playa floor is only 10–20 cm lower than Locus B on the south side of the basin, but 20–100 cm below the east, north, and west sides of the basin (Figure 3). The basin is roughly elliptical in shape, 130 m northwest–southeast and 80 m southwest–northeast. The bulk of the playa fill is brown mud with varying amounts of sand (Table IV). Coring and trenching indicates that the mud is inset against the older sands and Btkb soil in Locus B (Figure 5). This fill rests on a fine sand substrate (stratum 1, $>$ 162 cm in Tables IV and V), essentially identical to the fine sand of the older sand sheet in Trench 4. Immediately below the playa mud, clay coats are present on weak ped faces in the sand (stratum 1b, 162–187 cm in Tables IV and V). This likely represents clay mechanically infiltrated down from the floor of the playa through the very porous, well-drained sands rather than the result of pedogenesis. The effects of the playa environment on the 1b sands are also evident in the iron and manganese stains (Table IV), common in sands below playa muds on the High Plains (Holliday et al., 1996). Platy structure in 1b may reflect primary bedding on the playa floor (also apparent in the lower muds, as noted below). The contact between 1b and the more typical playa muds is also gradational, suggesting an initial mixing of playa mud on the sandy floor of the playa.

Table III. Description of Trench 4, Boca Negra Wash site.

Soil horizon	Depth (cm)	Description
A	0–1	Yellowish brown (10YR 5/4d) to dark brown (4/3m) loamy sand; very fine granular structure; fine roots common; moderate reaction suggests carbonate from dust; clear, smooth.
Bwk1	1–14	Yellowish brown (10YR 5/4d) to dark brown (4/3m) silt loam; coarse, strong sbk fine carbonate concretions; clear, smooth.
Bwk2	14–19	Strong brown (7.5YR 4/6d) to dark brown (4/4m) silty clay loam; coarse, strong sbk; fine roots common; faint clay stains, no films; clear, smooth.
Bwb1	19–23	Strong brown (7.5YR 4/6d, 4/6m) loamy sand; medium and coarse weak sbk; clear, smooth with sand-size basalt grains along boundary.
Btk1b2	23–65	Brown (7.5YR 5/4d) to strong brown (4/6m) silty clay loam; very coarse, strong abk; clear, smooth boundary.
Btk2b2	65–75	Yellowish brown (10YR 5/4d) to dark brown (4/4m) silty loam to silty clay; coarse, strong sbk; abrupt, smooth boundary.
Bwkb2	75–113	Light yellowish brown (10YR 6/4d) to light yellowish brown (4/4m) loamy sand; medium, weak sbk;

Note. Munsell numbers and terms used to describe color. d = dry; m = moist; wk = weak; mod = moderate; str = strong; med = medium; sbk = subangular blocky; abk = angular blocky; pr = prismatic; cont = continuous, discont = discontinuous.

The top of the stratum 1a sands yielded OSL ages of 23.8 ± 1.9 ka (UIC914Q) and 26.4 ± 1.7 ka (UIC914F; Table II). These ages are statistically indistinguishable from one another and from the date of 24.1 ka from sand from beneath the Folsom occupation in Trench 4. This suggests that a full glacial age sand sheet is draped across the landscape and further supports the interpretation that the playa muds are inset against this older sand sheet.

The playa mud is > 160-cm thick in the center of the playa. It is divisible into several distinct zones based on structure and texture (Figure 5). The base of the mud (stratum 2, 126–162 cm in Table IV) is a strong brown silt loam with well-expressed structure. Strong platy structure (stratum 2a, 146–162 cm in Table IV) may be a relict of primary bedding. The structure above (in stratum 2b, 126–146 cm in Table IV, and another transition zone) is likely related to pedogenic structure in the overlying stratum 3. The middle portion of the mud (stratum 3a, 81–126 cm in Table IV) is a brown silt loam, but with moderately expressed soil characteristics, including prismatic structure, clay films on ped faces, and secondary calcium carbonate (Table IV). The upper mud (stratum 3b, 47–81 cm in Table IV) has more sand and less silt than the underlying layers (Table V), and also exhibits the strongest pedogenic expression with well-developed prismatic structure and continuous clay films.

Radiocarbon dating indicates that the mud began to accumulate ~14,000 ^{14}C yr B.P. (~16,600 cal yr B.P.), that is, prior to the Paleoindian occupation, but more or less peaked during Folsom time (~10,450 ^{14}C yr B.P. for stratum 2a, ~10,200 ^{14}C yr B.P. for stratum 2b or ~12,300 to ~11,800 cal yr B.P.; Table I; Figure 5). The Folsom-age muds of stratum 2 cover an area of ~100 × ~30 m in the center of the playa basin. Mud continued to accumulate into the Holocene, but the rate of sediment accumulation

Table IV. Description of Trench 9, Boca Negra Wash site.

Unit	Soil horizon	Depth (cm)	Description
5	A	0–10	7.5 YR 4/4d, 4/3m (dark brown) "silt cap" with str med sbk; clear, smooth boundary.
	Bw	10–15	7.5YR 5/6d (strong brown), 4/4m (dark brown) "silt cap" with mod med sbk; abrupt, smooth boundary.
	2C1	15–22	7.5YR 5/8d, 4/6m (strong brown) sand; massive, unbedded; abrupt, smooth boundary.
	3C2	22–27	7.5YR 5/6d (strong brown), 4/4m (dark brown) clay with mod med sbk; clear, smooth boundary.
4	4C3	27–32	7.5YR 5/8d, 4/6m (strong brown) sand; massive, unbedded; abrupt, smooth boundary.
	5C4*	32–40	7.5YR 5/6d (strong brown), 4/4m (dark brown) clay with mod med sbk; abrupt, smooth boundary.
	6C5	40–47	7.5YR 5/8d, 4/6m (strong brown) sand with wk fine sbk; faint bedding locally apparent; abrupt, smooth boundary.
3b	7ABtb1	47–52	7.5YR 4/4d, 4/3m (dark brown) silty clay; mod med sbk; thin, cont clay films on ped faces; clear, smooth boundary.
	7Btb1	52–81	7.5YR 5/4d (brown), 4/4m (dark brown) silty clay; str med sbk; thin, cont clay films on ped faces; v. hard; clear, smooth boundary.
3a	7Btk1b1	81–92	7.5YR 5/4d (brown), 4/4m (dark brown) silty clay; wk fine pr and str fine sbk; common carbonate films and threads on ped faces; very hard; clear, smooth boundary.
	7Btk2b1	92–126	7.5YR 5/4d (brown), 4/4m (dark brown) silty clay; wk fine pr and str fine sbk; few carbonate films and threads on ped faces; very hard; clear, smooth boundary.
2b	7C1b1	126–146	7.5YR 6/6d (reddish yellow), 5/6m (strong brown) silty clay; str med pr and wk/med mod sbk; very hard; clear, smooth boundary.
2a	7C2b1	146–162	7.5YR 6/6d (reddish yellow), 5/6m (strong brown) silty clay; wk sbk and str med platy; very hard; clear, smooth boundary.
1b	7C3b1	162–187	7.5YR 5/6d (strong brown), 4/4m (dark brown) sandy clay; str med platy; transition zone between 1a & 2a; gradual boundary.
1a	8Cb1	187–220	7.5YR 5/8d, 4/6m (strong brown) sand; wk sbk.

Note. d = dry; m = moist; wk = weak; mod = moderate; str = strong; med = medium; sbk = subangular blocky; abk = angular blocky; pr = prismatic; cont = continuous; discont = discontinuous.
* Clay at 32–40 cm is localized in lenses; in some sections of trench wall (mainly toward the north end), the clay is absent and the zone 27–47 cm is all sand.

slowed: ~6030 ^{14}C yr B.P. at 87–97 cm, ~2810 ^{14}C yr B.P. at 47–52 cm (the top of the playa mud; Table I; Figure 5). The slowing sedimentation rate is also indicated by weathering and soil formation in the stratum 3 muds, including rubification and development of a weak argillic and calcic horizon (Btkb; Tables IV and V).

Above the thick playa mud are interbedded layers of sand and mud (i.e., a mix of younger eolian sand and muddy basin fill), locally totaling up to 50 cm thick (Tables IV and V; Figure 5). Sand is the most common deposit, and a ubiquitous layer of sand

Table V. Laboratory data for samples from Boca Negra Wash, Trench 9.

Unit	Soil horizon	Depth (cm)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)	Sand (%)	Silt (%)	Clay (%)	Organic carbon (%)	$CaCO_3$ (%)
5	A	0–10	Trace	Trace	3	14	24	41	40	19	1.2	5
	Bw	10–15	Trace	1	8	36	23	68	23	9	0.2	4
	2C1	15–22	Trace	4	9	19	16	48	34	18	0.2	5
	3C2	22–27	Trace	4	9	19	16	48	34	18	0.3	5
4	4C3	27–32	Trace	3	12	40	23	78	15	7	0.3	1
	5C4	32–40	Trace	3	12	40	23	78	15	7	0.3	1
	6C5	40–47	1	4	10	25	20	60	30	10	0.1	2
3b	7ABtb1	47–52	Trace	Trace	5	16	21	42	45	13	0.3	2
	7Btb1	52–81	Trace	Trace	3	13	18	34	55	11	0.2	1
3a	7Btk1b1	81–92	Trace	Trace	3	12	22	37	54	9	0.1	1
	7Btk2b1	92–126	Trace	Trace	2	9	18	29	62	9	0.1	Trace
2b	7C1b1	126–146	Trace	Trace	2	8	16	26	60	14	0.1	Trace
2a	7C2b1	146–162	Trace	Trace	2	6	12	20	64	15	0.2	Trace
1b	7C3b1	162–187	Trace	Trace	2	5	13	20	68	12	0.1	Trace
1a	8Cb1	187–220	Trace	1	12	30	18	61	30	9	0.1	Trace

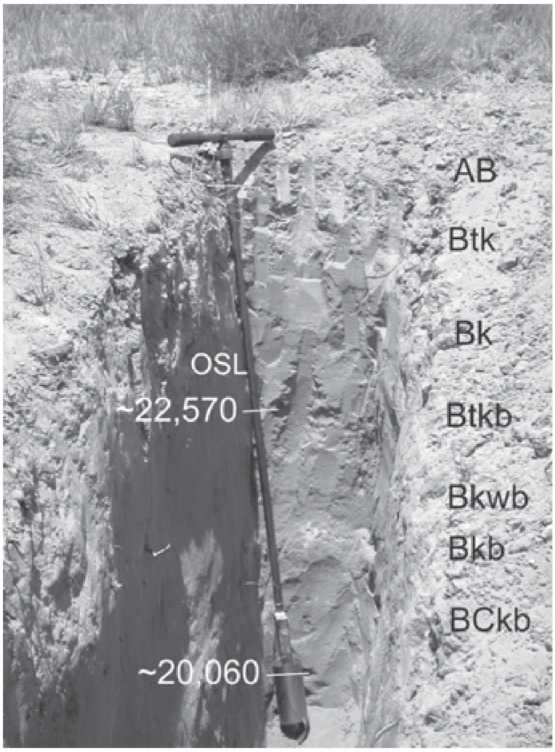

Figure 6. The dune trench (Figure 2) with soil horizonation and optically stimulated luminescence (OSL) ages indicated.

(stratum 4) rests on the stratum 3 mud throughout most of the playa and laps onto the younger sand with the Bw horizon in Locus B (Figure 4). Carbonized plant fragments from stratum 4 date to ~560 ^{14}C yr B.P. (Table I; Figure 5). Upper stratum 4 exhibits weak pedogenic modification in the form of an A–Bw soil profile. Locally, the surface of the playa floor is underlain by a silty mud (stratum 6), perhaps derived from historic dust. In the center of the playa, a lens of mud identical physically to the underlying, thicker playa muds was encountered within the stratum 4 sands (stratum 5, Tables IV and V; Figure 5). The stratum 4 sands probably represent episodic eolian deposition ($<$ 2800 ^{14}C yr B.P.) in a playa setting, and the mud lens represents a brief return to playa conditions ($<$ 560 ^{14}C yr B.P.) following each episode of sand deposition.

Radiocarbon dating in the playa and the stratigraphic position of the Folsom artifacts in Locus B indicate that during the Folsom occupation, the floor of the playa was ~150 cm deeper than today. The Folsom people were likely camping on a stable landscape with a relatively well-developed soil that had already been in place for ~10,000 years. Initial stages of ponding on the floor of the depression began ~14,000 ^{14}C yr B.P. or ~16,600 cal. yr B.P. Thus, accumulation of the playa mud and the development of the Btk soil in Locus B were coeval in part.

Table VI. Description of the Dune Trench, Boca Negra Wash area.

Soil horizon	Depth (cm)	Description
AB	0–6	Light brown (7.5YR 6/4d) to brown (4/4m) medium–fine sand; massive; litter of organic matter at and near surface; clear, abrupt boundary.
Btk1	6–14	Light brown (7.5YR 6/4d) to brown (4.5/4m) medium–fine sand with fine platy structure; hard–very hard; carbonate common as rootlet molds, grain coats and 5-mm nodules; clear, smooth boundary.
Btk2	14–34	Light brown (7.5YR 6/4d) to brown (4.5/4m) medium–fine sand with mod med sbk; hard–very hard; carbonate common as films and threads on ped faces and 5–10-mm nodules; abrupt, wavy boundary.
Bk1	34–44	Light brown (7.5YR 6/4d) to brown (4.5/4m) medium–fine sand; structureless; carbonate common as diffuse grain coatings and soft 10-mm nodules; clear, smooth boundary.
Bk2	44–62	Brown (7.5YR 5.5/4d, 4.5/4m) fine sand with dispersed medium grains; structureless; dispersed carbonate and silt replacing cicada (?) burrows; common as diffuse grain coatings and soft 10 mm nodules; abrupt, wavy boundary.
Btkb	62–78	Light brown (7.5YR 6/4d) to brown (5/4m) medium–fine sand (quartz w/common dark grains) with wk med sbk; hard; thin, patchy clay films on grains; weakly calcareous; abrupt, wavy boundary.
Bkwb	78–110	Brown (7.5YR 5/4d, 4/4m) medium–fine sand (quartz with common dark grains); soft; massive; weakly calcareous; abrupt, wavy boundary.
Bkb	110–117	Pink (7.5YR 7/3d) to brown (5/4m) medium–fine sand (quartz w/common dark grains); massive; common krotovinas; Stage I calcic horizon; abrupt, wavy boundary.
BCkb	117–170	Brown (7.5YR 5/4d, 4/4m) medium–fine sand (quartz with common dark grains); soft; massive; rare carbonate bodies as 2–4-cm bodies.

Note. d = dry; m = moist; wk = weak; mod = moderate; str = strong; med = medium; sbk = subangular blocky.

Sheets of eolian sand are discontinuous across the uplands away from the playa basin. Approximately 800 m to the north–northwest of the BNW, playa eolian sand is piled up against a rise or buckle in the surface basalt flow. A Belen/Plainview (Paleoindian) projectile point was found on the surface near these dunes. Given the possibility that the dunes buried a Paleoindian occupation, a trench was cut, exposing 165 cm of eolian sand (Figures 2 and 6). An auger hole in the floor of the trench penetrated another 105 cm of sand resting on basalt. The trench cut through two soils formed in the sand. The upper soil, at the surface, is a truncated Btk–Bk profile (Table VI). Buried in the dune is an older Btk profile (Table VI). OSL samples were collected from both layers of sand (Figure 5). They yielded two ages that are statistically indistinguishable (Table II) and average ~21,000 calendar years.

Sand sheets were well exposed in cuts along a northeast–southwest road that runs along the east side of the playa basin and in a road cut running east–west from the west side of the playa (Figure 3). Four stratigraphic units were identified in these cuts (Table VII; Figure 7). The oldest unit was exposed at the base of the cuts and is a well-developed buried Bt soil horizon (Btb3 in Table VII; Figure 7), probably formed in a sand sheet. This soil is identical in morphology to the Bt horizon formed in the older sand sheet exposed in Locus B and Trench 4, and is considered a stratigraphic

Table VII. Description of the Road Cut section, Boca Negra Wash area.

Soil horizon	Depth (cm)	Description
C	0–23	Brown/strong brown (7.5YR 5/5 sl. moist) fine–medium sand; loose; clear smooth lower boundary.
Bwb1	23–38	Light brown (7.5YR 6/4d) fine sandy loam; wk pr and mod sbk; few faint carbonate films on ped faces; clear smooth lower boundary.
Btwkb2	38–59	Brown (7.5YR 5/4d) fine sandy loam; mod pr and mod sbk; thin, disc clay films on ped faces; common carbonate films and threads on ped faces; clear smooth lower boundary.
Btwb2	59–73	Strong brown (7.5YR 5/6d) fine sandy loam; wk pr and mod sbk; thin, patchy clay films on ped faces; clear smooth lower boundary.
Cb2	73–87	Reddish yellow (7.5YR 5.5/6d); fine sand; very weak sbk; abrupt lower boundary.
Btb3	87–110	Strong brown (7.5YR 4/6d); fine sandy loam; str pr and str abk; thin cont clay films on ped faces.

Note. d = dry; m = moist; wk = weak; mod = moderate; str = strong; med = medium; sbk = subangular blocky; abk = angular blocky; pr = prismatic; cont = continuous.

equivalent. Above this soil are three sand sheets. The lowest sheet, resting on the well-expressed Bt horizon, is composed of fine sand ~50 cm thick with a weakly expressed Bt horizon (Btwkb2 complex in Table VII; Figure 7). In addition to translocated clay, the soil also exhibits secondary calcium carbonate. Given the position of the carbonate in the upper part of the soil profile, it was probably derived from the overlying soil (i.e., the b2 soil is welded to the b1). The overlying sand sheet is ~15 cm thick and is weakly altered by development of a Bw horizon (Bwb1 horizon in Table VII; Figure 7). The youngest layer is ~25 cm thick and composed of loose, poorly sorted medium and fine sand with no evidence of postdepositional alteration (C horizon in Table VII; Figure 7). The sand layer resting on the well-expressed Bt horizon produced an OSL age of ~6100 B.P. (Table II; Figure 7). This age seems reasonable given the development of a weakly expressed Bt horizon in the unit and formation of a Bw horizon in the overlying sheet sand. These data are consistent with information on rates of minimal Bt horizon development and Bw formation elsewhere in the Rio Grande Valley (Gile et al., 1981). The uppermost sandsheet is likely Historic in age, if not a 20th century artifact of land disturbance. The Bwb1 soil probably correlates with the upper Bw (formed in Unit 4) identified in the playa and the Bw soil in the Locus B area.

BOCA NEGRA WASH CARBON ISOTOPES AND C/N RATIOS

The stable carbon isotope values from Trench 9 are indicative of essentially unidirectional warming from the latest Pleistocene through the middle Holocene (Figure 8). The values are most negative (indicative of more cool season grasses) in the earliest part of the record (~14,000 ^{14}C yr B.P.), ranging from –20‰ to –16‰; however, they become progressively less negative and reach maximum values of –14‰ at ~4000 ^{14}C yr B.P. (Figure 8). This is indicative of an increase in C4 (warm season) contributions to soil organic matter of about 50% to 90% over the same period. The percentage of organic carbon is low, increasing from about 0.1% to 1.2% from the earliest

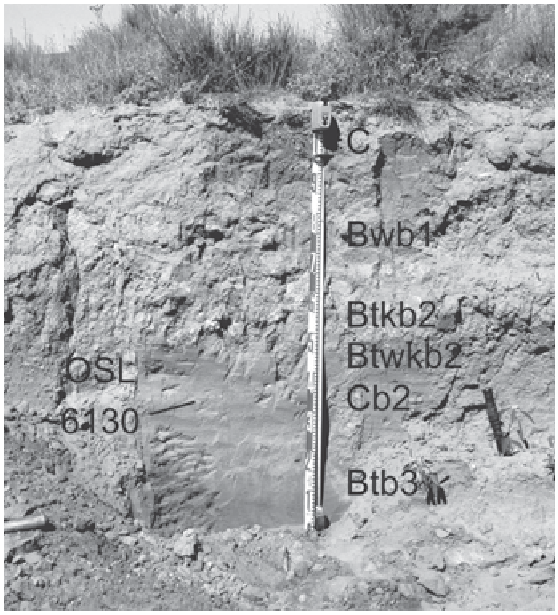

Figure 7. The road cut (Figure 2) with soil horizonation and optically stimulated luminescence (OSL) age indicated.

to latest part of the record. There is a small (~0.1%) increase in the percentage of organic carbon at ~10,500 ^{14}C yr B.P., possibly indicative of an increase in biological productivity in and around the playa during Folsom occupation of the site.

The C/N values vary between 5.0 and 8.0, but are consistently lowest between ~12,000 and 10,200 ^{14}C yr B.P. (Figure 8), overlapping the timing of Folsom occupation of the site (somewhere between 10,900 and 10,200 ^{14}C yr B.P., based on dating elsewhere; Holliday, 2000). The particle-size distribution shows surprisingly little variation in clay content, although the best-expressed facies of the playa muds (i.e., stratum 2) shows an increase in clay of about 5% relative to under- and overlying strata. The isotopic and elemental data suggest that more organic matter was derived from aquatic sources between ~12,000 and 10,000 ^{14}C yr B.P., whereas the sedimentological data indicate the basin fill is most finely textured during the same interval. In short, the playa basin probably held water more often, at least seasonally, and was likely characterized by relatively lush vegetation when dry (compared to modern times) during the latest Pleistocene and earliest Holocene, including the time of the Folsom occupation. Whether the more negative stable carbon isotope values are the result of more cool-season grasses or more trees and shrubs on the landscape is uncertain. However, if considered along with the C/N values and sedimentological data, suggest cooler conditions during the latest Pleistocene relative to the Holocene.

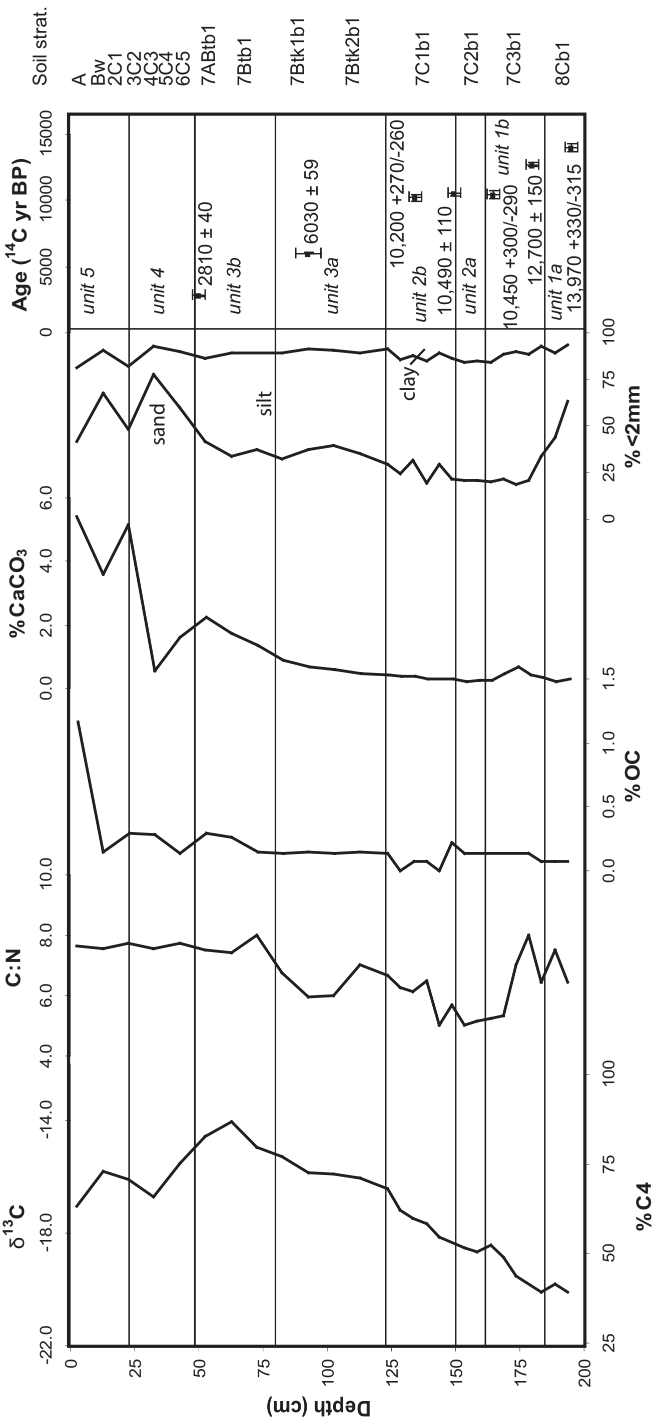

Figure 8. Plot of stable carbon isotopes, organic carbon data, C/N ratios, and sand fractions from Trench 9.

Primary concerns of the isotopic and C/N records are whether they have been modified because of diagenesis. The low C/N ratios of soil organic matter are consistent with other studies (e.g., Sollins et al., 1984; Krull and Skjemstad, 2003) and are probably the result of decomposition. Rather than showing a monotonic decrease with depth (i.e., time), our record shows swings to both greater and lesser values, which likely reflect initial variability in the source organic matter. Studies of the effects of decomposition on isotopic ratios show that changes in $\delta^{13}C$ values do occur during the conversion of litter to SOM (see Ehleringer et al., 2000, for discussion). Shifts approximately 1–2‰ have been observed in C3 ecosystems (Nadelhoffer and Fry, 1988; Balesdent et al., 1993); however, Wedin et al. (1995) found a depletion of ~1‰ in the decomposition of C4 grass litter. Nevertheless, studies of relatively long-term effects of decomposition (i.e., soil depth profiles) indicate that there is progressive ^{13}C enrichment in SOM through time (Nissenbaum and Schallinger, 1974; Nadelhoffer and Fry, 1988; Balesdent and Mariotti, 1996; Boutton, 1996). Thus, it is possible that the $\delta^{13}C$ values in the isotope record from Boca Negra playa reflect maximum values, and initial values may have been 1–2‰ more negative. Determining whether our stable isotope record reflects changes due to diagenesis or decomposition will be a focus of future research.

DEANN'S PLAYA, THE BOND PLAYAS, AND BV PLAYA STRATIGRAPHY

The stratigraphy and landscape settings associated with the playas investigated on the west side of the volcanoes are essentially the same as that identified in and near BNW. There are two principal differences between the two areas. Relief is higher around the playas west of the volcanoes because there is more relief on the surface of the basalt (Figure 9). This is probably because these playas are within 500–1000 m of the volcanic eruption centers. Further, most of the basalt is exposed at the surface; that is, the older sand sheet does not cover the basalt around the playas west of the volcanoes. Indeed, the only deposit of significant thickness covering the basalt is the playa fill itself.

The four playas are roughly in a northwest–southeast alignment (Figure 2). Deann's playa is the northernmost (Figure 2) and is ~90 m in diameter. Based on data from a line of nine Giddings core holes, the fill is ~200 cm thick in the center of the basin and consists of a basal sand (Unit 1), pedogenically altered mud (Units 2 and 3), and a thin surface layer of sand (Unit 4; Tables VIII and IX; Figure 10). At the base of the section is a dense Stage III calcrete, probably encasing basalt. Sand of stratum 1 rests on the basalt and grades up into the mud of Unit 2. The muds are up to ~160 cm thick in the center of the basin. In the center of the basin, where Unit 2 is thickest and deepest, it exhibits some weak platy structure (Unit 2a), possibly reflecting original bedding. Unit 2a occupies an area ~60 m in diameter. The mud of stratum 3 is strongly modified by pedogenesis with formation of a Bt–Btk profile. It is somewhat sandier than in BNW playa, especially near the playa margins, probably reflecting sandy eolian additions. The overlying sand of stratum 4 is the typical surface deposit on the floor of Deann's playa, although locally stratum 3 is at the surface. Stratum 4 is somewhat modified by weak pedogenesis in the form of a Bw horizon

Figure 9. Bond Playa South looking northeast with truck and drill rig at core 04-1 and a segment of the volcanoes forming the skyline in the middle distance.

Table VIII. Description of Deann's playa, West Mesa, Albuquerque Basin.

Unit	Soil horizon	Depth (cm)	Description
5/6	Bw	0–9	Dark brown (7.5YR 4/4d, 3/4m) fine sandy loam; wk med sbk; abrupt boundary.
3	Btb	9–38	Dark brown (7.5YR 4/4d, 3/4m) silty clay; cse pr and cse sbk; clear boundary.
	Btk1b1	38–76	Brown (7.5YR 5/4d) to dark brown (4/4m) silty clay; med pr and med sbk; few carbonate threads and patches; clear boundary.
	Btk2b1	76–100	Strong brown (7.5YR 4/6d) to dark brown (4/4m) silty clay; cse pr and cse sbk; common carbonate films and threads; clear boundary.
	Btk3b1	100–120	Strong brown (7.5YR 4/6d) to dark brown (4/4m) silty clay; cse pr and cse sbk; few to common carbonate films and threads; clear boundary.
1b	Btkb2	120–140	Strong brown (7.5YR 5/6d, 4/6m) fine sand; massive with few clay films and threads of carbonate; clear boundary.
	C(t)	140–165	Strong brown (7.5YR 5/6d, 4/6m) fine sand; massive with few clay films; clear boundary.
	C	165–200	Strong brown (7.5YR 5/6d, 4/6m) fine sand; massive, unbedded; abrupt boundary.
	K	200–203	Pink (7.5YR 8/4d) to light brown (6/4m) massive calcrete.

Note. d = dry; m = moist; wk = weak; mod = moderate; str = strong; med = medium; sbk = subangular blocky; abk = angular blocky; cse = coarse; pr = prismatic.

Table IX. Laboratory data for samples from Deann's playa.

Unit	Soil horizon	Depth (cm)	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Sand	Silt	Clay	Organic carbon (%)	$CaCO_3$ (%)
5/6	Bw	0–9	Trace	1	4	15	28	48	43	9	0.7	0
3	Btb	9–38	Trace	1	5	13	19	38	53	9	0.3	0
	Btk1b1	38–76	Trace	1	6	14	17	38	54	8	0.5	Trace
	Btk2b1	76–100	Trace	1	3	8	13	25	64	11	0.5	Trace
	Btk3b1	100–120	Trace	1	3	9	15	28	64	8	0.4	1
1b	Btkb2	120–140	1	2	15	37	21	76	19	5	0.4	1
	C(t)	140–165	—	—	—	—	—	—	—	—	—	—
	C	165–200	1	2	16	39	20	78	17	5	0.3	0
	K	200–203	4	4	11	34	22	75	14	11	0.7	38

Note. No data are available for Ct horizon in Unit 1b.

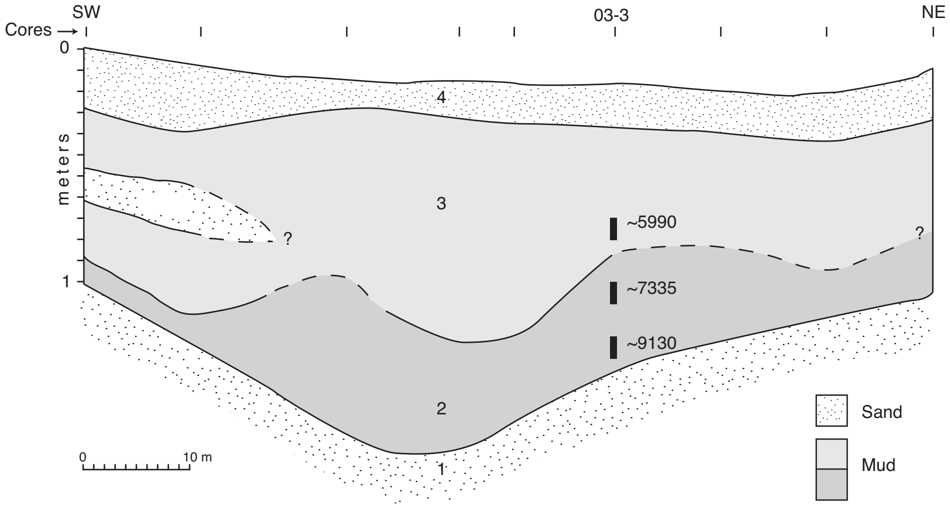

Figure 10. Stratigraphic cross-section of Deann's playa with radiocarbon ages in uncalibrated years B.P. (see Table I). Lab data are from the core to the left (south) of 03-4.

(Table VIII). Radiocarbon dating (Figure 10) indicates that most of the mud in Deann's playa accumulated in the first half of the Holocene. Lower stratum 2 in the deepest part of the playa mud is likely of Paleoindian age.

A Folsom occupation is present at the southern end of Deann's playa, extending over an area approximately 50 m north–south by 75 m east–west. Although discovered during a survey in 2001 (Huckell, 2002), subsequent research revealed it had been found previously by Judge (1973). From it, he collected two channel flake fragments, two pieces of debitage, a scraper, and one complete Archaic point. Testing was conducted in 2002–2003, and included surface collection, topographic mapping, and the excavation of seven 1-m units. A Folsom point midsection, 2 biface fragments, 6 complete and fragmentary unifacially retouched flake tools, a graver, and 4 utilized flakes were recovered, along with approximately 230 pieces of debitage (5 of which were channel flake fragments; Huckell and Ruth, 2004). Although only 2.5 km west of BNW, the suite of lithic raw materials used for artifact manufacture was quite different. Debitage of locally available (Santa Fe Formation) cobbles of chalcedony and chert dominated the assemblage, and the most abundant nonlocal material was a lustrous, opaque white chert, likely derived from the Zuni Mountains. As at BNW, 40 fragments of bison tooth enamel were present, suggesting that Deann's site is another example of a processing camp occupied after a successful bison kill around the playa.

The Bond playas, lying at the western base of the Bond Volcano cone, are a pair of basins separated by a low sill (Figures 2, 9, and 11). Each basin is ~220 m in diameter. The coring transect ran from the center of Bond South across the sill to the center of Bond North (Figure 11). The stratigraphy in both basins is similar and

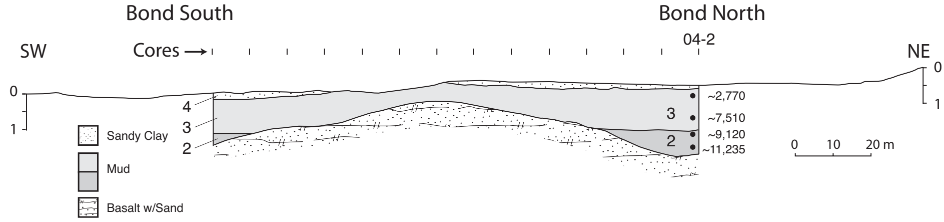

Figure 11. Stratigraphic cross-section of the Bond playas with radiocarbon ages in uncalibrated years B.P. (see Table I). The coring transect ran from the center of Bond North to the center of Bond South. The description (Table X) is from the northernmost core (04-2), the same section that was dated by radiocarbon.

essentially reproduces that observed at BNW and Deann's playa (Table X, Figure 11). The fill in each is up to ~230 cm thick. Stratum 1 sand is at the base, resting on carbonate-engulfed basalt and buried by silty clay mud. The sand is draped across the sill between the two basins (Figure 11), indicating that it is of eolian origin. The upper sand (1b) immediately below the playa mud is enriched in clay and iron and manganese oxides, all probably the result of postburial, subplaya alterations. In the center of each playa, the 1b sand and the 2a mud are also platy, probably reflecting some primary bedding. Stratum 2a occupies a relatively small area (~30-m diameter) in each basin. Stratum 2b appears to be somewhat more extensive, but stratum 3 is thicker and covers most of each basin. Stratum 3 also exhibits pedogenic modification in the form of Bt and Btk horizonation. Upper stratum 3 also drapes across the sill and can be physically traced from one basin to the other (Figure 11). Stratum 3 is at the surface at most coring localities. A few millimeters to a few centimeters of unweathered sand is locally present. The only evidence for a Unit 4 or 5 equivalent is the veneer of sand at the surface and the presence of sand coats on ped faces in upper stratum 3. One possible explanation for the more or less absence of relatively coarse stratum 4 and 5 sand in these playas is that there was no source, whereas in the BNW area, the wash could supply some sand.

Radiocarbon ages from Bond North (Table I; Figure 11) reveal a geochronology very similar to that documented at BNW. The Unit 2 muds essentially span the Paleoindian occupation of the region and show that the playa was an active wetland during Folsom time. The playa was also aggrading through much of the Holocene.

The BV playa (named for the Bond–Vulcan cones) is south–southeast of Bond South (Figure 2). It is ~200 m in diameter. Only one core was recovered from the fill. The lower half of the section (almost 2 m thick) includes stratified sand with local pockets of secondary carbonate and a weakly expressed Bt horizon. Above is ~160 cm of gray-brown playa mud with a weak Bt horizon in the upper 20 cm. Sand (perhaps equivalent to Unit 4) with an A horizon forms the surface of the playa floor. The three radiocarbon ages from the thick playa fill suggest a record of playa conditions and playa filling much longer than the other dated sections. The base of the playa mud is of Paleoindian age (~10,150 ^{14}C yr B.P.), as in the other dated sections though at the younger end. Below are older deposits, however, and the base of the

Table X. Description of Bond North playa (core 04-2; see Figure 11), West Mesa, Albuquerque Basin.

Unit	Soil horizon	Depth (cm)	Description
		0–2	Dark brown (7.5YR 4/2d, 3/2m) loose sand.
4	Bw1	2–13	Dark brown (7.5YR 4/2d, 3/2m) loamy sand; str sbk.
4	Bw2	13–22	Dark brown (7.5YR 4/4d, 3/3m) loamy sand; str sbk.
3	Btb	22–66	Dark brown (7.5YR 4/2d, 3/2m) wk fine pr and str med abk, thin cont clay films on ped faces.
3	Btk1b	66–100	Brown (7.5YR 5/2d) to dark brown (3/2m) wk fine pr and str med abk, thin cont clay films and common carbonate threads and films on ped faces.
3	Btk2b	100–110	As above, but very common carbonate; few basalt fragments.
3	Btk3b	110–131	As above, but carbonate more common but fainter; few basalt fragments.
2	Btk4b	131–137	As above, but hint of platy structure; few basalt fragments.
2	Btk5b	137–175	As above, but less common carbonate although thicker, more apparent films on ped faces; few basalt fragments.
2a?1b?		175–190	Pinkish gray (7.5YR 6/2d) to dark brown (3/2m) fine sandy mud; platy; common Fe-oxide (7.5YR 5/6) and some Mn-oxide along fracture planes; common basalt fragments.
2a?1b?		190–220	As above; more common Fe-oxide and gleying along fracture planes and root channels; common basalt fragments.

Note. d = dry; m = moist; wk = weak; mod = moderate; str = strong; med = medium; sbk = subangular blocky; abk = angular blocky; pr = prismatic.

section is only slightly younger (~21,210 cal yr B.P.) than the OSL ages from the older eolian deposits (~23,000 yr B.P.). The interstratified eolian sediment below the playa mud may contain a post–Last Glacial Maximum (LGM) signal of episodic aridity.

DISCUSSION AND CONCLUSIONS

Judge, Dawson, and a few avocational archaeologists (Dawson and Judge, 1969; Judge and Dawson, 1972; Judge, 1973) were the first to recognize the presence of playas in proximity to many of the Paleoindian sites on the West Mesa of the Albuquerque Basin. Until 1999, no further field research on the Paleoindian archaeology or playa geology of the area was undertaken. Our work is the first subsurface study of the playas; it has yielded considerable data on their stratigraphy and geochronology, which, in turn, is shedding light on Paleoindian and post-Paleoindian landscape evolution and environmental change.

The origin of the playas is unclear. The Bond playas and Deann's playa likely represent depressions on the surface of basalt flows, but BNW playa may be a small drainage blocked by eolian sand. However, it too fills what appears to be a low on the surface of the basalt. In any case, all of the basins we investigated were partially filled with eolian sand before they became playa basins. Eolian sand is also locally common on the uplands. Sand below the BNW playa deposits, in Trench 4 beneath the Folsom occupation at Locus B and in upland dunes near BNW, produced OSL ages with standard deviations that all overlap and demonstrate eolian sand deposition across the area sometime between ~21,000 and ~26,000 cal yr B.P. Further, the stratigraphy and buried soil in the upland dune trench show that there were at least two phases of late Pleistocene eolian sedimentation. These data indicate that the area was arid, or at least had an abundant supply of eolian sand, during the early LGM.

When the playa basins formed is unclear. They may represent undulations on top of the sand sheets draped over lows on the basalt, or the basins may have formed via wind deflation sometime after the sand sheet was deposited. Unit 1b, the stratigraphic transition zone between the eolian sand and playa mud, exhibits hints of ped structure. It may, therefore, be a kind of soil B horizon, and thus represent a period of stability on top of the sand prior to playa sedimentation. In any case, the presence in 1b of organic-rich fines mixed in with the sand suggests that the floor of the playa became stabilized by vegetation. If the eolian sediments (and possible deflation to form the basin) represent aridity and the playa mud represents conditions wetter than today, the weak soil may represent the transition to more moist conditions.

The playa basins clearly were present by the time the first Paleoindian occupants arrived on the West Mesa, and the BNW playa (and likely others) began to hold water soon after the LGM ~14,000 ^{14}C yr B.P. (~16,800 cal yr B.P.). The basins have 1–2 m of playa fill, demonstrating that the local landscape had more relief in the latest Pleistocene than it does today. The fine-grained, somewhat more organic-rich character of the playa fill is suggestive of a heavily vegetated playa floor, owing to more moist conditions, that trapped eolian dust. This dust would decrease infiltration through the sand, further impeding drainage. The C/N ratios and radiocarbon dating (Figure 8) show that the basin floor shifted from more terrestrial to more aquatic vegetation sometime between ~14,000 and ~10,450 ^{14}C yr B.P. Thus, a combination of geomorphic and climatic environmental factors may have contributed to the development of paludal conditions on the floor of the basins.

Regional studies with data on environmental trends that can be compared to the early evolution of the West Mesa playas and associated eolian record are rare. One of the few localities is the Estancia Basin, ~65 km east of the West Mesa and on the east side of the Sandia Mountains. Lake levels in the basin fluctuated between low stands and high stands, presumably indicating arid and wet cycles, respectively, throughout oxygen-isotope Stage 2, including the period 23.0–16.6 k cal yr B.P. (Allen and Anderson, 2000; Allen, 2005). The major cycle of eolian deposition (and aridity) at BNW was sometime ~26,000 to ~21,000 cal yr B.P., which includes at least two dry cycles in the Estancia Basin (Allen and Anderson, 2000; Figure 12). The onset of more moist paludal conditions in the BNW playa at ~14,000 ^{14}C yr B.P. coincides with the final series of high stands in the Estancia Basin (Allen and Anderson, 2000; Figure 12). The LGM record proper (~20,000 to ~15,000 ^{14}C yr B.P.) apparently is not preserved in our study sites.

The BNW playa and the other study playas provide no clear stratigraphic differentiation for the period ~12,700 to ~10,450 ^{14}C yr B.P. We are, therefore, unable to resolve the environmental conditions in and around the playas when Clovis occupants arrived in the area or during the Clovis–Folsom transition. As noted above, aquatic conditions appeared sometime between ~14,000 and ~10,450 ^{14}C yr B.P. The record from the Estancia Basin is similarly obscure for this period, other than indicating dessication followed by a final high stand sometime between 12,000 and 10,000 ^{14}C yr B.P. (Allen and Anderson, 2000). The oldest playa muds at BNW likely are at least correlative partially to the final high stand in the Estancia record. Whether this wetter phase occurred before or during the Clovis occupation, overlapped the Clovis–Folsom occupation, or occurred only during Folsom time (i.e., its relationship to the Allerød and Younger Dryas Chronozones from ~12,000 to ~10,000 ^{14}C yr B.P.) remains unknown.

The stratigraphic record of playa sedimentation clearly begins during Folsom time. The top of the lithological transition (Unit 1b) from eolian sand (Unit 1a) to playa mud (Unit 2a) is dated to ~10,450 ^{14}C yr B.P. but has a large standard deviation and overlaps with the next higher radiocarbon age of ~10,490 ^{14}C yr B.P. at the top of Unit 2a.

Paleoindian hunter–gatherers would have found a landscape dotted with depressions containing wetlands on their floors that were clearly focal points for Folsom activity, as recognized 25 years ago by Judge. Our investigations have provided some indications of the reasons that sites of ancient hunters are frequently found near them. Water (as surmised by Judge) was certainly a compelling reason, but likely as important was the localized presence of different, or perhaps higher, density plant resources; both resources attracted bison. The sparse but clear faunal evidence at BNW and Deann's site indicated that successful bison kills occurred around the playas at these two sites. What appear to be single-component occupations—as at Deann's site—may represent one-time kill-camp sites at many of these playas; the two spatially discrete loci at BNW may reflect reuse of that site and perhaps others. We hypothesize that this evidence represents repetitive Folsom use of the Llano de Albuquerque and West Mesa by Folsom groups operating primarily in northwestern New Mexico, judging from lithic evidence. The search for bison within this expanse of desert grassland was likely opportunistic, and focused principally upon successfully finding a group of bison in a location where they could be successfully stalked and killed. The playa basins probably provided a critical element of predictability to that search and thereby increased the chances of a successful kill (Huckell, 2002). The method or methods by which such kills may have been made are uncertain, but opportunities for trapping are not apparent in the modern landscape, especially if one discounts the hunting of bogged animals (Frison, 1991:157–158). Perhaps surround-type hunts, targeting cow–calf nursery herds, is a reasonable hypothesis. Creating a situation where flight is not an obvious means of escape and taking advantage of the strong social bonds that keep cows and calves together when facing predators may be the keys to success in such situations. Certainly, the several known examples of kills adjacent to playas in open terrain suggest that such situations were successfully sought and exploited in places such as the San Luis Valley (Jodry, 1999).

The BNW playa during the Folsom occupation was at its wettest, based on C/N ratios, and likely at its coolest, based on stable C isotopes, of any time during the past ~10,500 ^{14}C yr B.P. These same data sets document drying and warming trends throughout the subsequent Paleoindian occupation of the region and the rest of the Holocene. These data also provide compelling evidence toward an explanation of variability in Paleoindian land use on the West Mesa. As noted, Folsom sites are more commonly associated with playas than are later Paleoindian components. Basin fill becomes increasingly coarser-textured and C/N values of SOM increase slightly after 10,200 ^{14}C yr B.P. These data may indicate that playa basins became less reliable sources of water and vegetation for game during the later Paleoindian period relative to the Folsom era, resulting in Belen/Plainview and Cody groups focusing more on perennial drainages and springs (Dawson and Judge, 1969; Judge and Dawson, 1972). A limited systematic survey of paleo-lake Otero in the Tularosa Basin to the southeast revealed a similar trend: The Folsom sites are in closer proximity to the site of the paleo-lake compared to the later Paleoindian sites, which are more widely scattered throughout the basin (Wessel et al., 1997).

Stable-carbon isotope trends indicate that the basins warmed through the early Holocene. Middle Holocene eolian sand (in the BNW road-cut) further suggests that the area was subjected to drying, culminating in wind erosion and development of a sand sheet across the area in the middle Holocene (~6100 cal yr B.P.). Although stable carbon isotope values indicate just over 90% C4 vegetation (warm season grasses) in and around the basin, the moderately developed Unit 3b soil suggests a relatively stable landscape between ~5000–3000 ^{14}C yr B.P., a period of known cirque glaciation and periglacial activity in the Southern Sangre de Cristo Mountains to the northeast (Armour et al., 2002). The upper playa muds are dated to the late Holocene (2000–3000 cal yr B.P.), indicating that playa conditions terminated at that time. Interbedded muds and eolian sand sheets in the upper BNW section are indicative of cycles of drier and wetter conditions on the playa floor.

These studies provide strong affirmation that the small playa basins in the Middle Rio Grande contain excellent records of past environments and are valuable tools for understanding human behavior. As rare features in a landscape dominated by eolian geomorphic processes, playas provide localized depositional environments where more fine-grained records of past climate and vegetation can be obtained. Our studies are continuing, but it is clear that they are, at present, only a beginning glimpse of a complex, informative record of the late Pleistocene and Holocene.

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