Research Article

Chronostratigraphic and Paleoenvironmental Evidence for Marsh Habitats during the Early Pueblo I (A.D. 700–900) Occupation of Ridges Basin, Southwest Colorado, USA

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Ridges Basin was home to one of the largest early village communities in the American Southwest. The short-lived occupation grew rapidly around A.D. 750, construction peaked in the A.D. 780s, but Ridges Basin was depopulated by A.D. 810. Chronostratigraphic, paleoenvironmental, and archaeological investigations indicate that abundant food resources related to intermittent marsh habitats attracted migrants into the basin and aided the growing population. Extreme droughts between A.D. 795 and 809 led to decreased crop yields and marsh desiccation. We attribute the abrupt depopulation of Ridges Basin to declining environmental conditions and societal stresses. We describe the impact of marsh formation on the inhabitants, and explore the wider implications of marshes and reservoirs on the Puebloan landscape. We suggest that early Puebloans positioned their settlements in proximity to natural marshes to take advantage of the abundant plant and animal resources, which later Puebloans achieved through the construction of reservoirs.

INTRODUCTION

The American Southwest is well known for its generally dry climatic regime and the variable distribution of precipitation, making reliable water sources of critical importance to modern and ancient populations. Perennial and intermittent rivers and drainages mitigated some of the effects of recurrent drought, but many streams are presently so deeply entrenched, and may have been in the past, that their waters are not useful for irrigation. Moreover, drainages that can be used for irrigation, such as the Rio Grande and Colorado River, can flood disastrously (Cordell, 1997; Anderson and Neff, 2011). On the Colorado Plateau, seeps and springs, conditioned by overlying rock of varying permeability, were important sources of water for domestic use and for hand-watering crops. In addition to these natural features, human-built water storage features (reservoirs) in association with pre-Hispanic settlements have been documented throughout the northern Southwest. These range from the construction of simple earthen berms across exposed slickrock to more formal and labor-intensive water-storage features (Wilshusen, Churchill, & Potter, 1997). Most of these features are associated with large settlements dating to the Pueblo II and Pueblo III periods (A.D. 900–1300). Pueblo I (A.D. 700–900) sites do not tend to have reservoirs. Instead, some of them were situated in proximity to naturally occurring bodies of standing water or marshes. We suggest that this is not an accident and that there is a historical connection between the association of Pueblo I villages with marshes and later villages with human-built reservoirs. This linkage was both practical, in terms of providing important water and food resources, and symbolic, as many Pueblo origin myths incorporate or involve standing bodies of water.

Water storage is still of major concern in the Southwest; this is evident most obviously in the construction of massive reservoirs throughout the region in the last 50 years. The most recent large-scale reservoir to be constructed was in Ridges Basin, just south of the modern town of Durango, Colorado. In preparation for the construction of this Bureau of Reclamation reservoir, a team of researchers, which included the authors, conducted archaeological investigations at 74 archaeological sites in

Ridges Basin. Presently, water pumped out of the Animas River and into Ridges Basin has submerged many of these sites, the majority of which were pit-house habitations dating to the early Pueblo I period (A.D. 700–825). The Sacred Ridge site, with 22 pit structures, was the largest settlement in the basin and appears to have functioned both as a village and as a community center for smaller contemporaneous pit-house settlements throughout the basin. Although the Ridges Basin community was one of the largest in the Southwest during the early Pueblo I period, its peak occupation lasted for only about 60 years, from about A.D. 750 to about A.D. 810. Climatic reconstructions identify increasingly severe droughts and cold temperatures toward the end of the occupation period. Extreme social conflict is also evident at this time in the Ridges Basin community (Potter & Chuipka, 2010) and the combination of environmental and social stresses undoubtedly played a role in the rapid depopulation of the basin in the early ninth century A.D.

Of primary focus are the landscape dynamics that led to the formation of a marsh environment where Basin Creek exits Ridges Basin. The presence of abundant marsh resources during early Pueblo I times potentially attracted people to Ridges Basin, and the drying of the marsh toward the end of the occupation may have exacerbated an already stressed community. We use the term marsh to mean an intermittent wetland characterized by grasses, rushes, or reeds, and supporting a variety of plants and animals adapted to seasonally high groundwaters (Keddy, 2010). While we were aware that occupants of later Puebloan upland settings built their own marshy habitats in the form of reservoirs (Wilshusen, Churchill, & Potter, 1997), it was not until we began this research that we encountered several examples of other early Puebloan sites situated near natural marshes to take advantage of wetland resources.

In this paper, we explore the geomorphic, paleoenvironmental, paleoclimatic, and cultural conditions that influenced the Pueblo I habitation in Ridges Basin. The first part of this paper presents stratigraphic, sedimentologic, pollen, and radiocarbon data supporting the existence of a marsh in Ridges Basin during the early occupation, and describes the impact of natural marshlands on the inhabitants of Ridges Basin. We then explore the wider implications of marshes and built reservoirs on the Puebloan landscape. We suggest that some early Puebloans positioned their settlements in proximity to natural marshes to take advantage of the resources associated with these rich landscape features much like later Puebloans achieved through the construction of human-made reservoirs.

ENVIRONMENTAL SETTING

Ridges Basin is a triangular valley in southwest Colorado (Figure 1) with the southern and eastern sides of the triangle formed by a bend in the regionally extensive, eastward dipping Hogback Monocline. The southern, eastern, and northern edges of Ridges Basin are bounded by Basin Mountain, Carbon Mountain, and Wildcat Ridge, respectively (Figure 2). Eastward flowing Basin Creek exits Ridges Basin at the southeast corner, at the monoclinal flexure between Basin and Carbon Mountains. The bedrock formations are a sedimentary sequence of rocks deposited by the Cretaceous Sea (Blair et al., 1996). The eastern and southern slopes are easily eroded, dark gray Lewis Shale, with the more resistant, reddish-yellow Cliff House Sandstone, forming the peak of Carbon Mountain and the ridgeline of Basin Mountain. In the western part of the basin, the Pictured Cliffs Sandstone (which underlies the Lewis Shale) forms Wildcat Ridge. The combined factors of the easily eroded Lewis Shale, the orientation of the Hogback Monocline, the eastward-dipping bedrock, and the erosive action of Basin Creek caused the center of the basin to be carved into its present shape.

Surficial deposits within the basin include colluvium on ridge crests, alluvial fans along the base of Carbon and Basin Mountains, loess deposits on Wildcat Ridge, and floodplain alluvium deposited by Basin Creek (Kirkham & Navarre, 2004). The colluvial deposits on eroded ridges appear to be concordant with the late Quaternary glacial outwash terraces along the Animas River Valley (Gillam & Blair, 1999). No evidence of glacial deposits or ancient river systems traversing the basin was encountered. Older deposits underlying the Holocene alluvium appear to be altered lake sediments. The only processes to have affected the basin's geomorphic setting were those that originated within the basin, with the exception of the nutrient-rich loess deposits on Wildcat Ridge (Anderson, 2008b).

The elevation of the basin floor is about 2057 m (6749 feet), and the highest point in the catchment is on Basin Mountain at 2513 m (8245 feet). Basin Creek, which flows west to east, was confined by a steep-walled, straight-to-meandering 2–8 m deep arroyo prior to reservoir construction. The clay and salt-rich substrates are resistant to erosion, particularly given the low stream gradient (0.0075). In the distant past, Ridges Basin was a closed, internally drained landform. During the historic and modern periods, Basin Creek flowed out of Ridges Basin through an incised arroyo. Extensive historic and modern irrigation canals transported water that was pumped up over the Wildcat Mountain divide from La Plata Creek. At present Ridges Basin is closed once

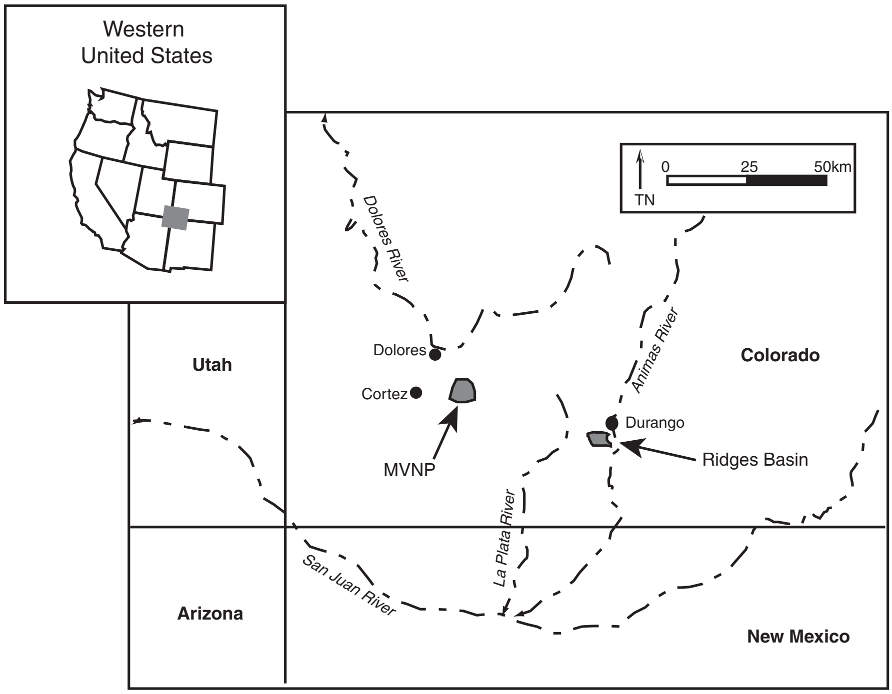

Figure 1 Map showing locations discussed in the text, including Ridges Basin, Mesa Verde National Park (MVNP), and Dolores, Colorado.

again due to the construction of a dam at the outlet, creating a reservoir for domestic and agricultural water use. Many of the archaeological sites and geomorphic features discussed below are now inundated by Lake Nighthorse.

CULTURAL SETTING

The archaeological record of Ridges Basin was thoroughly investigated from 2002 to 2005 during data recovery in preparation for the construction of a reservoir (Potter & Chuipka, 2007). Several cultural features in Ridges Basin date to the time period in North America when hunting and gathering groups of Paleoindian (9500–6000 B.C.) and Archaic (6000 B.C.–A.D. 400) peoples traversed the landscape. Although early agriculturalist Basketmaker II (approximately 1000 B.C. –A.D. 500) and Baskemaker III (A.D. 500–700) sites also occur, the Pueblo I (A.D. 700–900) habitations represent the main occupation in Ridges Basin. The complete lack of Pueblo II (A.D. 900–1150) and Pueblo III (A.D. 1150–1300) sites in Ridges Basin, a period represented by the largest villages and highest populations elsewhere in the American Southwest, is noteworthy (Fuller, 1988). People returned to the Basin during the Protohistoric (approximately A.D. 1400–1800) period. During historic and modern times farming dominated land use in Ridges Basin. Our research focused on the numerous agricultural sites dating between A.D. 700 and 810.

The early Pueblo I period in the northern American Southwest is characterized by population aggregation and movement to elevations above 1830 m (6000 feet), most likely as a quest for cooler, moister farming conditions (Toll & Wilson, 2000). The coalescence of previously dispersed populations into some of the earliest villages in upland environments entailed both a reformatting of the social landscape and exposure to new and different natural landscapes (Wilshusen & Potter, 2010; Bellorado & Anderson, 2013). This was certainly the case for the community that formed in Ridges Basin in the early 8th century A.D. Groups began moving into this unoccupied upland valley around A.D. 700 and organized themselves into settlement clusters throughout the basin. The largest of these clusters, the Sacred Ridge site, was a small village on a knoll at the west end of the basin. It contained 22 pit houses and communal ritual architecture and appears to have functioned as the ritual and social center of a dispersed pit-house community. This village-centered social landscape emerged in the context of unique and prominent natural landscape features, such as fertile soils and a relatively large wetland (Anderson, 2008a,b).

Sites of this time period are typically characterized by pit houses that are between 4 and 9 m in diameter (Figure 3). Surface mud and stick structures that often

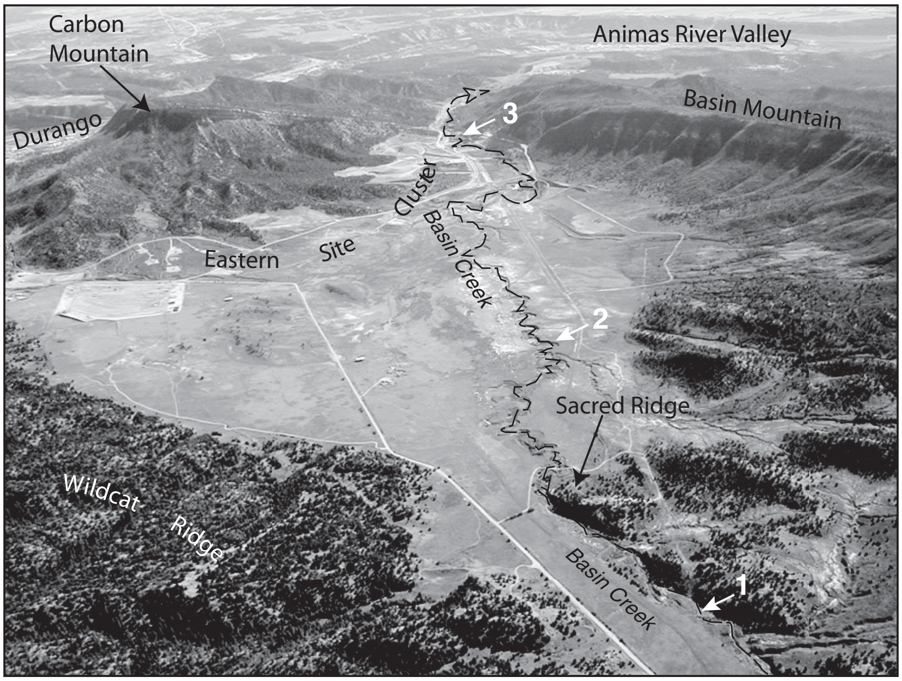

Figure 2 Aerial view of Ridges Basin showing features discussed in the text. View to the east. Numbers indicate location of dated profiles: 1. BC 10, 2. P1 and BC 15, 3. 04-03(B), and 04-04.

formed arcs around the northwestern edges of the pit structures were used primarily for storage. Kernel density analysis and *K*-means clustering analysis have identified four distinct spatial clusters of sites in Ridges Basin: the Eastern, Western, North-central, and Sacred Ridge (Potter, 2010). Particular attributes of each site cluster (e.g., ceramic types, architecture, flaked stone assemblages, and recovered perishable materials) also differentiate them and have led researchers to discuss the different clusters as representing groups with distinct social identities (Potter & Yoder 2008; Allison, 2010; Douglas & Stodder, 2010; McClellend, 2010).

Tree-ring dates from habitation structures document limited construction activities in the basin as early as the

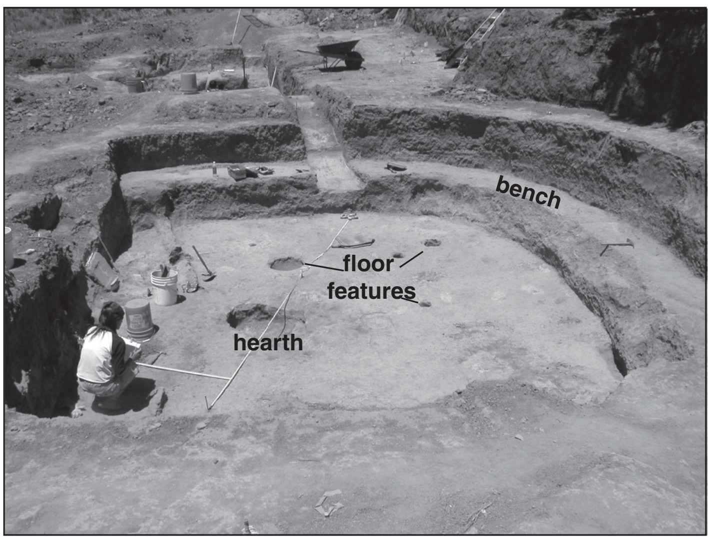

Figure 3 Photograph of an early Pueblo I pit house in Ridges Basin.

A.D. 600s. The period of increasing population and habitation construction is between A.D. 750 and 809, with more than 50% of the recovered tree ring cutting dates falling in this interval. The last cutting dates at Sacred Ridge are A.D. 802 and 803, and those in the basin are A.D. 809, indicating the years that construction stopped. A.D. 809 is also the second driest year on record for the A.D. 750–820 time period (Cook et al., 1999, 2004, 2007; Anderson, 2008c), with A.D. 799 being the driest and A.D. 797 the third driest on record. The Pueblo I occupation of Ridges Basin came to an abrupt end around A.D. 809 following a dramatic and violent event with the massacre of more than 35 individuals whose processed remains were found in a pit structure at Sacred Ridge (Potter & Chuipka, 2010). Ridges Basin was never repopulated during the later Pueblo II and III periods (Fuller, 1988).

METHODS

Studies of floodplain alluvium are hallmarks of Southwestern geoarchaeological studies for several reasons (Hack, 1942; Antevs, 1955; Waters & Haynes, 2001; Hereford, 2002). Alluvial settings are common loci for agriculture, sources of water for domestic consumption and irrigation, and areas for plant and animal resource procurement. Alluvial settings also preserve a record of past landscape changes, including episodes of downcutting, filling, and soil formation. Often, sediments contain pollen, ostracod, phytolith, and clastic material commonly used in paleoenvironmental and paleolandscape studies. In short, alluvial settings can provide abundant data on land use and environmental changes to lend insights into prehistoric behavior patterns (Dean et al., 1985; Dean, 1988, 1996; Gumerman, 1988; Karlstrom, 1988). Combining environmental data with radiocarbon age estimates of the various depositional units within the Basin Creek alluvial sequence is critical to identifying landscape processes active during prehistoric times that may have influenced the cultural history of Ridges Basin.

The chronostratigraphic and paleolandscape reconstruction of Ridges Basin is based on 18 radiocarbon dates, 41 stratigraphic profile descriptions, 68 soil horizon descriptions, 24 sediment samples, and 10 pollen samples. Soils and sediments were described according to methods set forth by the Soil Survey Staff (1999). Grain-size analysis was performed using an LS 230 Coulter Laser Particle-size Analyzer at Northern Arizona University. Percentage of organic matter was determined by the loss on ignition method at IAS Laboratories, Phoenix. Pollen samples were analyzed by Dr. Vaughn Bryant at the University of Texas, Austin (Bryant, 2005). Climatic reconstructions used to discuss paleoclimate conditions are from the Laboratory of Tree Ring Research at the University of Arizona, Tucson and from Cook et al. (1999, 2004, 2007). Paleoclimates are discussed using the Palmer Drought Severity Index (PDSI) that utilizes instrumented data, including monthly temperature and precipitation, available water-holding capacity of the soil, evapotranspiration, and latitude (as an indication of solar insolation) to determine historic drought conditions (Palmer, 1965). PDSI values are commonly used to evaluate drought impacts on agriculture. Researchers then compare PDSI calculations to the tree rings for the years of record, thereby obtaining an index that can be used to determine prehistoric PDSI values. Annual PDSI values for the prehistoric period are derived from ancient trees found at archaeological sites. The reconstructed June PDSI values used here are from 1229 ancient and living trees in the Durango, Colorado area. Interpretations of the cultural landscape are based on related studies in Ridges Basin including soil nutrient studies (Anderson, 2008b), archaeobotanical studies (Adams & Murry, 2008; Adams, Murray, & Bellorado, 2009; Adams & Reeder, 2009), faunal analysis (Potter & Edwards, 2008), and experimental garden plots (Bellorado, 2007, 2009).

Radiocarbon samples were analyzed by Beta Analytic, Inc. Miami, Fla., who also provided age calibration using Intcal 98 (Stuiver et al., 1998). All radiocarbon assays are from accelerator mass spectrometry (AMS) analysis on charred detrital material, unspecified as to type. In the discussion below, radiocarbon assays are presented as the two-sigma calibrated age ranges, unless otherwise indicated. All radiocarbon samples are detrital charcoal, except Beta 175852 from a hearth near the surface of an alluvial terrace.

Detrital charcoal is not the best material for dating sediments for two reasons. First, the sample may derive from any set of rings between the pith and outer rings of trees. For long-lived varieties the age of the tree may be several hundred years, thus reducing the accuracy in assigning the resultant date to the age of the associated deposits. Second, charcoal from a burnt tree may not be washed into alluvial deposits for tens or hundreds of years, again reducing the accuracy of dating-associated sediments. For example, based on several lines of evidence (see below), Beta 181666 and 207211 are interpreted to be older charcoal redeposited into younger alluvium. The deposits in Ridges Basin contained only one *in situ* feature and only sparse amounts of charcoal. Nonetheless, with the two exceptions discussed above, multiple samples from the same profiles returned age ranges in proper stratigraphic order.

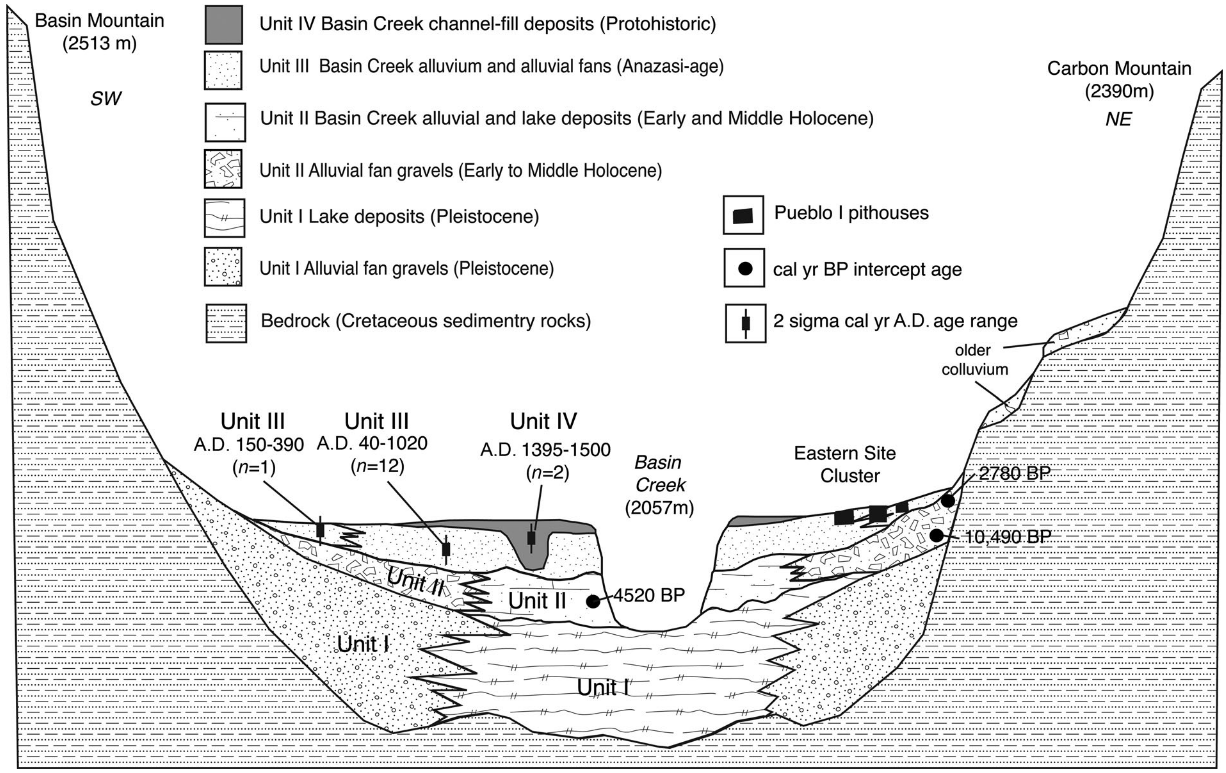

Figure 4 Schematic cross-section of Ridges Basin illustrating geomorphic relationships between depositional Units I–IV. *n*, number of samples dated per unit. Distance across is about 1 km.

RESULTS

The landscape of Ridges Basin was intensely modified by modern farming and irrigation activity. Arroyos that cut deeply into the piedmont and floodplain deposits exposed many useful sections for stratigraphic analysis and interpretation of the ancient landscape. Geomorphic and stratigraphic investigations identified four main depositional units (Unit I–IV) in Ridges Basin. Each of the four units consists of alluvial fans and temporally associated basin-fill sediments, such as alluvium, lacustrine, or marsh deposits (Figure 4). Unit I consists of Pleistocene colluvial gravels, alluvial fans, and lake deposits. Unit II contains early to middle Holocene alluvial fans, and Basin Creek alluvial and lake deposits. Unit III consists of the late Holocene intermediate alluvial fans, Basin Creek alluvium, and ponded or marsh deposits associated with the Pueblo I habitation. Unit IV consists of the younger protohistoric alluvial fans, and Basin Creek alluvial and ponded deposits. The results of the radiocarbon dating and stratigraphic analysis are presented below, starting with alluvial fans along the Carbon Mountain piedmont and progressing to floodplain deposits of Basin Creek.

Chronostratigraphy of Alluvial Fans

The oldest surficial deposits observed are Unit I colluvial gravels high on the narrow, eroded ridges emanating from Carbon Mountain, and a buried alluvial fan with an argillic soil horizon (Figure 4). The elevation of the colluvium is concordant with Pleistocene glacial outwash deposits along the Animas River, so are tentatively assigned a Pleistocene age (Gillam & Blair, 1999). Pleistocene deposits were not investigated in detail because the focus of the research is on the late Holocene depositional sequence.

Three different alluvial fans of Holocene age are inset below the Pleistocene colluvial deposits. The base of the oldest alluvial fan (Unit II) dates to the early Holocene, with an age range of 10560–10280 cal. yr B.P. from charcoal collected at a depth of 8.25 m below the alluvial fan surface (Table I). Dispersed charcoal flecks from an Archaic hearth associated with the uppermost deposits of this alluvial fan provides an age range of 2950–2740 cal. yr B.P.

Intermediate age alluvial fans (Unit III) are inset below the older alluvial fans, forming the most prominent

Table I AMS radiocarbon ages used in the chronostratigraphic reconstruction of Ridges Basin, Colorado, USA. All dated material is charred wood, unspecified as to type.

Sample No.	Beta No.	Profile No.	Conventional Age (B.P.)	Two-Sigma Calibrated (B.P.)	Two-Sigma Calibrated (A.D./B.C.)	Calibrated Intercept (B.P.)	Calibrated Intercept (A.D./B.C.)	$^{13}C/^{12}C$	Unit
ALP BCK RC3	181668	P1	440 ± 40	530–450	1420–1500	505	A.D. 1445	−25.7	IV
ALP BCK RC2	181667	P1	520 ± 40	625–605	1325–1345	530	A.D. 1420	−23.0	
				555–505	1395–1445				
RC0402	204285	04-04	1080 ± 40	1060–930	890–1020	970	A.D. 980	−22.5	III
ALP-07-05	228160	04-04	1660 ± 40	1180–970	770–980	1060	A.D. 890	−25.9	
ALP-07-01	228159	04-04	1150 ± 40	1170–960	780–980	1060	A.D. 890	−23.9	
ALP-053	207212	BC15	1190 ± 40	1230–1210	720–740	1080	A.D. 870	−25.0	
				1190–990	760–960				
ALP BCK RC1	181666	P1	1240 ± 40	1270–1065	680–885	1175	A.D. 775	−20.6	
ALP-051	207210	BC15	1250 ± 40	1270–1070	680–880	1180	A.D. 770	−24.0	
ALP BCK RC4	181669	P1	1250 ± 40	1275–1070	675–880	1180	A.D. 770	−23.1	
ALP BCK RC5	181670	P1	1300 ± 40	1295–1165	655–785	1260	A.D. 690	−26.0	
ALP-054	207213	BC15	1320 ± 40	1300–1170	650–780	1270	A.D. 680	−23.3	
BC10	204283	BC10	1380 ± 40	1330–1260	620–690	1290	A.D. 660	−23.3	
ALP-052	207211	BC15	1620 ± 40	1580–1410	370–540	1530	A.D. 420	−21.3	
ALP-262-SP3-1	177943	262	1760 ± 40	1800–1560	150–390	1700	A.D. 250	−20.8	
RC0401	204284	04-03 (B)	1890 ± 40	1900–1720	40–230	1840	A.D. 110	−25.1	
ALP BCK RC6	181671	RC6	4040 ± 40	4785–4780	2835–2830	4520	B.C. 2570	−22.5	II
				4595–4420	2645–2470				
ALP-RC1B	177942	RC1B	9280 ± 40	10560–10370	8610–8420	10490	B.C. 8540	−21.8	II
				10330–10280	8380–8330				
5LP175-PD3-1	175852	RC1B	2700 ± 70	2940–2740	1000–790	2780	B.C. 830	−25.0	II

landform on the Carbon Mountain piedmont. This is the location of the stockaded hamlets of the Eastern Cluster of early Pueblo I archaeology sites. The alluvial fans are dissected by a dendritic arroyo network that reveals 3 m of alluvial fan stratigraphy. The Pueblo I level is 30–40 cm below the modern ground surface. A radiocarbon age of A.D 150–390 was obtained on detrital charcoal at 30 cm below the buried Pueblo I surface. Therefore, the intermediate aged alluvial fan began aggrading prior to about A.D. 150–390 and continued until after the Pueblo I occupation. As discussed below, these dates have important implications for damming Basin Creek.

The youngest fan deposits (Unit IV) are inset below the intermediate fan in its proximal reaches, but prograde over the intermediate fan and the top of the upper Basin Creek alluvial terrace at its distal edges. Although the youngest fan deposits are undated, the surface has a relatively youthful appearance, perhaps only a few hundred years old and is correlated with the post-occupation period of Basin Creek aggradation that began after approximately A.D. 1450 (see below). The youngest fan was covered by rabbitbrush, whereas most of the older fans were covered by sagebrush and sparse piñon-juniper. Historic and modern irrigation deposits bury fence posts by up to 1 m of sediments in some locations along the floodplain.

Chronostratigraphy of Floodplain Alluvium

Floodplain deposits were documented where two alluvial terraces occur along the main arroyo of Basin Creek. The highest terrace (T2) was formed by incision into the floodplain by the modern arroyo, whereas the lower terrace (T1) occurs within the confines of the modern arroyo. The T2 terrace ranges in height from 3 to 8 m, depending on the location along Basin Creek's course, shallower at the upstream direction, and deeper downstream. The T1 terrace is less than 2 m high and is actively aggrading. In the summer of 2003, two extreme rainfall events produced flooding conditions and bank full discharges that were calculated to be 30 m^3/s (approximately 800 ft^3/s). These discharges overtopped the T1 terrace, depositing sediment and organic material on the terrace tread.

In general, the stratigraphy of T2 is dominated by horizontally layered alluvial deposits assigned to Unit III and overtopped by Unit IV. In most locations (Figure 5) the underlying Unit II sediments are obscured from view. A stable paleolandscape is represented by a buried paleosol, demarcating the upper surface of Unit III. The paleosol can be traced along the 1 km length of the Basin Creek arroyo, from upstream of Sacred Ridge to the outlet (see

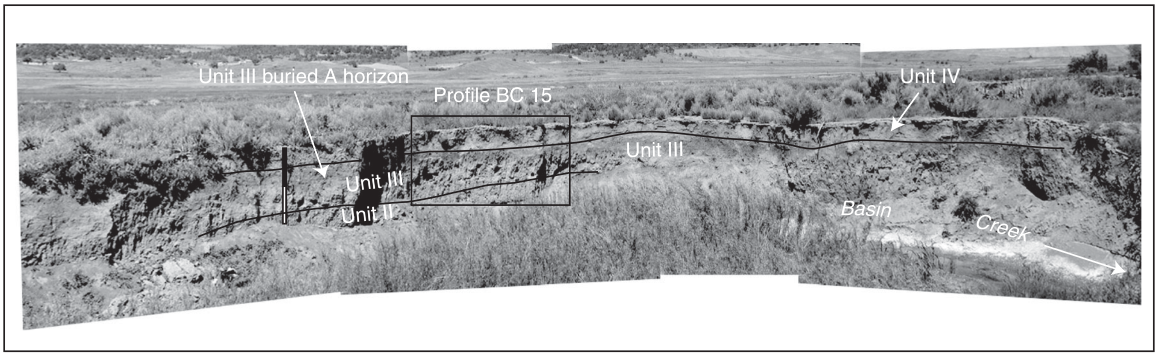

Figure 5 Photographic panel of Profile BC 15 showing stratigraphy exposed along Basin Creek arroyo. Stadia rod is 2.0 m high. View is to the north.

Figure 2). The paleosol is 30 cm thick and buried by about 40 cm of Unit IV alluvium. It has a dark gray color (5Y 4/1), a strong angular blocky soil structure, and a loam to clay loam texture. The associated C horizon is comprised of horizontally laminated alluvium that fines upwards, transitioning into a buried A horizon, suggesting cumulic soil forming processes.

Upstream and Mid-Valley Reaches

Three profiles characterize the stratigraphic and chronologic properties of Basin Creek alluvium in the upstream (BC 10) and mid-valley (Profile 1 and BC15) locations. Profile BC 10 is in the uppermost reaches of Basin Creek, upstream from Sacred Ridge (Figure 2). The section contained a well-defined sequence of Unit III and IV deposits. Detrital charcoal from Unit III returned a calibrated age range of A.D. 620–690.

Profile 1 is a 3 m high and 15 m long section of exposed alluvium in the middle reaches of Basin Creek (Figure 2), containing several layers of stacked alluvium, the buried paleosol, and a deeply cut paleochannel (Figure 6a). Unit II, the lowest depositional unit in this profile, consists of laminated and massive silt and sand deposits with distinct reddish brown and gray redoximorphic features suggestive of fluctuating groundwater conditions. Erosional processes truncated the upper boundary of Unit II, producing an undulating surface. The lower part of Unit III consists of numerous sandy and gravelly lenses less than 10 cm thick, including a series of decimeter long charcoal-rich lenses. Charred material from one of the charcoal lenses returned an age of A.D. 675–880. The upper portion of Unit III had a finer texture and increasingly thinner lenses when compared to the lower sections. The lenses graded upward becoming more clay-rich and darker, eventually grading into the buried paleosol, suggesting that the buried paleosol was formed by cumulic processes. Charcoal from the base of the paleosol dated A.D. 655–785.

An alluvial channel cut into both the Unit II and Unit III deposits contained charcoal, a Pueblo I sherd, and cow bones. Two separate charcoal samples located in the upper layers of the channel returned protohistoric ages. One of the samples dated A.D. 1325–1345 and 1395–1445, while the other sample's age range is A.D. 1420–1500. The cow bone in the upper sections of the channel indicates that alluviation occurred during the historic period, because cows entered the region after the Spanish introduced them in the 1500s. Charcoal from the bottom of the channel returned an age of A.D. 680–885, which is comparable in age to the associated pottery at the same level. Based on the two radiocarbon ages in the A.D. 1400s and the cow bones, we interpret this channel as dating to the post-A.D. 1400 period. We interpret the A.D. 680–885 charcoal sample and associated Pueblo I pottery as having been eroded from the Puebloan-aged sediments and redeposited in the protohistoric channel.

Profile BC 15 provided perhaps the best exposure and the greatest opportunity to obtain a sequence of stacked radiocarbon samples (Figure 6b). Profile BC 15 is a 50-m long and 5-m high arroyo wall that contained the same sequence of alluvial deposits as in Profiles 1 and BC 10 (Figure 2). Unit III was clearly defined by the lower silty sands grading upward into the more clay and organic matter rich, dark gray paleosol (Figure 7). Charcoal found at several stratigraphic levels returned results consistent with the previous profiles. Age ranges for the lowest samples are A.D. 680–880 and above that A.D. 370–540. A concentrated, charcoal-rich lens at the base of the A horizon returned an age range of A.D. 650–780. A single detrital charcoal sample from within the Unit III paleosol dated A.D. 720–740 and 760–960.

We use the three radiocarbon results from Profile BC 15 that have overlapping age ranges to constrain the age of Unit III between about A.D. 650 and 960. The

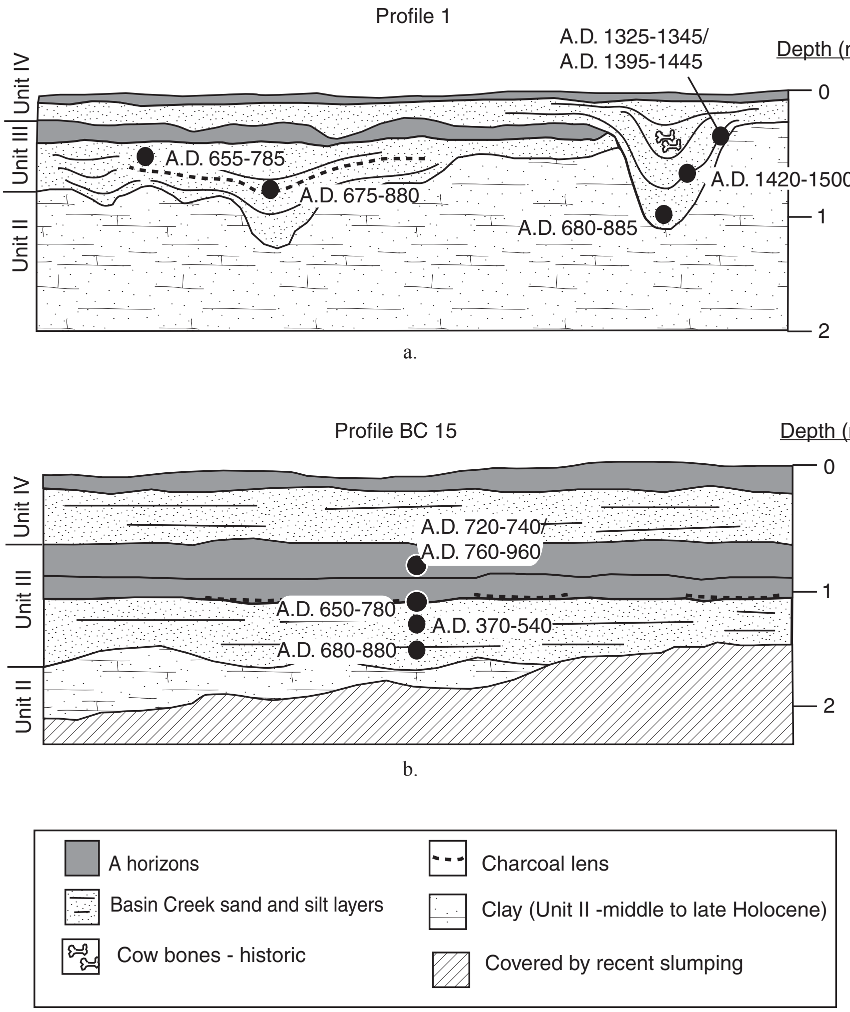

Figure 6 Chronostratigraphic relationships for Profile 1 (a) and BC 15 (b). Radiocarbon dates are two-sigma calibrated ranges.

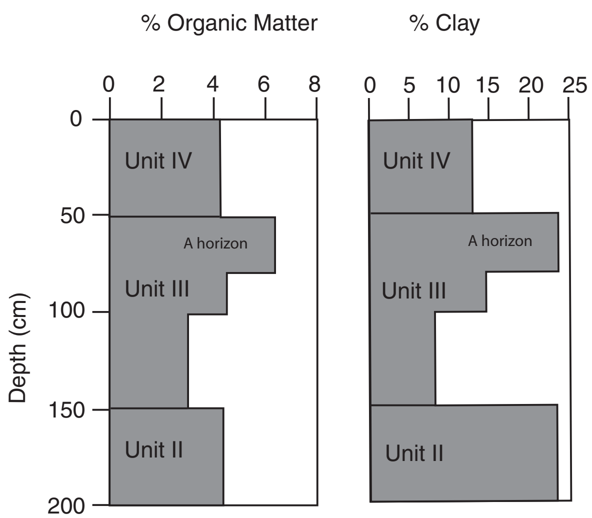

Figure 7 Percentage of organic matter and clay in Profile BC15.

cumulic paleosol therefore began developing in this area of the basin at this time. It seems probable, though not proven, that the out of sequence charcoal sample dating to A.D. 370–540 is redeposited from older eroded Unit III sediments.

Downstream and Constriction Reaches

Five profiles characterize the stratigraphic and chronologic properties of Basin Creek alluvium in the downstream reach (Profile 04-03 (B) and Profile 04-04), and at the constriction point (Profiles CD-1, 2, and 3; Figure 2). Alluvial fans from Carbon and Basin Mountains coalesced to constrict the outflow and create a ponded, marshy environment (Figure 8a). Profile 04-03(B) contains layers rich in clay and organic matter that interfinger with alluvial fan sand and gravel, representing an aggradational sequence. Aggradation in this part of the basin began as early as A.D. 40–230, based on a radiocarbon age

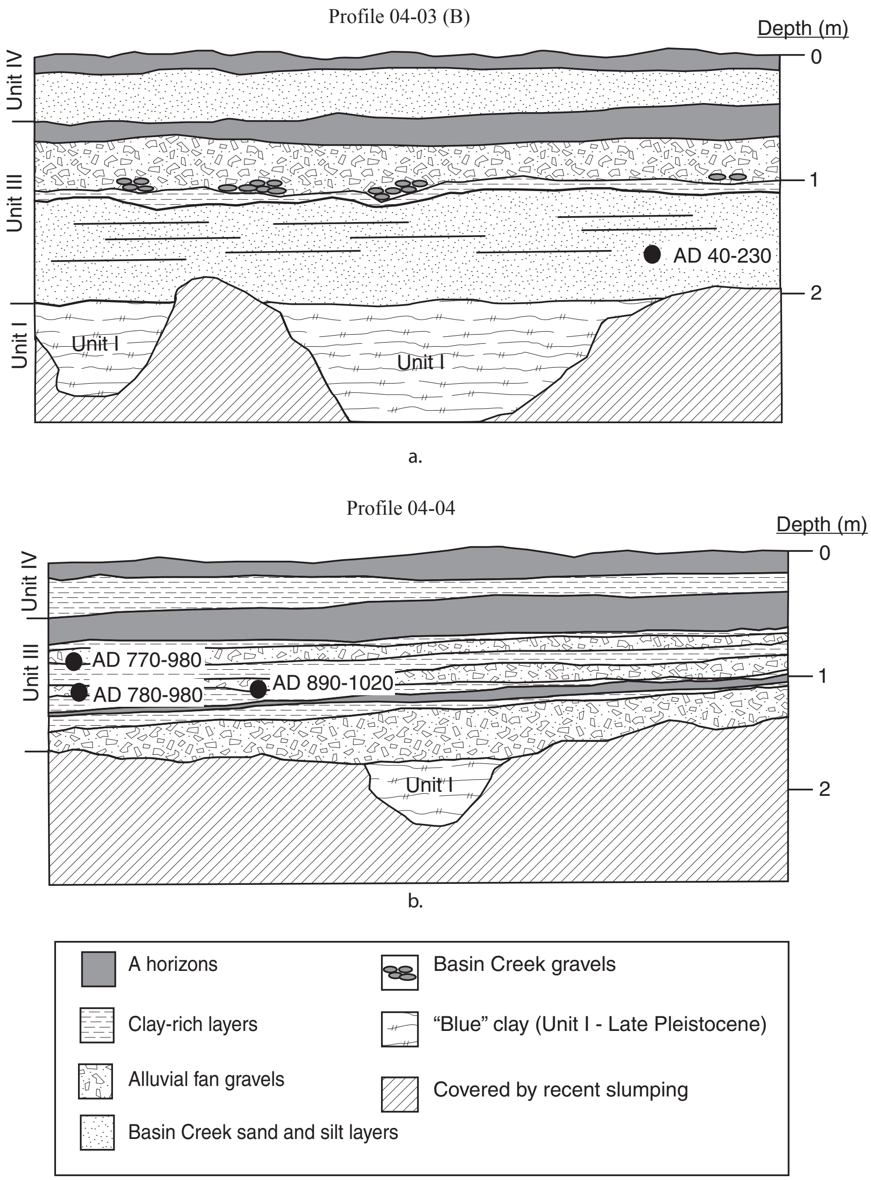

Figure 8 Chronostratigraphic relationships for Profiles 04-03-B (a) and 04-04 (b). Radiocarbon dates are two-sigma calibrated ranges.

obtained from charcoal buried deep in Unit III. The Unit III deposits are more intensely weathered near the constriction due to the fluctuating water table than comparable aged sediments in the upstream locations. The fluctuating water table results in wetting and drying conditions that increase the rate of physical weathering primarily by volume changes related to shrinking and swelling clays, and salt crystallization. Under these conditions, chemical weathering commonly proceeds by hydration and oxidation/reduction processes (Birkeland, 1999).

Profile 04-04 contains Unit II, III, and IV deposits. Unit II is mostly buried by slopewash materials and therefore not described or sampled here (Figure 8b). Unit III deposits consist of numerous clay and organic matter rich lenses, a thin buried soil, and the paleosol discussed earlier. Three radiocarbon samples obtained on charred twigs returned overlapping age ranges. Twigs have only a few growth rings so are generally thought to return more reliable radiocarbon results than chunks of charcoal that could be from any set of annual rings of long-lived trees.

In Profile 04-04, the lower layer returned two overlapping age ranges from separate samples: A.D. 780–980 and A.D. 890–1020. A few centimeters above this, another sample dated to A.D. 770–980. Therefore, the broadest age ranges for these strata are A.D. 770–1020. Based on these three radiocarbon results, the buried paleosol

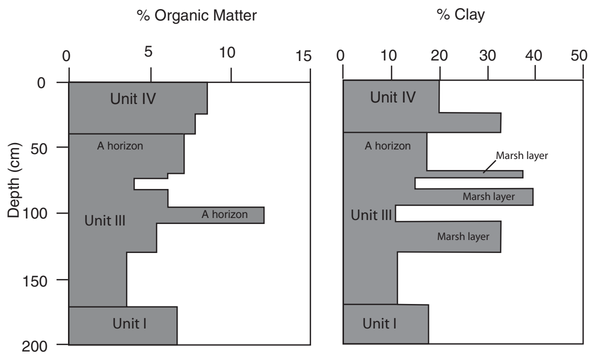

Figure 9 Percentage of organic matter and clay in Profile 04-04.

seems to be younger in this location than in the upstream sections, suggesting that the landscape stabilized upstream, while the more active marsh environment did not stabilize until later in time. Underlying the dated deposits were another three marsh layers rich in clay and organic matter. The thin, dark, organic-rich marsh deposits contains 5–13% organic matter and the clay layers have up to 40% clay compared to less than 10% for the alluvial fan layers (Figure 9). Based on stratigraphic correlation and depositional interpretation, the marsh deposits span the early Pueblo I period.

Unit IV is represented by an aggradational sequence related to protohistorical alluvial activity (Figure 8). Unit IV in this location consists of clay layers indicative of marsh conditions that buried the Unit III paleosol (Figure 10). Stratigraphically, the marsh sediments near the top of Profile 04-04 correlate with the sandy alluvium in the upstream reaches dating to A.D. 1325–1500.

Just downstream of Profile 04-04 are three critical, though undated, sections. Profiles CD-1, CD-2, and CD-3 are located on the Basin Mountain alluvial fan that constricted streamflow and created the marsh deposits (Figure 11). CD-1, on the downstream edge of the alluvial fan, is dominated by alluvial fan gravels and does not contain marsh deposits. CD-2 is at the center of the alluvial fan and does not contain marsh deposits, only alluvial fan sand and gravel. CD-3, on the upstream edge of the Basin Mountain alluvial fan, is also dominated by alluvial fan gravels, but importantly it contains a gray clay lens representative of the younger, protohistoric marsh. The fan deposits of CD-1, CD-2, and CD-3 are predominantly coarse-grained angular gravels derived from lithologies exposed along this portion of Basin Mountain.

The presence of ponded deposits indicates the flow of Basin Creek was restricted during the Pueblo I period (A.D. 700–900) and again during the Little Ice Age (A.D. 1400–1880). An aerial photograph of the coalescing alluvial fans illustrates this constriction point at the outlet of Basin Creek (Figure 12).

Evidence for the Pueblo I Marsh

In the upstream and mid-valley reaches, Profiles 1, BC 10, and BC 15 represent alluvial deposition and soil formation in Unit III. At the downstream and constriction point areas, Profiles 04-03 (B), 04-04, CD-1, CD-2, and CD-3 represent a progression within Unit III from alluvial deposition to increasingly ponded sediments to exclusively alluvial fan deposits dating to the Pueblo I period (Figure 11). The ponded sediments are clay and organic matter rich, often laminated with gray clay and silt layers, and grade laterally uphill into progressively coarser materials. Ponded layers contain 30–40% clay. These sedimentological properties indicate standing water and reducing conditions. The sedimentary characteristics discussed above indicate water flowed into the marsh from Basin Creek and from the tributary fans.

To determine the environmental conditions of the ponded deposits, they were investigated for paleoenvironmental indicators, including ostracods and pollen. Ostracods are microscopic arthropods sensitive to water conditions, including salinity, alkalinity, temperature, and turbidity. No ostracods were found in any of the 10 samples submitted for analysis. Pollen grains were extremely decayed in all sampled horizons such that statistical analysis is of limited interpretive value. Therefore, we interpret the pollen results qualitatively by the presence of significant taxa. Nonetheless, useful results were obtained from seven of the 10 analyzed samples (Figure 10). The genus *Zea* was found in several of the samples, including the surface soil (perhaps from modern farming) and the buried paleosol. *Typha* (cattail) was found in three samples, two of which date to the Pueblo I Period. The presence of *Typha* pollen supports the interpretation that the clay and organic matter rich sediments are representative of marshy habitats. *Typha* pollen recovered from alluvial fan gravel is most likely due to bioturbation processes. The other *Typha* pollen was recovered from the Unit I clays, indicating marsh condition existed here during the Pleistocene as well.

Along with the geomorphic and paleoenvironmental data discussed above, the archaeobotanical and faunal records suggest that a marshy habitat most likely existed close to the Eastern Cluster. Excavations of Eastern Cluster farmsteads yielded abundant cattail, reedgrass, and bulrush pollen (Adams & Murry, 2008). The faunal record contained various water-adapted species not found at other Ridges Basin sites, including swan or crane (*Cynus/Grus* sp.), cinnamon teal (*Anas cyanoptera*), duck (*Anas sp.*), Belted kingfisher (*Ceryle alcylon*), and fish (carp, minnow, other sucker family; Potter & Edwards, 2008). These fauna are rarely found in other

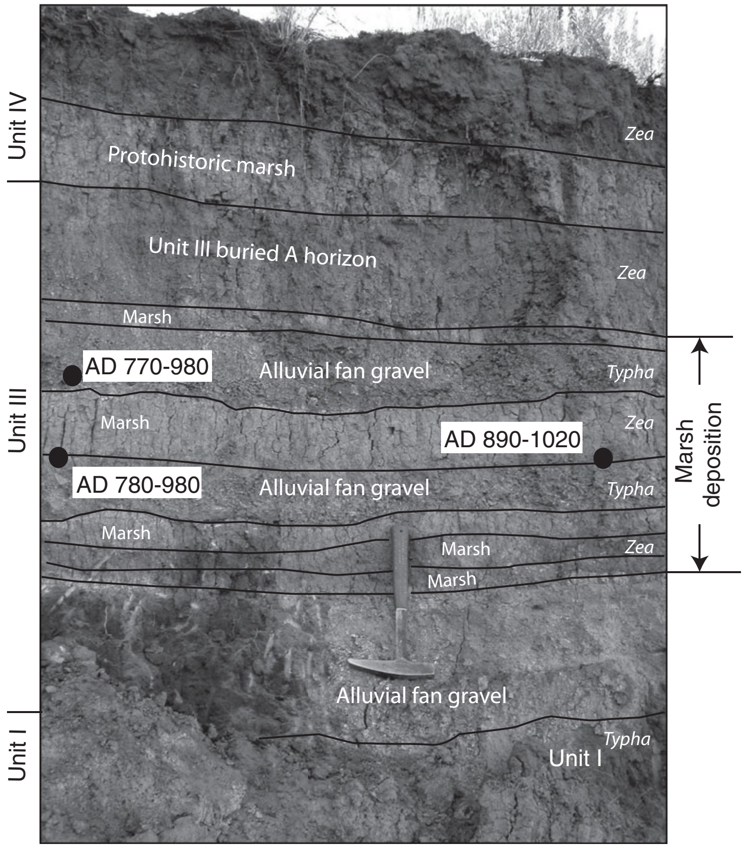

Figure 10 Photograph of Profile 04-04 showing a buried horizon, marsh, and alluvial fan layers. Radiocarbon dates are two-sigma calibrated ranges. Note locations of cattail (*Typha*) and maize (*Zea*) pollen recovered from indicated horizons.

early Pueblo I assemblages, except those located near marshes (Wilshusen, 2008).

The presence of wetland fauna and flora in the archaeological record of the Eastern Cluster strongly suggests these people took advantage of the rich and varied natural resources provided by the nearby marsh environment. Based on these studies, the presence of abundant marsh food resources, particularly cattail, would certainly attract migrants to Ridges Basin. Studies by Simms (1987), for example, determined that cattail pollen has a high caloric return, partly because of the ease of harvesting, relative abundance in marsh habitats, and high calorie content. He found that the *Typha* energy return rates average 6055 Kcal/hr compared with 1125 for *Pinus monophylla* (singleleaf pinyon nuts), and 347 Kcal/hr for *Achnatherum hymenoides* (rice grass). Adams and Murray (2008) undertook a scoring system for plants in Ridges Basin based on kilocalories per hour, seasonal availability, abundance, reliability, and other factors. They too determined that cattail has the highest caloric return of any plant in Ridges Basin, with a resource score of 7558 compared with 416 for rice grass, 322 for pinyon pine, and between 220 and 340 for maize.

DISCUSSION

Geomorphic History of Ridges Basin

The geomorphic history of Ridges Basin is reconstructed using the results of the chronostratigraphic investigations of dated alluvial fan and floodplain sediments. The four major depositional units, Units I–IV, present a sequence of geomorphic activity extending from the late Pleistocene through the Holocene. Although Unit I is not dated, it is assumed to be Pleistocene in age based on the geomorphic position and degree of weathering. The colluvial gravels found high on eroded ridges of Carbon Mountain are concordant with the high glacial outwash terraces along the Animas River valley. Along the distal edges of the surrounding piedmonts, a buried Unit I alluvial fan with a well-developed argillic paleosol grades basinward into the "blue clay" lake deposits that have distinct gray (5Y 5/1) and red (5YR) redoximorphic mottles. We postulate that Ridges Basin had a lake in it during the Pleistocene and that the lake formed as a result of hillslope and alluvial fans constricting the outflow. Where exposed in the center of the basin, Unit I lies directly on bedrock.

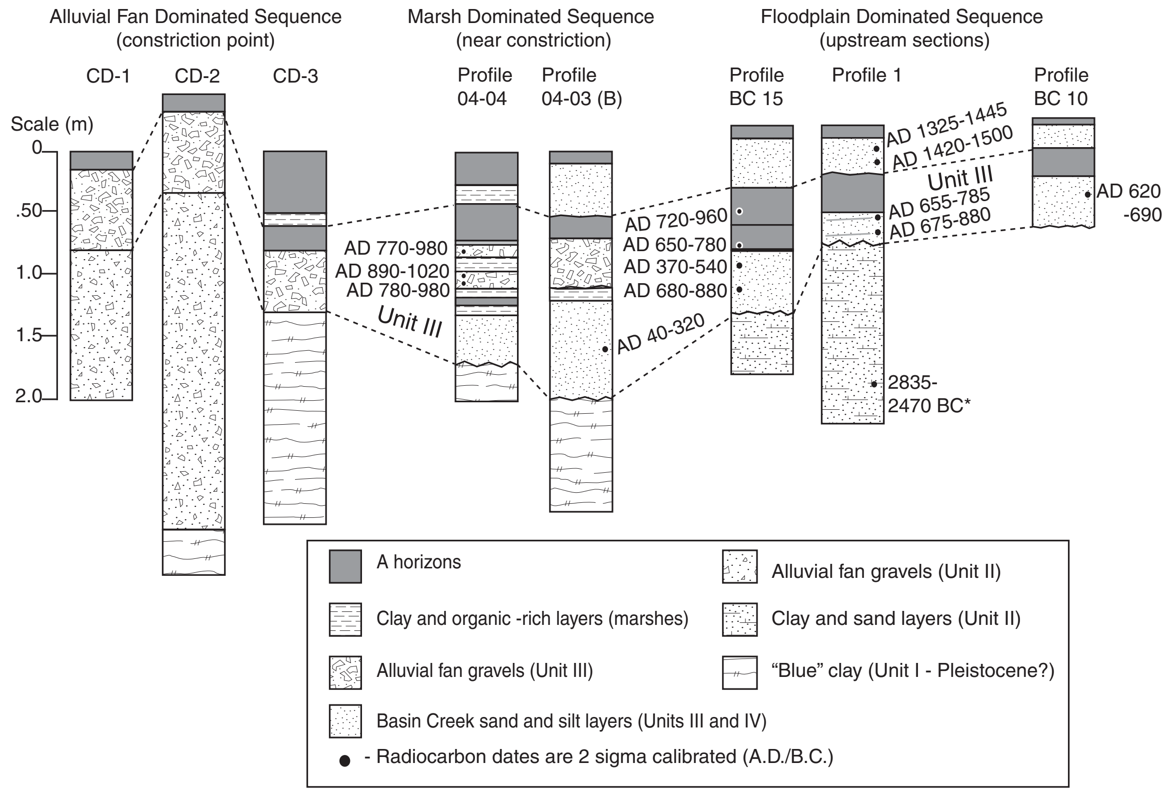

Figure 11 Basin Creek chronostratigraphy. "*" is a sample from a separate location and extrapolated to Profile 1.

Unit II consists of more than 4 m of finely bedded alluvial sand and silt layers, interfingering with finely laminated clay lenses interpreted to be lake deposits. No cut/fill channels were seen within this unit. Unit II is bounded by erosional contacts above and below as indicated by abrupt wavy boundaries with the underlying Unit I and overlying Unit III deposits. Horizontal layering of thinly bedded stratigraphy and clayey deposits

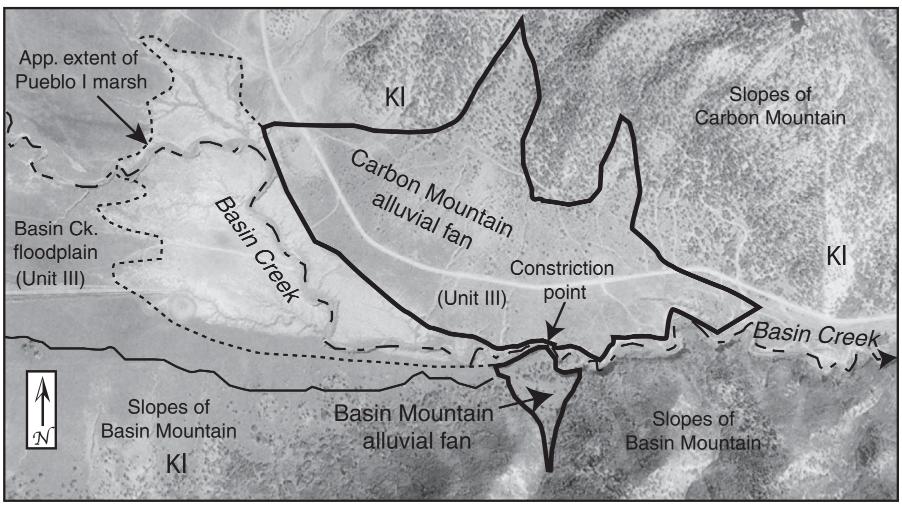

Figure 12 Aerial view of constriction point where the Carbon and Basin Mountain alluvial fans coalesce to create ponding conditions and marsh habitats. Kl is Lewis Shale bedrock.

indicate slow aggradation. Substantial secondary alteration due to fluctuating water tables produced grayish brown (2.5Y 5/2) colors. Along the piedmont of Carbon Mountain, Unit II alluvial fans began aggrading by about 10,500 years ago, and stopped before about 2700 years ago. The Unit II alluvial fans are correlated with lake deposits dated to about 4500 years old. We infer that as with the Unit I lake deposits, the lake deposits of Unit II resulted from alluvial fans damming (or constricting) the outflow of Basin Creek. The erosional boundary separating the Unit I and Unit II deposits infer a period when the constriction was breached and downcutting occurred. Likewise, the erosional boundary between Unit II and the overlying Unit III indicates a period of erosion after about 4500 B.P. (2500 B.C.), but prior to the earliest date on Unit III (A.D. 40–230).

Twelve radiocarbon ages on floodplain deposits, and one on alluvial fan deposits, place the Unit III depositional sequence between A.D. 40 and 1020. Unit III alluvial fans were aggrading by about A.D. 300 or so, and continued to aggrade after A.D. 800, based on radiocarbon ages and buried Pueblo I sites. Unit III is characterized by a fining upward sequence with very coarse sand and gravel at its base grading upwards into very fine sand and silt lenses. The fining upwards sediments culminate in the formation of a prominent organic-rich cumulic soil (paleosol) exposed in the arroyo throughout the basin. Toward the outlet where the alluvial fan constricts outflow, Unit III facies change from alluvial sands to ponded silt and clay layers that interfinger laterally with angular alluvial fan gravels (Figure 11). The lateral and axial facies changes include fine-grained marsh (ponded) deposits and coarser-grained alluvial fan material. Grayish brown (2.5YR 5/2) to light olive brown (2.5YR 5/4) deposits fill broad, shallow, undulating channels with coarse sand and pebble lenses along the erosional contact with the underlying Unit II. These shallow gravel-filled channels represent periods when Basin Creek overtopped the alluvial fan constriction, cutting shallow channels into the underlying deposits. At various times between A.D. 620 and 1020, marsh habitats existed, and for much of that time supplied important foods and other economically important resources to the early Pueblo I inhabitants of Ridges Basin.

The Unit III paleosol represents a time-transgressive period of landscape stability following alluvial aggradation and marsh development. A slightly older radiocarbon age range (A.D. 650 to 960) in the upper reaches of Basin Creek compares to younger ages (A.D. 890–1020) in the lower reaches. These age differences suggest that the landscape stabilized earlier in the upper reaches than in the lower. The lower reaches continued to experience intermittent ponding, alluviation, cumulic soil formation, and shallow downcutting as a result of the dynamic interactions between the tributary fans and the axial stream. Floodplain stabilization near the outlet could not occur until after these processes stopped, sometime after A.D. 890–1020 (Figure 11). The paleosol was then buried by a protohistoric pond associated with Unit IV aggradation.

Unit IV alluvial fans are not well dated, but are inset below the Unit III fans and prograde onto the basin where they interfinger with Unit IV alluvial deposits of Basin Creek. Unit IV deposits in Basin Creek date to A.D. 1325–1500, the protohistoric period. Unit IV ponded sediments occur in the outlet location overtopping the Unit III paleosol.

Geomorphic processes responsible for the formation of the Pueblo I marsh are from alluvial fan deposition and resultant constriction of Basin Creek (Figure 12). Aerial images illustrate that the two coalescing fans, Carbon Mountain from the north and Basin Mountain from the south merge where Basin Creek flows out of Ridges Basin. During Pueblo I times, a marsh formed where these two fans came together. During the project, a temporary dam was constructed at about the same location because it is the narrowest location to block outflow (Figure 13).

Climatic Considerations

Using regional dendroclimatic reconstructions, Dean, Doelle, and Orcutt (1994) found that between A.D. 750 and 925, climatic conditions were unfavorable for agriculture due to reduced effective moisture and floodplain degradation. Euler et al. (1979) referred to this period as a "hydrologic minimum extending from about A.D. 750 to 925," and associated it with three population declines in the A.D. 700s. However, in Ridges Basin we see floodplain aggradation and marsh formation during this time period.

The PDSI for the Durango area indicates that between about A.D. 750 and 770 the climate is characterized by increased effective moisture and favorable maize production (Anderson, 2008c; Bellorado, 2007; Bellorado and Anderson, 2013; Figure 14). Our chronostratigraphic investigations also indicate this is a time of floodplain aggradation. Culturally, populations began increasing during this period, with some of the wettest years occurring during the 780s; A.D. 780, 784, 785, and 787 were very to extremely wet (Table II). Maize production would have been favorable during this time, and marsh resources abundant, so it may not be a coincidence that the period of greatest construction at Sacred Ridge occurred during the A.D. 780s (Potter, 2010, Figure 8.2).

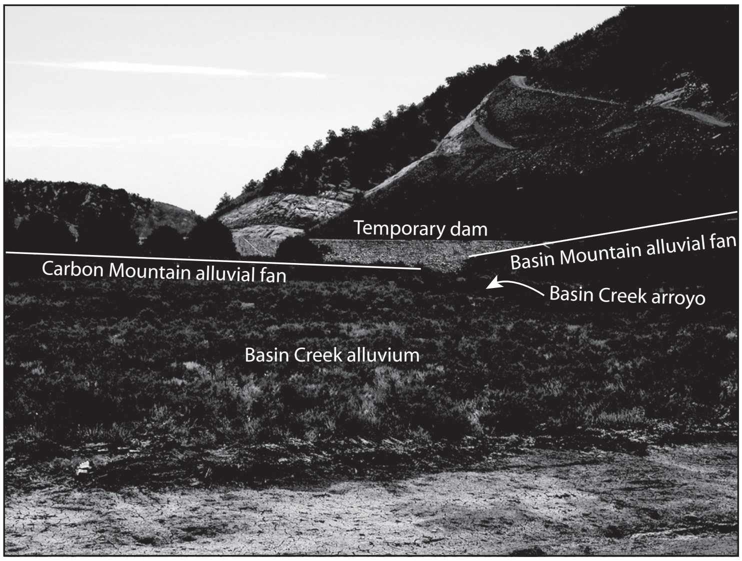

Figure 13 Photograph facing downstream (east) showing area where alluvial fans from Carbon and Basin Mountains constrict the outflow of Basin Creek from Ridges Basin. Note temporary modern dam at approximately same location.

The PDSI indicates that the years A.D. 795, 797, 799, 807, and 809 rank as severe and extreme drought years with PDSI values ranging from –3.720 to –4.865 (Table II). Ridges Basin was vacated by A.D. 810. The drought years prior to A.D. 810 would have had a negative impact on the inhabitants if the drought adversely affected maize production. At this time, there is ample evidence of intersettlement-cluster conflict, most notable in the mutilated remains of at least 35 individuals uncovered in a pit structure on Sacred Ridge (Potter & Chuipka, 2010). It is highly probable that the drying of the marsh due to increased drought—along with low maize production, local overhunting as evidenced by the faunal record, and ethnic differences among settlement clusters—exacerbated societal tensions and led to the massacre and the eventual depopulation of the basin.

Natural Marshes and Built Reservoirs

Many Pueblo I villages were preferentially located where marshes existed to take advantage of the abundant resources provided by marsh habitats. Later, Puebloans

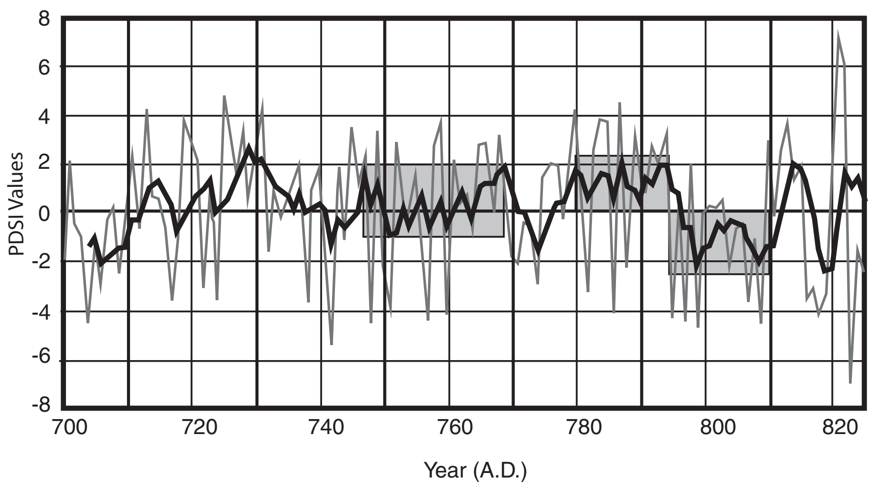

Figure 14 PDSI values for the Durango area for the period A.D. 700–825. Positive values are wetter, negative values are drier. Population increases around A.D. 750 when the climate was relatively stable. Increased construction at the Sacred Ridge site occurred during wetter periods in the A.D. 780s. A downturn in climate during the 790s continued until A.D. 809, when Ridges Basin became depopulated. Gray lines are the annual PDSI values and the black line is the 10-year moving average. Time periods discussed in text are highlighted in gray.

Table II Ten driest and five wettest years during the A.D. 750–820 Pueblo I occupation in Ridges Basin based on the Palmer Drought Severity Index (Palmer, 1965).

Year (A.D.)	Ppt. (cm)	PDSI Value	Drought Conditions
799	18.1	−4.865	Extreme
809	18.3	−4.764	Extreme
797	18.6	−4.586	Extreme
757	18.9	−4.461	Extreme
795	18.9	−4.432	Extreme
786	19.2	−4.319	Extreme
818	19.3	−4.266	Extreme
760	19.3	−4.230	Extreme
751	19.9	−3.934	Severe
807	20.0	−3.720	Severe
Year (A.D.)	Ppt. (cm)	PDSI Value	Wet Conditions
787	37.0	4.458	Extreme
780	36.6	4.304	Extreme
784	35.6	3.794	Very
813	35.5	3.728	Very
785	35.3	3.640	Very

constructed reservoirs as part of a built natural and cultural landscape. Valuable marsh resources, such as cattail, grow naturally in association with such reservoirs (Wright, 2007). Thus, Puebloan peoples essentially created wetlands through the impoundment of waters and the construction of reservoirs. The examples discussed below are from southwest Colorado where natural and built reservoirs have been studied, including Sagehen Flats and Woods Canyon near Dolores, and Morefield and Prater canyons in Mesa Verde National Park. The presence of naturally occurring wetlands (e.g., marsh, cienega, bosque, lake, pond) is not a unique landscape component in the mosaic of early Pueblo settlements. As part of the Dolores Archaeological Program, the Sagehen Flats marsh dated to A.D. 585–785, again illustrating the inhabitants' preference to locate early villages near marshes (Clay, 1985; Petersen, 1985). Like Ridges Basin, the Sagehen Flats drainage was constricted by alluvial fan activity, and because of the intermittent character of alluvial fans, the constriction was not permanent (Petersen, 1985). Natural environments such as these undoubtedly led to subsequent incorporation of water impoundment projects into societal behavior, thereby ″saving (water) for a rainy day″ (Anschuetz, 1995). Excavations on Mesa Verde confirmed the presence of two large Pueblo I reservoirs in Morefield and Prater Canyons (Wright, 2007), which, if filled, would have held 100,000 gallons of water each. Stratigraphic relationships, redoximorphic soil colors, pollen analysis, and radiocarbon dating confirm that the reservoirs were constructed between A.D. 750 and 800.

Wilshusen, Churchill, and Potter (1997) reported the results of excavations of the Woods Canyon reservoir, which was associated with a late Pueblo III village, and summarized evidence for more than 38 reservoirs dating to the Pueblo II period or later. They suggested that there are probably many more such reservoirs in southwestern Colorado. They also argue that ″the accumulation of water in this area may have had secondary benefits such as attracting game for nearby hunting or producing wetland ruderal foods such as cattail . . . ″ (1997:675).

The landscape setting of villages with nearby marshes is not a coincidence. Cattails provide the highest return on resource investment in terms of calories, and having this in abundance close to home would-be particularly advantageous. Constructing a reservoir *per se*, or impounding waters that create reservoir/marsh environments, would-be a resource boon for the population. Although built ″reservoirs″ might have been rather shallow features during much of the year, the wet ground would extend out in a larger area than the reservoir, potentially supporting a variety of migratory and wetland birds and plants, such as willow, sedges, cottonwood, cattail, and reeds. Late period sites (approximately A.D. 1250) are commonly located near springs and include walls that surround (or enclose) the site. One attribute of the enclosing walls at the canyon heads might be to reduce water flow, conserve soil, and create wetland.

Built marshes also hold religious and spiritual significance for Puebloan descendants. Marshes and marsh reeds are prominent in Native American creation stories. According to Cushing (1992), for example, the Zuni creation story describes the physical world as "marshy, young, and unstable." Kaiklo, the eldest son of the Katchina Maker, "enters the undersea world by way of a reed ladder, very much like descending into a kiva[1] through the roof hole." Later when Kaiklo returns bringing knowledge to his people "there is a loud and joyful procession from the lake to the gathered clans . . . where he instructs all of the elders and spiritual leaders in the full story of the creation . . . ″ (Cushing, 1992).

The remains of ancient reservoirs may be subtle and difficult to see on the modern landscape, presenting particular challenges to their investigation. Reservoirs seldom represent formalized constructions, and rarely have well-constructed walls or geomorphic features been found that might indicate the presence of impounded water. Physical evidence for constructed reservoirs or wetlands probably do not remain on the landscape much longer than the human community that can maintain them. They silt in and require dredging, a

[1]A kiva is a subterranean structure in which rituals are performed.

time-consuming, economically expensive task. Reservoirs are often located in heads of channels, gullies, or streams where they may be easily eroded. Reservoirs made of earth mounded up around a depression with earthen diversion channels are very difficult to identify on survey, and, as with some of the recently documented reservoirs on Mesa Verde, only revealed after fire clears the vegetation (Wright, 2007). Extensive research and new techniques may need to be employed to evaluate the presence of a reservoir. For example, Benson et al. (2014) applied digital topographic analysis, sediment transport modeling, and paleoclimate data to reevaluate Far View reservoir (formerly Mummy Lake) in Mesa Verde National Park, and concluded that it could not possibly function as a water control and storage feature. Although long debated (Breternitz, 1999), the Far View reservoir is now considered to be a ceremonial structure within a large-scale ritual landscape.

Natural marshes associated with archaeological sites may also be difficult to identify, particularly if geomorphic investigations are not included in research designs. The modern geomorphic setting might not provide immediate clues to the existence of a prehistoric wetland. The marshes at Ridges Basin and Sagehen Flats were identified only during extensive geomorphic and paleoenvironmental investigations. Even then, their age and association with cultural activities may not be easy to determine. For example, Force et al. (2002) and Force (2004), working near Chaco Canyon National Monument in northern New Mexico, suggested that Chaco Wash was intermittently dammed by eolian processes to form the so-called "Chaco Lake" during the Pueblo II occupation there. Researchers then related cultural development at Chaco Canyon, measured by building construction, to the influence of lacustrine conditions on alluvial aggradation, channel cutting, and irrigation. Chaco Canyon is one of the most important archaeological sites in North America and a direct relationship between geomorphic activity and cultural development would-be significant (Vivian et al., 2006). However, more recent studies suggest that a lake never existed in this location during the Pueblo II Period, thus questioning the influence of an intermittent wetland on the cultural development of Chaco Canyon inhabitants (Hall, 2010; Love et al., 2011).

Clearly the identification of wetlands, marshes, and reservoirs is an important, but difficult to investigate part of the prehistoric cultural landscape in the American Southwest. Continued research focused on understanding the timing and significance of wetlands, marshes, and reservoirs would-be a valuable contribution—not only for prehistoric resource-procurement activities, but also for the ceremonial and spiritual life of Pueblo people.

CONCLUSIONS

Four main conclusions can be drawn from our geoarchaeological research in Ridges Basin. First, the integrated geomorphic, chronostratigraphic, paleoenvironmental, and archaeological results identify the presence of a marsh during Pueblo I habitation. The chronostratigraphic record includes 16 radiocarbon assays from eight profile sections to link the ponding of Basin Creek and subsequent marsh formation to lateral alluvial fan activity. During the A.D. 700s coalescing, alluvial fans from Carbon and Basin Mountain constricted flow of Basin Creek, creating intermittent marsh habitats in Ridges Basin. Previous studies had not considered that a marsh was present, or that the abundant marsh resources were likely the initial attraction of prehistoric inhabitants to the basin and may have influenced their departure. The archaeobotanical and faunal records indicate that waterfowl, fish, and cattail supplemented maize cultivation, the dominant source of food.

Second, climate reconstructions show that extreme wet years occurred in the 780s, when the majority of the Pueblo I construction was undertaken at Sacred Ridge. Extreme and severe droughts occurred during the late 700s and early 800s. The most extreme drought year between A.D. 750 and 820 occurred in A.D. 799, with a severe drought in A.D. 807 and the second most extreme drought in A.D. 809. According to the tree-ring chronology for Ridges Basin, the last cutting date on architectural wood was A.D. 809, indicating that construction stopped that year. At about this time 35 individuals were massacred as a result of intracommunity violence. Direct relationships between environmental conditions and the massacre cannot be proven, but it is probable that the extreme droughts lead to decreased crop yields, drying of the marsh, and loss of valuable food resources, further stressing the Ridges Basin community. Ridges Basin was depopulated by A.D. 810.

Third, not only do natural and man-made wetlands provide water and food resources, but they feature prominently in Puebloan communities. Pueblo I settlements located near marshes both in Ridges Basin and elsewhere indicate that proximity to abundant marsh resources was an important part of the Pueblo I landscape. Notably the natural marshes in Sagehen Flats in the Dolores Archeology Project and the Morefield and Prater Canyon reservoirs on Mesa Verde all date to the Pueblo I Period. Later in time, Pueblo II and III people brought the marshes with them to mesa tops and broad upland areas in the form of man-made reservoirs to take advantage of the water and food resources, and for ceremonial significance.

Finally, investigations of prehistoric settlement dynamics can benefit greatly by the incorporation of detailed geoarchaeological research, including chronostratigraphic and paleoenvironmental reconstructions focused on specific cultural periods.

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REFERENCES

Adams, K.R., & Murray, S.S. (2008). Archaeobotanical results. In J.M. Potter (Ed.), Animas–La Plata Project: Environmental studies (pp. 193–233). SWCA Anthropological Research Papers No. 10, Vol. X. Phoenix, AZ: SWCA Environmental Consultants.

Adams, K.R., & Reeder, T. (2009). Catchment Analysis: A quantitative evaluation of wild plant food potential surrounding three Pueblo I settlement clusters. In J.M. Potter (Ed.), Animas–La Plata project: Special studies (pp. 249–295). SWCA Anthropological Research Papers No. 10, Vol. XIII. Phoenix, AZ: SWCA Environmental Consultants.

Adams, K.R., Murray, S.S., & Bellorado, B.A. (2008). Archaeobotanical supportive research projects. In J.M. Potter (Ed.) Animas–La Plata project: Environmental studies (pp. 145–169). SWCA Anthropological Research Paper No. 10, Vol. X. Phoenix, AZ: SWCA Environmental Consultants.

Allison, J.R. (2010). Animas–La Plata Project: Ceramic studies. SWCA Anthropological Research Papers No. 10, Vol. XIV. Phoenix, AZ: SWCA Environmental Consultants.

Anderson, K.C. (2008a). Landscape change and stability in Ridges Basin—Implications for Pueblo I habitation. In J.M. Potter (Ed.), Animas–La Plata project: Environmental studies (pp. 33–62). SWCA Anthropological Research Paper No. 10, Vol. X. Phoenix, AZ: SWCA Environmental Consultants,.

Anderson, K.C. (2008b). Ridges Basin soil fertility—Implications for prehistoric agriculture. In J.M. Potter (Ed.), Animas–La Plata project: Environmental studies (pp. 63–80). SWCA Anthropological Research Paper No. 10, Vol. X. Phoenix, AZ: SWCA Environmental Consultants.

Anderson, K.C. (2008c). The early Pueblo I climate of Ridges Basin—Inferences from dendroclimatic reconstructions. In J.M. Potter (Ed.), Animas–La Plata project: Environmental studies (pp. 13–32). SWCA Anthropological Research Paper No. 10, Vol. X. Phoenix, AZ: SWCA Environmental Consultants.

Anderson, K.C., & Neff, L.T. (2011). The influence of paleofloods on archaeological settlement patterns during A.D. 1050–1170 along the Colorado River in the Grand Canyon, Arizona, USA. Catena, 85, 168–186.

Anschuetz, K.F. (1995). Saving a rainy day: The integration of diverse agricultural technologies to harvest and conserve water in the lower Rio Chama Valley, New Mexico. In H. Wolcott Toll (Ed.), Soil, water, biology, and belief in prehistoric and traditional southwestern agriculture, New Mexico Archaeological Council Special Publication 2. Denver: C and M Press.

Antevs, E. (1955). Geologic-climatic dating in the west. American Antiquity, 20(4), 317–335.

Bellorado, B.A. (2007). Breaking down the models: Reconstructing prehistoric subsistence agriculture in the Durango District of southwestern Colorado. Unpublished master's thesis, Department of Anthropology, Northern Arizona University, Flagstaff, AZ.

Bellorado, B.A. (2009). A Reconstruction of prehistoric subsistence agriculture in Ridges Basin. In J.M. Potter (Ed.), Animas La Plata project: Special studies (pp. 215–234). SWCA Anthropological Research Paper No. 10, Vol. XIII. Phoenix, AZ: SWCA Environmental Consultants.

Bellorado, B.A., & Anderson, K.C. (2013). Early Pueblo responses to climate variability: Farming traditions, land tenure, and social power in the Eastern Mesa Verde Region. Kiva, 78(4), 377–416.

Benson, L.V., Griffin, E.R., Stein, J.R., Friedman, R.A., & Andrae, S.W. (2014). Mummy Lake: An unroofed ceremonial structure within a large-scale ritual landscape. Journal of Archaeological Science, 44, 164–179.

Birkeland, P.W. (1999). Soils and geomorphology. New York: Oxford University Press.

Blair, R., Casey, T.A., Romme, W.H., & Ellis, R.N. (1996). The western San Juan Mountains: Their geology, ecology and human history. Boulder, CO: University of Colorado Press.

Breternitz, D.A. (1999). The 1969 Mummy Lake excavations, site 5MV833. Boulder, CO: Wright Paleohydrological Institute.

Bryant,V. (2005). Results of pollen analysis, report submitted to SWCA, Inc. Flagstaff, AZ: Environmental Consultants.

Clay, V.L. (1985). The history of the marsh in Sagehen Flats: The sedimentary record. In K.L. Petersen, V.L. Clay, M.H. Mathews, & S.W. Neusius (Eds.), Studies in environmental archaeology (pp. 217–227). Denver, CO: United States Department of Interior Bureau of Reclamation.

Cook, E.R., Meko, D.M., Stahle, D.W., & Cleaveland, M.K. (1999). Drought reconstructions for the continental United States. Journal of Climate, 12, 1145–1162.

Cook, E.R., Woodhouse, C.A., Eakin, C.M., Meko, D.M., & Stahle, D.W. (2004). Long-term aridity changes in the western United States. Science, 306(5698), 1015–1018.

Cook, E.R., Seager, R., Cane, M.A., & Stahle, D.W. (2007). North American drought: Reconstructions, causes, and consequences, Earth-Science Reviews, 81, 93–134
Cordell, L. (1997). Archaeology of the southwest. San Diego, CA: Academic Press.
Cushing, F.H. (1992). The mythic world of the Zuni. Albuquerque, NM: University of New Mexico Press.
Dean, J.S. (1988). Dendrochronology and paleoenvironmeental reconstruction on the Colorado Plateaus. In G.J. Gumerman (Ed.), The Anasazi in a changing environment (pp. 119–167). Cambridge: Cambridge University Press.
Dean, J.S. (1996). Demography, environment, and subsistence stress. In J. Tainter and B.B. Tainter (Eds.), Evolving complexity and environmental risk in prehistoric southwest (pp. 25–56), SFI Stud. Sci. Complexity, Vol. 24. Westview Press, Boulder: Addison-Wesley.
Dean, J.S., Euler, R.C., Gumerman, G. J., Plog, F., Hevly, R.H., & Karlstrom, T.N.V. (1985). Human behavior, demography, and paleoenvironment on the Colorado Plateaus, American Antiquity, 50(3), 537–554.
Dean, J.S., Doelle, W.H., & Orcutt. J. (1994). Adaptive stress, environment, and demography. In G.J. Gumerman (Ed.), Themes in southwest prehistory (pp. 53–86). Santa Fe, NM: School of American Research Press.
Douglas, M.T., & Stodder, A.L.W. (2010). Skull morphology in the ALP skeletal series. In E. M. Perry, A. L. W. Stodder, & C. A. Bollong (Eds.), Animas–La Plata project: Bioarchaeology (pp. 197–222). SWCA Anthropological Research Paper No. 10, Vol. XV. Phoenix, AZ: SWCA Environmental Consultants.
Euler, R., Gumerman, G.J., Karlstrom, T.N.V., Dean, J.S., & Hevly, R.H. (1979). The Colorado plateaus: Cultural dynamics and paleoenvironments. Science, 205, 1089–1101.
Force, E.R. (2004). Late Holocene behavior of Chaco and McElmo Canyon drainages (Southwest U.S.): A comparison based on archaeologic age controls. Geoarchaeology: An International Journal, 19(6), 583–609.
Force, E.R., Vivian, R.G., Windes, T.C., & Dean, J.S. (2002). Relation of “Bonito” paleo-channels and base level variations to Anasazi occupation, Chaco Canyon, New Mexico, Archaeological series 194. Tucson, AZ: Arizona State Museum, University of Arizona.
Fuller, S.L. (1988). Archaeological investigations in the Bodo Canyon area, La Plata County, Colorado. Prepared by S.L. Fuller, UMTRA Archaeological Report No. 25.
Gillam, M.L., & Blair, R.W. (1999). Quaternary and environmental geology of the Animas River valley, Colorado and New Mexico. Friends of the Pleistocene-Rocky Mountain Cell 1999 Field Trip guidebook. Durango, CO: U.S. Geological Society.
Gumerman, G.J. (Ed.). (1988). The Anasazi in a changing environment. Cambridge, UK: Cambridge University Press.
Hack, J.T. (1942). The changing physical environment of the Hopi Indians of Arizona. Papers of the Peabody Museum of American Archaeology and Ethnology, Vol. 35(1), Harvard University.
Hall, S.A. (2010). New interpretations of alluvial paleovegetation records from Chaco Canyon, New Mexico, New Mexico Geological Society Guidebook, 61st Field Conference, Four Corners Country, 231–246.
Hereford, R. (2002). Valley-fill alluviation during the Little Ice Age (ca. A.D. 1400–1880), Paria River basin and southern Colorado Plateau, United States. Geological Society of America Bulletin, 114, 1550–1563.
Karlstrom, T.N.V. (1988). Alluvial chronology and hydrologic change of Black Mesa and nearby regions. In G.J. Gumerman (Ed.), The Anasazi in a changing environment (pp. 45–91). Cambridge, UK, Cambridge University Press.
Keddy, P.A. (2010). Wetland ecology: Principles and conservation, 2nd ed. Cambridge, UK: Cambridge University Press.
Kirkham, R. & Navarre, A.K. (2004). Geologic map of Basin Mountain 7.5-minute quadrangle, La Plata County, Colorado County La Plata, Colorado Geological Survey Report No. OF01—04.
Love, D.W., Gillam, M.L., Benson, L.V., Friedman, R., Miller, P.L., & Vincent, K.R. (2011). Geomorphology, hydrology, and alluvial stratigraphy in lower Chaco Canyon do not support the possible existence of prehistoric sand-dammed ephemeral lakes, New Mexico Geology, 33(4), 107–123. Data Repository 20110003.
McClelland, J.A. (2010). Dental wear and pathologies. In E. M. Perry, A.L. W. Stodder, & C.A. Bollong (Eds.), Animas–La Plata project: Bioarchaeology (pp. 157–180). SWCA Anthropological Research Papers No 10, Vol. XV. Phoenix, AZ: SWCA Environmental Consultants.
Palmer, W.C. (1965). Meteorological drought. Research paper no. 45. Washington, D.C.: U.S. Department of Commerce Weather Bureau.
Petersen, K.L. (1985). The history of the marsh in Sagehen Flats: The pollen record. In K.L. Petersen, V.L. Clay, M.H. Mathews, & S.W. Neusius (Eds.), Studies in Environmental Archaeology, compilers, D.A. Breternitz principle investigator (pp. 229–238). Denver, CO: United States Department of Interior–Bureau of Reclamation.
Petersen, K.L. (1988). Climate and the Dolores River Anasazi, University of Utah Anthropological Papers, 113, 1–151.
Potter, J.M. (2010). Animas-La Plata Project: Final synthetic report. SWCA Anthropological Research Paper No. 10, Vol. XVI. Phoenix, AZ: SWCA Environmental Consultants.
Potter, J.M., & Chuipka, J.P. (2007). Early Pueblo communities and cultural diversity in the Durango area: Preliminary results from the Animas–La Plata Project. Kiva, 72(4), 407–430.
Potter, J.M., & Chuipka, J.P. (2010). Perimortem mutilation of human remains in an early village in the American

Southwest: A case for ethnic violence. Journal of Anthropological Archaeology, 29, 507–523.

Potter, J.M., & Edwards, J.S. (2008). Vertebrate faunal remains. In J.M. Potter (Ed.), Animas–La Plata Project: Environmental studies (pp. 243–285). SWCA Anthropological Research Paper No. 10, Vol. X. Phoenix, AZ: SWCA Environmental Consultants.

Potter, J.M., & Yoder, T.D. (2007). Introduction. In T.D. Yoder & J.M. Potter (Eds.), Animas–La Plata project: Ridges basin excavations—Eastern basin sites (pp. 4–7). SWCA Anthropological Research Paper No. 10, Vol. IV. Phoenix, AZ: SWCA Environmental Consultants.

Potter, J.M., & Yoder, T.D. (2008). Space, houses, and bodies: Identity construction and destruction in an early Pueblo community. In M.D. Varien & J.M. Potter (Eds.), The social construction of communities: Agency, structure, and identity in the pre-Hispanic southwest (pp. 21–40). Lanham, MD: AltaMira Press.

Salzer, M.W., & Kipfmueller, K.F. (2005). Reconstructed temperature and precipitation on a millennial timescale from tree-rings in the southern Colorado Plateau, U.S.A. Climatic Change, 70(3), 465–487.

Simms, S.R. (1987). Behavioral ecology and hunter-gatherer foraging: An example from the Great Basin. BAR International Series 381, British Archaeological Reports. Oxford: Archaeopress, Oxford.

Soil Survey Staff. (1999). Soil taxonomy; a basic system of soil classification for making and interpreting soil surveys, Natural Resources Conservation Service, United States Department of Agriculture agricultural handbook 436. Washington DC.

Stuiver, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormac, G., Van Der Plicht, J., & Spurk, M. (1998). INTCAL98 radiocarbon age calibration 24000–0 cal BP. Radiocarbon, 40(3), 1041–1083.

Toll, H.W. & Wilson, C.D. (2000). Locational, architectural, and ceramic trends in the Basketmaker III occupation of the La Plata Valley, New Mexico. In P. Reed (Ed.), Foundations of Anasazi culture: Basketmaker-Pueblo transitions (pp. 19–43). Salt Lake City: University of Utah Press.

Vivian, G.R., Van West, C.R., Dean, J.S., Akins, N.J., Toll, M.S., & Windes, T.C. (2006). Ecology and economy. In S.H. Lekson (Ed.), The archaeology of Chaco Canyon: An eleventh-century Pueblo Regional Center (pp. 45–65). Santa Fe, NM: School of American Research Press.

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

Wilshusen, R.H. (2008). Summary. In T.D. Yoder & J.M. Potter (Eds.), Animas–La Plata project: Ridges basin excavations–Eastern basin sites (pp. 377–413). SWCA Anthropological Research Paper No. 10, Vol. IV. Phoenix, AZ: SWCA Environmental Consultants.

Wilshusen, R.H., & Potter, J.M. (2010). The emergence of early villages in the American Southwest: Cultural issues and historical perspectives. In M. Bandy, & J. Fox (Eds.), Becoming villagers: Comparing early village societies (pp. 165–204). Tucson, AZ: The University of Arizona Press.

Wilshusen, R.H., Churchill, M.J., & Potter, J.M. (1997). Prehistoric reservoirs and water basins in the Mesa Verde region: Intensification of water. American Antiquity, 62, 664–681.

Wright, K. (2007). Mummy Lake paleohydrology study. Boulder, CO: Wright Paleohydrological Institute.

