Late Pleistocene and Early Holocene Lake-Level Fluctuations in the Lahontan Basin, Nevada: Implications for the Distribution of Archaeological Sites

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The Great Basin of the western U.S. contains a rich record of late Pleistocene and Holocene lake-level fluctuations as well as an extensive record of human occupation during the same time frame. We compare spatial-temporal relationships between these records in the Lahontan basin to consider whether lake-level fluctuations across the Pleistocene-Holocene transition controlled distribution of archaeological sites. We use the reasonably well-dated archaeological record from caves and rockshelters as well as results from new pedestrian surveys to investigate this problem. Although lake levels probably reached maximum elevations of about 1230–1235 m in the different subbasins of Lahontan during the Younger Dryas (YD) period, the duration that the lakes occupied the highest levels was brief. Paleoindian and early Archaic archaeological sites are concentrated on somewhat lower and slightly younger shorelines (1220–1225 m) that also date from the Younger Dryas period. This study suggests that Paleoindians often concentrated their activities adjacent to large lakes and wetland resources soon after they first entered the Great Basin. © 2008 Wiley Periodicals, Inc.

INTRODUCTION

A long-standing goal of archaeology has been to understand how people utilized various resources across the landscape and through time. This is especially the case in the Great Basin of the U.S., where numerous evolutionary-ecological models explaining prehistoric-period foraging behavior have been developed and tested (Simms, 1987; Jones & Madsen, 1989; Bettinger, 1991; Metcalfe & Barlow, 1992; Barlow, 1998). When studying Great Basin Paleoindians, however, chronicling and
explaining change has been hampered by two factors: (1) climate and environments oscillated rapidly during the time when humans first occupied the region, and (2) few well-dated early-period archaeological sites have been found that contain cultural remains required to precisely measure human adaptive change across the Pleistocene–Holocene transition.

In this paper, we bring together geological and archaeological evidence to examine whether there is a strong correlation between elevations of dated archaeological sites and dated fossil lake-margin features in the subbasins of Pleistocene Lake Lahontan. Buried archaeological sites and lake-margin landforms are dated through radiocarbon (\(^{14}\)C) methods, while surface archaeological sites are dated through typological (“index fossil”) information.\(^1\)

The end of the Pleistocene was a period of rapid environmental change in the Great Basin and greater American southwest. Large lakes that filled many of the Great Basin’s valleys reached their climatic highstands between about 14,000 and 13,000 \(^{14}\)C B.P. (~16,700 and 15,300 cal. B.P.) and soon thereafter began dramatic declines (Benson & Thompson, 1987). By 11,000 \(^{14}\)C B.P. (~12,900 cal. B.P.) shallow lake and marsh resources were probably restricted to some of the valley bottoms (Benson & Thompson, 1987; Morrison, 1991; Oviatt, Currey, & Sack, 1992; Adams & Wesnousky, 1998; Godsey, Currey, & Chan, 2005; Oviatt et al., 2005). Evidence of low water tables and restricted water sources has been used to hypothesize an extensive “Clovis-age” drought that ended about 10,900 \(^{14}\)C B.P. (~12,870 cal. B.P.) (Haynes, 1991, 2005), but the geographic extent and intensity of this prolonged period of aridity is not yet known (Holliday, 2000). Shortly after this time, however, water tables and lake levels appear to have risen again, leading to the formation of moderate-sized lakes in the Bonneville and Lahontan basins of Utah and Nevada (Benson et al., 1992; Briggs, Wesnousky, & Adams, 2005; Oviatt et al., 2005) and the development of “black mats” of organics over desert springs (Quade, Forester, & Pratt, 1998). This mesic interval, dating to between about 11,000 and 10,000 \(^{14}\)C B.P. (~12,900–11,470 cal. B.P.), is likely correlative to the Younger Dryas stade (Benson et al., 1992; Quade, Forester, & Pratt, 1998; Alley, 2000; Briggs, Wesnousky, & Adams, 2005; Oviatt et al., 2005). Following 10,000 \(^{14}\)C B.P. (~11,470 cal. B.P.), lake levels across the Great Basin again receded, but precisely when and with what rapidity are not well understood and may have varied by basin and even subbasin. In the Bonneville basin, ground-water discharge continued on the basin floor until about 9000 \(^{14}\)C B.P. (~10,200 cal. B.P.) (Oviatt, Madsen, & Schmitt, 2003), and the same may be true for some subbasins of the Lahontan basin.

While paleoecologists have recently made significant progress toward understanding late Pleistocene and early Holocene climate change in the Great Basin and desert southwest, archaeological research has begun to lag behind. We still do not

\(^1\) We dually present dates as \(^{14}\)C ages (reported in \(^{14}\)C years before present [\(^{14}\)C B.P.]) and calibrated ages (cal. B.P.). Radiocarbon ages were calibrated using CALIB v. 5.0.2html (Stuiver, Reimer, & Reimer, 2005) and reported with 2 error ranges in Tables I and II. We report broad age ranges (\(^{14}\)C B.P.) as thousand years ago (ka). For the sake of brevity, calibrated ages in the text are reported as the peak of the probability density function or the midpoint of the 1 distribution. In the case of multiple intercepts, the midpoint of the highest peak is used.
know precisely when the first people arrived in the region; however, this event likely occurred by 11,000 $^{14}$C B.P. ($\sim$12,900 cal. B.P.), the approximate time of the well-dated Clovis culture of the Great Plains and desert southwest (Haynes, 1991; Haynes, 2002a; Meltzer, 2004; Waters & Stafford, 2007). The oldest dated archaeological sites in the Great Basin are from caves or rockshelters (Bedwell, 1973; Bryan, 1988; Beck & Jones, 1997; Goebel et al., 2003; Graf, 2007; Dansie & Jerrems, 2005; Jenkins, 2007), but most of these records are not well dated or taphonomically not well understood. Conversely, although there are many open-air sites thought to date to at least 9000 $^{14}$C B.P. ($\sim$10,200 cal. B.P.) (Connolly & Jenkins, 1999; Wriston, 2003; Pinson, 2004), most of these occur in surface or near-surface contexts that can not be reliably $^{14}$C dated (e.g., Rusco & Davis, 1987; Hutchinson, 1988; Tuohy, 1988b; Graf, 2001; Smith, 2006). Their presumed late Pleistocene or early Holocene ages are based on results of obsidian-hydration analysis and/or the occurrence of projectile points diagnostic of the Paleoindian period—fluted and unfluted, concave-based points or Great Basin stemmed points (Hockett, 1995; Jones & Beck, 1999; Jones et al., 2003). Although the use of such relative-dating techniques can help us establish that Paleoindians occupied a site during the late Pleistocene–early Holocene period (i.e., earlier than about 8000 $^{14}$C B.P. [$\sim$8890 cal. B.P.]), they rarely provide precise chronological data needed to relate a specific human occupation to a specific climatic event. For example, although some concave-based points may be synchronous with the Clovis culture (i.e., 11,100 to 10,800 $^{14}$C B.P. [$\sim$12,900–12,830 cal. B.P.]), Grayson’s (1993) caution still holds that fluted points in the Great Basin are undated and may not be directly related to dated Clovis elsewhere in North America (Beck & Jones, 2007; Beck et al., 2004). Stemmed points span the entire period in question, from about 10,900 to 8000 $^{14}$C B.P. ($\sim$12,870–8890 cal. B.P.) (Grayson, 1993; Beck & Jones, 1997), and they even may be contemporaneous with or older than Clovis (Bryan, 1988; Davis, 2001; Beck & Jones, 2007).

Another means of estimating ages of early archaeological sites in the Great Basin is the relative dating of associated geologic landforms. Many early open-air sites occur along margin features of now-extinct lakes and marshes that existed during the late Pleistocene and early Holocene (Grayson, 1993). Although archaeologists rarely find these sites on the highest shorelines, many occur on lower shorelines that are still well above basin floors. The traditional interpretation of this relationship is that Paleoindians were present when the lakes were at moderately high levels and that they utilized associated biotic resources (Campbell, 1936; Campbell & Campbell, 1937; Treganza, 1947; Davis, 1967; Willig, 1988). From this association stemmed the idea in the 1970s of the Western Pluvial Lakes Tradition, that “Paleoarchaic” peoples focused subsistence on lacustrine and marsh resources and maintained a relatively sedentary lifestyle (Bedwell, 1973; Willig, 1988). Oviatt, Madsen, and Schmitt (2003) recently argued that this was the case for the extensive marshland of the western Bonneville basin (see also Schmitt et al., 2007); however, most archaeologists have rejected the interpretation that early people were explicitly tethered to wetland sites, and instead hypothesize that lakes and marshes were merely one node in a much broader and more mobile subsistence procurement pattern (Grayson, 1993; Hockett, 2007; Pinson, 2008). It may be, too, that the placement
of some of these sites on fossil beaches is coincidental (Pinson, 1996), and that their occupations date to an arid interval of the latest Pleistocene or early Holocene, when lakes and marshes were largely dried up and the chief subsistence pursuit was hunting of terrestrial fauna. Active beaches may not have been good places to camp—they would have been wet and prone to flooding during storms; but as recently formed beach ridges that had become slightly elevated over a receding lake or marsh, they could have been attractive places to Paleoindians. However interpreted, many Paleoindian points occur on fossil lake-margin features in the Great Basin, and this relationship needs to be carefully evaluated.

Clearly, chronicling and explaining Great Basin Paleoindian adaptive change across the Pleistocene–Holocene transition will follow only the development of well-established paleoenvironmental records and precise archaeological site chronologies for the region’s varied hydrologic basins. In this paper, we call attention to the Lahontan basin of western Nevada, where recent geomorphic research has begun to document lake-level fluctuations during this critical time period. The Lahontan basin contains a rich archaeological record—from caves as well as open-air, surface settings—making this an ideal region to examine the influence of changing paleoenvironmental conditions on the spatio-temporal distribution of early archaeological sites, a key aspect of Paleoindian settlement–subsistence behavior. We first present two models of lake-level fluctuations from the late Pleistocene to the middle Holocene for the different subbasins of the Lahontan system. We then review the chronology of 14C-dated Paleoindian and early Archaic sites in the region, and consider it in the context of the lake-level models. Third, we present two case studies comparing the spatio-temporal distribution of relatively dated surface archaeological sites using typologically time-diagnostic projectile points. We use these comparisons to examine the distribution of Paleoindian sites and to consider whether site placement was directly influenced by lake-level fluctuations across the Pleistocene–Holocene transition. If this relationship is demonstrated, then development of this model may provide a predictive tool for locating surface and buried sites from this time period, and may assist in developing a more accurate subsistence-settlement model of Paleoindian and early Archaic lifeways.

**RADIOCARBON SAMPLE SELECTION AND USE**

The Lahontan basin possesses one of the best studied records of environmental change in a continental environment (Figure 1) (Morrison, 1991). Hundreds of radiocarbon ages have been generated over the last four decades that serve to constrain lake-level changes, vegetation changes, and periods of fluvial aggradation, drought, eolian activity, and alluvial fan deposition (Broecker & Orr, 1958; Broecker & Kaufman, 1965; Benson, 1978, 1981; Davis, 1978a, 1982; Benson & Thompson, 1987; Currey, 1988, 1990; Dansie, Davis, & Stafford, 1988; Benson et al., 1992; Benson, 1993; Benson, Kashgarian, & Rubin, 1995; Adams & Wesnousky, 1998; Harvey, Wigand, & Wells, 1999; Benson et al., 2002; Adams, 2003; Bell, House, & Briggs, 2005; Bell, Garside, & House, 2005; Briggs, Wesnousky, & Adams, 2005). This large collection of radiocarbon ages has been generated from a variety of materials, including shells,
Figure 1. Location map of the Lahontan basin showing geographic features, site locations, and the locations of other figures. Sill labels are shown in black boxes with white lettering. Sites are as follows: (1) Elephant Mountain Cave, (2) Handprint Cave, (3) Wallman Bison, (4) Falcon Hill (Shinniers localities, Empire Cave), (5) Guano Mountain localities (Chimney Cave, Crypt Cave, Cowbone Cave, Fishbone Cave), (6) Nicolarsen (Lake Winnemucca Cave), (7) Wizards Beach (Wizards Beach man, sagebrush cordage, mammoth bone, and ivory points), (8) Leonard Rockshelter, (9) Grimes Point (Grimes Point Burial Cave, Spirit Cave, Hidden Cave), (10) Sadmat site.
wood, charcoal, plant debris, bone, tufa, total organic carbon fraction of sediments, and bulk organic content of soils. Similarly, more than 100 $^{14}$C age estimates have been generated from archaeological contexts in the Lahontan basin since the 1950s, and these, too, were run on a variety of materials using a variety of pretreatment techniques. In this paper, not all radiocarbon samples reported in the literature are used to examine the relationship between lake-level fluctuations and the distribution of archaeological sites. Instead, radiocarbon samples are used in a hierarchical fashion with preference given to samples of organic carbon from well-defined settings, as suggested by Taylor, Long, and Kra (1992) and Trumbore (2000).

The depositional settings and provenience of radiocarbon samples is critically important when reconstructing lake-level fluctuations and comparing them to the spatio-temporal distribution of archaeological sites. In particular, we gave preference to samples whose depositional setting closely reflects lake level at the time of deposition, although samples that provide upper or lower limiting constraints on lake levels are also useful. We also considered the age, distribution, and depositional settings of volcanic tephra outcrops to reconstruct past lake levels and other landscape changes, following Davis (1982, 1983).

Dates on excavated archaeological samples from sealed, stratified contexts are preferred over those from surface contexts, especially when using such materials to reconstruct lake-level fluctuations, due to the possibility that surface finds could have been removed from their primary depositional contexts. Similarly, direct age estimates on perishable artifacts and cultural features (e.g., hearths) are considered more reliable age estimates than on bone (which can produce unreliable results if not suitably pretreated), wood, or dispersed charcoal that may or may not have been related to human activity. Bone samples that were highly purified before dating were preferred over those that were not.

LAKE-LEVEL HISTORY

The Lahontan basin in western Nevada and adjacent northeastern California is comprised of multiple, discrete structural basins that were integrated when lake levels were high but formed separate lakes or dry terminal subbasins when lake levels were low. The western subbasins of Lahontan include Pyramid Lake, Winnemucca Dry Lake, Honey Lake, Smoke Creek Desert, and Black Rock Desert, all of which are integrated by sills of varying elevations (Figure 1). Other major subbasins include the Carson Sink, Walker Lake, and Buena Vista Valley.

The Sehoo Lake cycle began in the Lahontan basin around 35,000 $^{14}$C B.P. and proceeded through a series of major lake-level fluctuations to culminate at the Sehoo highstand around 13,000 $^{14}$C B.P. ($\sim$15,300 cal. B.P.) (Morrison, 1991; Benson, Kashgarian, & Rubin, 1995; Adams & Wesnousky, 1998). The elevation of the highstand shoreline varies from about 1340 m near the center of the basin to about 1318 m at the northern edge, due to isostatic rebound and northward tilting (Adams, Wesnousky, & Bills, 1999; Bills, Adams, & Wesnousky, 2007). The lake rapidly retreated from its highstand so that by about 12,000 $^{14}$C B.P. ($\sim$13,830 cal. B.P.) it had dropped by more than 100 m (Thompson, Benson, & Hattori, 1986), separating into several
smaller lakes in different subbasins. The extent of this recession in each of the subbasins is not well known, but Morrison (1964, 1991) reports that the lake in the Carson Sink dropped to at least 1190 m based on the presence of a buried soil. At Pyramid Lake, cross-cutting relationships between Sehoo recessional shorelines and younger transgressive shorelines suggest that lake levels may have receded to below 1200 m soon after the highstand (Briggs, Wesnousky, & Adams, 2005).

Studies in the Carson Sink by Currey (1988, 1990) and Benson et al. (1992) concluded that lake level was around 1205 m between about 11,300 and 10,400 14C B.P. (~13,200–12,260 cal. B.P.) and inferred this to be the Younger Dryas highstand. At the Jessup embayment in the northwestern Carson Sink (Figure 1), Adams and Wesnousky (1998) reported stratigraphic and geomorphic evidence for a lake-level rise after the Lahontan highstand that reached an elevation of about 1235 m, but it was not dated. In a paleoseismic study along the Rainbow Mountain fault, in the southeastern Carson Sink (Figure 1), Caskey et al. (2004) dated a beach ridge at 1228 m to about 8060–9950 14C B.P. (~9000–11,330 cal. B.P.).

For the Pyramid Lake subbasin, Benson et al. (1992) reported that a lake reached a surface elevation of about 1220 m between 11,000 and 10,000 14C B.P. (~12,900–11,470 cal. B.P.), based on radiocarbon ages of tufa from about 1205 m and questionable dates on rock varnish developed on boulders at about 1220 m. More recently, Briggs, Wesnousky, and Adams (2005) refined the timing of post-highstand lake-level fluctuations through dating of organic material incorporated into beach ridges at the south end of Pyramid Lake and concluded that a lake reached an elevation of about 1230 m at some point after 10,820 14C B.P. (~12,840 cal. B.P.). Based on radiocarbon ages associated with water-soluble pack rat middens at Winnemucca Lake, lake level could not have exceeded 1230 m in the western subbasins since about 12,000 14C B.P. (~13,830 cal. B.P.) (Thompson, Benson, & Hattori, 1986). Born (1972) reported ages of 8800 14C B.P. (~9820 cal. B.P.) and 9720 14C B.P. (~11,160 cal. B.P.) on pieces of wood from delta slope deposits at about 1169 m and suggested that lake surface was 1220 m at the time of deposition. Two similar ages of 9970 and 9780 14C B.P. (~11,450 and 11,200 cal. B.P.) were reported by Prokopovich (1983) from delta sediments at about 1180 m, which generally supports the interpretations of Born (1972).

Davis (1982) summarized paleoenvironmental conditions in the Lahontan basin at the time the Mazama tephra was deposited (6845 14C B.P. [~7730 cal. B.P.]), concluding that lake-surface elevation was at about 1200 m in the Carson Sink and may have been as low as 1155 m in the Pyramid Lake basin. It is unclear, however, what evidence was used for the hypothesized Pyramid Lake elevation.

LATEST PLEISTOCENE–EARLY HOLOCENE ARCHAEOLOGICAL CHRONOLOGY

At least 47 radiocarbon assays from the Lahontan basin provide some chronological control over the archaeological record of the region between about 12,000 and 7000 14C B.P. (~13,830–7830 cal. B.P.) (Table I). Because most of these dated archaeological materials occur at elevations exceeding 1235 m (likely the highest level that
### Table I. Cultural radiocarbon ages from the Lahontan basin between 12,000 and 7000 ¹⁴C B.P.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lab #</th>
<th>Age (¹⁴C B.P.)</th>
<th>Sample material</th>
<th>Age (cal. B.P.) (2)</th>
<th>Elevation (m)</th>
<th># in Figures.</th>
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<td>Handprint Cave</td>
<td>Beta-21885</td>
<td>10,740</td>
<td>charcoal</td>
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<td>8380</td>
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<td>1276</td>
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<td>GX-13744</td>
<td>9660</td>
<td>sagebrush bark</td>
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<td>Catlow twined burial mat</td>
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<td>10,900</td>
<td>wood</td>
<td>11,986–13,404</td>
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<td>7028–7055</td>
<td>1232</td>
<td></td>
<td>Heizer and Hester 1978; Orr 1974; Hattori 1982:15</td>
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<td>7567–7742</td>
<td>1232</td>
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<td>Connolly and Barker 2004</td>
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<td>UCR-3477</td>
<td>9470-60</td>
<td>plain weave mat</td>
<td>10,564–10,876</td>
<td>Fowler et al. 2000</td>
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<td>Hidden Cave Entrance</td>
<td>UCR-3635</td>
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<td>10,265–10,735</td>
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<td>Tuohy and Dansie 1997:25</td>
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<td>9410-60</td>
<td>twined tule mat</td>
<td>10,438–10,455</td>
<td>Tuohy and Dansie 1997:25</td>
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<td>9460-60</td>
<td>twined tule mat</td>
<td>10,525–10,527</td>
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<td></td>
<td></td>
<td>10,575–10,703</td>
<td>21 Tuohy and Dansie 1997:25</td>
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<td>Spirit Cave Cremation no. 2</td>
<td>UCR-3478</td>
<td>9040-50</td>
<td>Twined cordage bag</td>
<td>9943–9989</td>
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<td>Spirit Cave Burial #1</td>
<td>UCR-3475</td>
<td>9300-70</td>
<td>human bone</td>
<td>10,272–10,640</td>
<td>Tuohy and Dansie 1997:25</td>
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<td><strong>Average of 2</strong></td>
<td>9230-46</td>
<td></td>
<td></td>
<td>10,289–10,582</td>
<td>23 Heizer 1951</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>7247–8588</td>
<td>Tuohy and Dansie 1997:25</td>
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lakes in the Lahontan basin reached during the past 11,000 \(^{14}\)C years (~12,900 cal. B.P.), they cannot be used to directly reconstruct lake-level fluctuations; however, we can use them to infer patterns in human settlement that possibly relate to changes in lake levels and environmental productivity.

**Pre-Younger Dryas**

Evidence of human occupation in the Lahontan basin prior to about 10,800 \(^{14}\)C B.P. (~12,830 cal. B.P.) is scant at best. It consists of two horse mandibles from Fishbone Cave that have been directly AMS \(^{14}\)C dated to ~11,350 and 11,210 \(^{14}\)C B.P. (~13,230 and 13,110 cal. B.P.) (Figure 1; site 5). According to Dansie and Jerrems (2005), both mandibles bear “strong evidence” of cultural modification, namely cut marks and impact fractures. According to Orr (1956), the mandibles originated from the cave’s level 4 and were associated with other broken bones, two stone tools, and a concentration of plant macrofossils. Among the latter were twisted sagebrush fibers and shredded juniper bark; fifty years ago the juniper was experimentally \(^{14}\)C dated to 11,200 \(^{14}\)C B.P. (~13,100 cal. B.P.) (Broecker & Orr, 1958). As Dansie and Jerrems point out, though, not all taphonomists who have examined the horse mandibles agree that they were unequivocally worked by humans (G.A. Haynes, pers. comm., 1999 [cited in Dansie & Jerrems, 2005:67]). Further, in their thorough review of the cave’s excavation, Dansie and Jerrems (2005:69–70) clearly document that Orr’s field notes and various publications about Fishbone Cave are not in agreement when it comes to describing the provenience and association of the recovered materials from level 4 and overlying level 3, calling into question the supposed association of the dated materials and unequivocal artifacts. Although we do not want to rule out the possibility that humans occupied Fishbone Cave before the onset of the Younger Dryas, present evidence for this is equivocal and needs to be replicated through either renewed excavation of Fishbone Cave or similar discoveries at other sites in the region.

**Younger Dryas**

After Fishbone Cave, the earliest possible evidence for humans in the Lahontan basin comes from Handprint Cave in the Black Rock Desert (Figure 1; site 2). The single age estimate from this site, 10,740 \(^{14}\)C B.P. (~12,810 cal. B.P.), is from charcoal recovered from underneath a Great Basin stemmed point (Bryan, 1988). The origin of the charcoal is not clear, however, and the shallow, unsealed stratigraphic context of the finds suggests that the charcoal and point may not be related at all. At most, the \(^{14}\)C age may provide a lower limiting age for the associated artifacts.

Of a slightly younger age are two osseous points from the Pyramid Lake subbasin that have been directly dated to 10,360 and 10,340 \(^{14}\)C B.P. (~12,170 and 12,150 cal. B.P.) (Dansie & Jerrems, 2005). These were found on an eroded surface (Wizards Beach) near Pyramid Lake’s historic low-stand (1158 m). Dansie and Jerrems (2005:68) state that one of these artifacts is made of mammoth ivory and the other of mammoth rib bone. Although they interpret them to represent a mid-Younger Dryas recession
of Pyramid Lake, we agree with Dansie and Jerrems (2005) that the “age of the ivory point and mammoth rib harpoon dates the death of the animal, not necessarily the date of deposition.” Because we cannot trace them back to their original geologic context, we cannot rule out the possibility that they represent younger, later-Paleoindian-aged or Archaic-aged artifacts made on mined fossil bone. After all, sagebrush cordage and human skeletal remains collected from the same beach are only \( \sim 9700–9300 \) \(^{14}\)C B.P. \((\sim 10,990–10,460 \text{ cal. B.P.})\) (Tuohy, 1988a; Tuohy & Dansie, 1997). Further, if these artifacts truly date to c. \( 10,350 \) \(^{14}\)C B.P. \((\sim 12,150 \text{ cal. B.P.})\) and are indeed made on mammoth ivory/bone, then they represent one of the latest persisting North American mammoths, which are commonly thought to have gone extinct by \( 10,800 \) \(^{14}\)C B.P. \((\sim 12,850 \text{ cal. B.P.})\) (Haynes, 2002b). Given these problems, we conclude that Fishbone Cave, Handprint Cave, and the Pyramid Lake finds provide only tentative evidence that humans existed in the Lahontan basin prior to the end of the Younger Dryas.

**Post-Younger Dryas**

Humans certainly inhabited the Lahontan basin by the onset of the early Holocene, \( 10,000–9000 \) \(^{14}\)C B.P. \((\sim 11,420–10,200 \text{ cal. B.P.})\). Evidence comes from three different subbasins. From Pyramid Lake come sagebrush cordage and human skeletal remains directly dated to \( 9700–9200 \) \(^{14}\)C B.P. \((\sim 10,990–10,460 \text{ cal. B.P.})\) (Wizards Beach) (Tuohy, 1988a, 1988b); from Winnemucca Dry Lake come human-produced textiles directly dated to \( 9600–9100 \) \(^{14}\)C B.P. \((\sim 10,880–10,240 \text{ cal. B.P.})\) (Shinners site A, Chimney Cave, and Crypt Cave) (Hattori, 1982; Fowler, Hattori, & Dansie, 2000); and from the Carson Sink come textiles (Grimes Point and Hidden Cave) and human skeletal remains (Spirit Cave mummy, Spirit Cave Cremation No. 2, and Spirit Cave Burial #1) directly dated to \( 9500–9000 \) \(^{14}\)C B.P. \((\sim 10,730–10,200 \text{ cal. B.P.})\) (Tuohy & Dansie, 1997; Fowler, Hattori, & Dansie, 2000). The Wallman bison, found eroding from lake deposits in the east arm of the Black Rock Desert, also dates to this time, although its association with a nearby Great Basin stemmed point is tenuous (Dansie & Jerrems, 2005). Taken together, these directly dated cultural remains indicate intensive human use of the Lahontan basin immediately following the Younger Dryas period.

That humans during the interval from \( 10,000 \) to \( 9000 \) \(^{14}\)C B.P. \((\sim 11,420–10,200 \text{ cal. B.P.})\) likely focused subsistence at least part-time on marsh or shallow-lake resources is suggested by the directly dated finds themselves. The early textile mats from Spirit, Hidden, Chimney, and Crypt caves are partly made of bulrush (Fowler, Hattori, & Dansie, 2000), and the fecal boluses of the Spirit Cave mummy contained numerous remains of cyprinid fishes (i.e., chubs and daces) (Eiselt, 1997). The sagebrush cordage, mammoth ivory, and bone tools from Wizards Beach have been interpreted to be fishing tools (Tuohy, 1988a; Dansie & Jerrems, 2005). Interestingly, though, none of these remains come from excavated habitation sites, leaving the impression that the early human occupants of the Lahontan basin only used the shallow lakes and marshes of western Nevada on a temporary, perhaps seasonal, basis. This interpretation conforms with recent technological analyses of surface lithic assemblages.
suggesting that Nevada's pre-Archaic foragers were highly mobile and transported finished stone tools across extensive territories (Graf, 2001; Jones et al., 2003; Smith, 2006, 2007; Goebel, 2007).

This intense period of human activity appears to have ended 9000 14C B.P. (~10,200 cal. B.P.). According to the archaeological 14C chronology, from 9000 until about 8000 14C B.P. (~10,200–8930 cal. B.P.), there is virtually no record of human occupation in the Lahontan basin. Of course, a few exceptions occur—a piece of Z-twined basketry from Shinners site A (Hattori, 1982), a Catlow twined burial mat and piece of netting from Fishbone Cave, and several sagebrush and tule sandals from Elephant Mountain Cave (Connolly & Barker, 2004)—but these appear to represent isolated occurrences of humans in an otherwise empty landscape. Interestingly, the sandals from Elephant Mountain Cave are identical to early Holocene footwear from south central Oregon (Connolly & Barker, 2004), suggesting that during this time the northern subbasins of Lahontan were periodically visited by early Archaic foragers from the northern Great Basin.

After 7800 and leading up to 5700 14C B.P. (~8600–6480 cal. B.P.), the frequency of 14C-dated archaeological cases seems to increase but not significantly. During this 2000-year interval, humans discarded organic artifacts in caves and rockshelters of the Black Rock Desert (Elephant Mountain Cave) (Connolly & Barker, 2004), Winnemucca Dry Lake (Shinners sites D and I, Lake Winnemucca Cave, Nicolarsen, Fishbone Cave, Guano Cave, and Cowbone Cave) (Orr, 1956; Adovasio, 1970; Hester, 1973; Rozaire, 1974; Heizer & Hester, 1978; Hattori, 1982; Connolly & Barker, 2004; Dansie & Jerremys, 2005), Carson Sink (Hidden Cave) (Thomas, 1985), and Humboldt Sink (Leonard Rockshelter) (Heizer, 1951), and they prepared human and dog burials in Leonard Rockshelter and Crypt Cave, respectively (Heizer, 1951). The character of artifact inventories and related technologies is significantly different from the earlier period of intense occupation 10,000–9000 14C B.P. (~11,420–10,200 cal. B.P.), indicating both major adaptive change at this time and a new resident population for the Lahontan basin (Connolly & Barker, 2004).

GEOLOGICAL STUDY SITES AND LAKE-LEVEL FLUCTUATIONS

Western Subbasins

The principal stream flowing into the western subbasins is the Truckee River, but prior to about 15,000 14C B.P. (~18,250 cal. B.P.), the Humboldt River also may have fed the western subbasins by flowing through Pronto Pass and eventually into the Black Rock Desert (Davis, 1982, 1990; Benson & Peterman, 1996) (Figure 1). Many other relatively minor streams including the Susan and Quinn rivers may have contributed substantial inflow at times in the past.

The elevations of sills surrounding Pyramid Lake and volumes of downstream basins (i.e., Smoke Creek Desert, Black Rock Desert) exerted strong controls on past lake levels because the lake surface was periodically pinned at the different sill elevations until the downstream basin filled and the then integrated lake could continue to rise. Major sills connecting Pyramid Lake to the other western subbasins
include Mud Lake Slough (1177 m), Emerson Pass (1202 m), and Astor Pass (1224 m) (Figure 1). Consequently, well-defined shoreline complexes should be found at or near these elevations because lake level was repeatedly stabilized for relatively long periods of time.

At the north end of Winnemucca Dry Lake (WDL), a sequence of well-defined beach ridges extends from the playa (~1152 m) up to the highstand (1338 m), making this one of the few places in the Lahontan basin where constructional shorelines can be traced through this entire elevation range. In the lower part of this sequence, several sets of shorelines have distinctive photographic and field characteristics that separate them from shorelines higher in the sequence and from each other (Figure 2). The lower beach ridges in the sequence, ranging in elevation from 1177 m to 1202 m, are primarily composed of granitic sand and are being reworked into dunes at their eastern ends due to the prevailing winds at that location. Beach ridges above this elevation contain greater amounts of gravel and are apparently less susceptible to eolian reworking. All shoreline and other feature elevations acquired for this study were surveyed with a total station or differential GPS system referenced to local benchmarks, which provides for an error of less than 10 cm. Elevations reported from previous studies and reviewed herein were probably acquired using a variety of techniques and may have substantially larger errors.

The historic highstand in WDL reached an elevation of 1175 m in 1882 (Russell, 1885; Harding, 1965). At the north end of the subbasin, this highstand is probably represented by the 1177 m beach ridge (Figure 2). The elevation difference between these measurements is within the natural variability expressed by shoreline features related to a single lake level (Atwood, 1994; Adams & Wesnousky, 1998).

The next group of shorelines upslope from the historic highstand extends from about 1185 m up to about 1195 m and dates between 3600 and 2600 14C B.P. (~3910 and 2750 cal. B.P.) (Figure 2). The late Holocene age range for this group of shorelines is indicated by multiple radiocarbon ages on a variety of materials from shorelines at the north end of WDL (Figure 2) and from correlative shorelines at the south end of Pyramid Lake (Briggs, Wesnousky, & Adams, 2005).

The 1202 m beach ridge at WDL is one of the larger ridges in this succession and likely formed in response to spill over the Emerson Pass sill (Figure 1). The large size of the 1202 m beach ridge complex is probably related to long stillstands and repeated spill events over Emerson Pass into the Smoke Creek Desert. Therefore, this beach ridge is probably a compound feature formed over multiple lake cycles.

The Mazama and Tsoyawata tephra beds are both found in an artificial exposure through fine-grained sediments ponded by the 1202 m beach ridge near the Coleman archaeological locality in the northern WDL (Figure 2). Each of the tephra beds is relatively pure at its base but grades upward into admixtures of silt and glass sherds over several centimeters. The tephras are separated by about 50 cm of silt and fine sand. The ages of the Mazama and Tsoyawata tephras—6845 14C B.P. (~7730 cal. B.P.) and 7015 14C B.P. (~7840 cal. B.P.), respectively (Bacon, 1983; Zdanowicz, Zielinski, & Germani, 1999)—indicate that this beach ridge was either active or already had been emplaced by late in the early Holocene. A trench excavated through
Figure 2. Map of the northern end of Winnemucca Dry Lake showing age of shoreline features and results of an archaeological survey. The Coleman site is at the west end of the 1218 m shoreline. The thin black line encloses the survey area.

the 1202 m beach ridge did not reveal the presence of tephra or materials suitable for radiocarbon dating.

At the south end of Pyramid Lake, Bell, House, and Briggs (2005) mapped a complex fluvial terrace sequence that stands about 10–20 m above the modern flood plain. The Nixon terrace fill is characterized by complex meander scroll topography that descends from about 1220 m down to about 1200 m, where the terrace is truncated by the 1200 m shoreline. The Mazama tephra is found in at least three locations within the Nixon terrace (Bell, House, & Briggs, 2005), all of which are found in the lower elevation deposits of the terrace from about 1198–1210 m. Several radiocarbon
ages in the range of 8000–7000 $^{14}$C B.P. ($\approx$8930–7830 cal. B.P.) (Table II) also support this age range for the Nixon terrace.

The upper age limit for the Nixon terrace is constrained by the ages of shorelines that transgressed to an elevation of 1231 m after recession from the Lahontan highstand and are truncated by the upper edge of the terrace (Bell, House, & Briggs, 2005; Briggs, Wesnousky, & Adams, 2005). Although Briggs, Wesnousky, and Adams (2005) did not directly date the 1231 m shoreline, a beach ridge in the same shoreline sequence at 1212 m provided an age of 10,820 $^{14}$C B.P. ($\approx$12,840 cal. B.P.) (Table II). This age may be from the transgressive limb of the post-highstand lake-level rise because it is derived from an articulated mollusk shell in relatively flat-lying beach gravel that in turn is overlain by the landward-dipping backsets of the surface beach ridge (Briggs, Wesnousky, & Adams, 2005). In this interpretation, the surface beach ridge at 1212 m dates from the regressive limb of this cycle. This interpretation also implies that the 1231 m beach ridge post-dates 10,820 $^{14}$C B.P. ($\approx$12,840 cal. B.P.).

A trench was excavated through a correlative beach ridge at 1231 m at the north end of WDL (Figure 2). This beach ridge consists of clean, well-washed gravel that stratigraphically overlies a fine-grained deposit covered by tufa fragments and that contains moderately large (\(\gtrsim\)1 m) tufa heads embedded within the surface and abundant gastropod shells throughout. These field relations are similar to those found at the Jessup embayment in the Carson Sink, where a clean, well-washed beach ridge overlying a tufa-covered surface was interpreted to represent a transgression to this level after regression from the highstand (Adams & Wesnousky, 1998). At the 1231 m WDL barrier (Figure 2), gastropods from backsets of the surface beach ridge yielded an age of 16,610 $^{14}$C B.P. ($\approx$19,640 cal. B.P.) (Table II).

We believe this age to be erroneous for the following reasons. First, the maximum age of the 1231 m beach ridge must be younger than the Lahontan highstand age of 13,070 $^{14}$C B.P. ($\approx$15,420 cal. B.P.) (Adams & Wesnousky, 1998) if this beach ridge is interpreted to have formed during regression from the highstand. Second, based on arguments presented by Briggs, Wesnousky, and Adams (2005), the 1231 m shoreline in the western subbasins represents a retransgression to this level after the Lahontan highstand. The 19,640 cal. B.P. age for the 1231 m beach ridge at WDL may be explained by gastropod shells being reworked into the beach ridge from the older, tufa-rich deposits located directly below.

A model for post-highstand lake-level fluctuations in the western subbasins is presented in Figure 3. This model is based on geological, archaeological, and pack rat midden evidence. The timing of the Lahontan highstand is constrained by the age of camel bones (13,070 $^{14}$C B.P. [$\approx$15,420 cal. B.P.]) found in a lagoon behind a highstand beach ridge in the Jessup embayment (Table II) (Adams & Wesnousky, 1998). The precipitous regression from the highstand is constrained by the age and elevations of pack rat middens found on the east shore of WDL (Thompson, Benson, & Hattori, 1986). Even a brief submersion will disaggregate middens, which means that lake level in the western subbasins has not exceeded 1231 m since the oldest of these was formed $\approx$13,940 cal. B.P. Lake level receded to at least 1202 m between 13,000 and 14,000 cal. B.P. and may have been lower before it again began to rise to a maximum elevation of about 1231 m. Lake level rapidly receded from 1231 m to at
Table II. Radiocarbon ages of geologic and midden materials used for reconstructing lake-level fluctuations between 13,000 and 7000 \(^{14}\)C B.P.

<table>
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<th>Location</th>
<th>Lab #</th>
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<th>Sample material</th>
<th>Age (cal. B.P.) ((\pm 2))</th>
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<th>Letter in Figures 3 &amp; 5</th>
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<td><strong>Western Subbasins</strong></td>
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<td>Pyramid Lake-Nixon Terrace</td>
<td>Beta-192174</td>
<td>7020 40 charcoal</td>
<td></td>
<td>7760–7950</td>
<td>1189</td>
<td>A</td>
<td>Bell et al. 2005</td>
</tr>
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<td>Beta-192173</td>
<td>7380 40 organic sed</td>
<td></td>
<td>8050–8330</td>
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<td>Beta-165453</td>
<td>7800 60 charcoal</td>
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<td>8430–8760</td>
<td>1207</td>
<td>C</td>
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<td>Beta-165461</td>
<td>7940 40 bone</td>
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<td>8640–8880</td>
<td>1207</td>
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<td>WIS-374</td>
<td>8800 90 wood</td>
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<td>1168</td>
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<td>L-8193</td>
<td>9970 140 wood</td>
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<td>1179</td>
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<td>Prokovich 1983</td>
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<td>Pyramid Lake delta ridge</td>
<td>CAMS-90412</td>
<td>10,820 35 pelecypod shell</td>
<td>12,800–12,880</td>
<td>1212</td>
<td>I</td>
<td>Briggs et al. 2005</td>
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<td>Fishbone Cave</td>
<td>L-245</td>
<td>11,200 250 juniper roots</td>
<td>12,760–13,640</td>
<td>1235</td>
<td>J</td>
<td>Thompson et al. 1986</td>
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<td>Guano Cave #11</td>
<td>A-3699</td>
<td>11,580 290 juniper</td>
<td></td>
<td>12,920–14,010</td>
<td>1230</td>
<td>K</td>
<td>Thompson et al. 1986</td>
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<td>Guano Cave #7B1</td>
<td>A-3696</td>
<td>11,810 230 juniper</td>
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<td>13,200–14,170</td>
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<td>11,890 250 juniper</td>
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<td>12,060 260 juniper</td>
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<td>A-3697</td>
<td>12,070 210 juniper</td>
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<td>13,440–14,730</td>
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<tr>
<td>Falcon Hill #2</td>
<td>A-3489</td>
<td>12,020 470 juniper</td>
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<td>13,000–14,250</td>
<td>1206</td>
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<td>Thompson et al. 1986</td>
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<td>Winnemucca Lake beach ridge</td>
<td>Beta-174833</td>
<td>16,610 80 gastropod shells</td>
<td>19,310–20,290</td>
<td>1231</td>
<td>This study</td>
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<tr>
<td><strong>Carson Sink</strong></td>
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<td>Rainbow Mtn beach ridge</td>
<td>GX-27181</td>
<td>8060 70 charcoal</td>
<td></td>
<td>8650–9135</td>
<td>1228</td>
<td>Q</td>
<td>Caskey et al. 2004</td>
</tr>
<tr>
<td>Rainbow Mtn beach ridge</td>
<td>LLNL-81208</td>
<td>9950 60 charcoal</td>
<td></td>
<td>9180–9200</td>
<td>1228</td>
<td>R</td>
<td>Caskey et al. 2004</td>
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<tr>
<td>Large meander scrolls on Humboldt</td>
<td>Beta-156642</td>
<td>9500 40 charcoal</td>
<td></td>
<td>10,605–10,620</td>
<td>NA</td>
<td>House et al. 2001</td>
<td></td>
</tr>
<tr>
<td>Humboldt Bar, shore-zone sand</td>
<td>Beta-29024</td>
<td>10,280 80 Anodonta shell</td>
<td>11,980–12,630</td>
<td>1198</td>
<td>S</td>
<td>Currey 1990</td>
<td></td>
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<tr>
<td>Top of Carson River paleodelta</td>
<td>Beta-24290</td>
<td>11,100 110 Tufa</td>
<td></td>
<td>12,570–13,390</td>
<td>1203</td>
<td>T</td>
<td>Currey 1988</td>
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<tr>
<td>Lahontan highstand at Jessup</td>
<td>NSRL-3014</td>
<td>13,070 60 camel bone</td>
<td></td>
<td>15,150–15,500</td>
<td>1339</td>
<td>V</td>
<td>Adams and Wesnousky 1998</td>
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</table>
least as low as 1153 m between 11,000 to 10,000 cal. B.P., which is constrained by the age of archaeological materials found at Wizards Beach along the northwest shore of Pyramid Lake (Tuohy & Dansie, 1997) (Table I). By about 10,160–9560 cal. B.P., lake level was rising through an elevation of 1168 m and may have attained an elevation near Emerson Pass and spilled into the Smoke Creek Desert. This rise is
constrained by the age and elevation of deltaic deposits (Born, 1972), the age of the Nixon terrace that grades to an elevation near 1200 m (Bell, House, & Briggs, 2005a), and the presence of the Mazama and Tsoyawata tephras ponded behind the 1202 m beach ridge at the north end of WDL (Figure 2).

Carson Sink

The Carson Sink is a broad, relatively flat-floored basin fed by the Humboldt and Carson rivers and sometimes the Walker River (Figure 1) (Russell, 1885; Benson & Thompson, 1987; Benson, Meyers, & Spencer, 1991; King, 1993; Adams, 2003). The hypsometry of the sink is such that relatively small lake-level rises correspond to large increases in surface area and volume (Benson & Mifflin, 1986; Adams, 2003). Large increases in surface area are directly related to large increases in evaporation, which suggests that lake levels in broad, flat basins respond more slowly to differences in the hydrologic balance than do lake levels in deep, narrow basins. Therefore, the response to a given increase in inflow would be expected to be slower and of lesser magnitude for Carson Sink than for the Pyramid and Winnemucca lake subbasins. The hypsometry of the Carson Sink also suggests that large areas of shallow wetlands and marshes were probably associated with a range of lake levels, in contrast to the much steeper-walled subbasins of Pyramid and Winnemucca lakes, where shallow wetlands were generally restricted.

The timing and magnitude of post-highstand lake-level fluctuations in the Carson Sink has been a matter of some debate. Morrison (1964, 1991) reported that Lake Lahontan receded from its highstand to an elevation as low as 1190 m in the Carson Sink before transgressing back up to about 1216 m. This post-highstand lake-level rise is called the upper Sehoo or S3, but it is poorly dated (Morrison, 1991). Morrison (1964, 1991) also identified a lower suite of late Holocene shorelines (Fallon alloformation), the highest of which is at about 1204 m. Currey (1988, 1990) and Benson et al. (1992) disagreed with a late Holocene age for the shoreline at 1204 m, concluding that it was formed between 11,300 and 10,380 14C B.P. (~13,190 and 12,230 cal. B.P.) (Table II). Their evidence included three radiocarbon ages from various lacustrine deposits at or just below 1203 m.

Expanding on observations made by Davis (1978a), Adams (2003) interpreted that the Turupah Flat tephra was deposited by wave overwash on the back side of the highest Fallon shoreline, indicating that a lake in the Carson Sink reached an elevation of 1204 m within the last 2000 years. The ages of a piece of detrital charcoal from directly beneath the tephra and an Anodonta (sp.) shell from a surface midden (Broecker & Kaufman, 1965) on the beach ridge further constrain the age of the 1204 m shoreline to between 800 and 900 cal. B.P. (Adams, 2003). Therefore, although a lake was likely fluctuating through this elevation during the latest Pleistocene, a lake also reached 1204 m in the latest Holocene.

Work in the Jessup embayment of the Carson Sink (Figure 1) identified a shoreline that represents a transgression up to an elevation of about 1235 m after the lake regressed from its highstand to an elevation as low as 1190 m (Adams & Wesnousky, 1998). Evidence for this interpretation includes the observation that shorelines found
around 1230–1235 m in the Carson Sink are commonly composed of clean, well-washed gravel and stratigraphically overlie tufa-covered shorelines. The tufa-covered shorelines were likely formed during the regression from the highstand, when alkalinity was increasing (Adams & Wesnousky, 1998). Thus, the overlying beach ridges of clean, well-washed gravel are interpreted to represent a retransgression to this same altitude because they were apparently formed at the margins of a fresher lake.

Controls on lakes at about 1230–1235 m include the Rawhide sill, which separates the Carson Sink from the downstream Rawhide Flats subbasin (Figure 1). The crest of the sill is composed of a gravel beach ridge with a channel cut through its center. A survey along the axis of the channel demonstrates that it slopes away from the beach ridge in both directions, indicating that the wind gap was likely cut by overflow from the Carson Sink into Rawhide Flats. The beach ridge comprising the Rawhide sill lies at an elevation of 1231.5 m, but the difference in elevation of this feature compared to the 1235 m beach ridge at Jessup is well explained by differential isostatic rebound between the two sites (Adams, Wesnousky, & Bills, 1999).

Caskey et al. (2004) excavated a trench through a beach ridge at an elevation of about 1228 m along the 1954 surface rupture trace of the Rainbow Mountain fault (Figure 1). Two detrital charcoal samples collected from deposits directly beneath the beach ridge constrain its age to younger than or coeval to 8060 \(^{14}\)C B.P. (~8980 cal. B.P.) or 9950 \(^{14}\)C B.P. (~11,330 cal. B.P.) (Table II). Even though there is a well-defined beach ridge complex at 1228 m in the Jessup embayment, the 1228 m beach ridge at Rainbow Mountain may be correlative to the 1235 m shoreline at Jessup due to differential isostatic rebound between the two sites (Adams, Wesnousky, & Bills, 1999) and fault offset at the Rainbow Mountain site (Caskey et al., 2004).

There is no age control on lake-level fluctuations in the Carson Sink between about 8000 and 7000 \(^{14}\)C B.P. (~8930 and 7830 cal. B.P.), until the Mazama and Tsoyawata tephras were deposited. At Mazama time, Davis (1982) surmised that a lake existed in the Carson Sink with a surface elevation of about 1200 m (Figure 4). This interpretation was based on occurrence of the Mazama and Tsoyawata tephra beds in lacustrine deposits at about 1193 m near Stillwater and in alluvial fan deposits at the base of the West Humboldt Range at about 1202 m (Davis, 1978a).

Based on data and observations for the Carson Sink, a model for post-highstand lake-level fluctuations is presented in Figure 5. This model is also based on geological and archaeological evidence, although there are fewer data than in the western subbasins. The subbasins share a common lake-level history for elevations above about 1265 m, the approximate elevation of the broad divide near Fernley and the Chocolate Butte sill (Figure 1). Below this elevation, the lakes fluctuated independently. Based on the presence of a buried soil, Morrison (1964, 1991) interpreted lake level to have receded to near the floor of the Carson Sink immediately after the highstand. Lake level then increased so that by about 13,000 cal. B.P. it was around 1200 m and by about 11,400 cal. B.P. it had reached about 1228 m. Preserved “mega-meander” features along the Humboldt River between Battle Mountain and Winnemucca with a minimum age of about 10,900 cal. B.P. support the idea that stream discharge into the Carson Sink was much higher than at present near the end of the Pleistocene (Davis, 1978b; House, Ramelli, & Wrucke, 2001; Miller et al., 2004).
Figure 4. Lake levels and extent of the Younger Dryas highstand (~12,100 cal. B.P.) in the Lahontan basin. Lake level reached about 1230 m in the western subbasins and about 1235 m in the Carson Sink. Lake levels are also shown at about 7800 cal. B.P. when the Mazama and Tsoyawata tephras were deposited.
Textile material from the Grimes Point burial at an elevation of about 1220 m dates to about 10,800 cal B.P., indicating that lake level must have been below this elevation at that time. Lake level is poorly constrained for the rest of the early Holocene, but was probably around 1200 m when the Mazama and Tsoyawata tephras were deposited (Davis, 1978a, 1982) (Figure 4).
ADAMS ET AL.

ARCHAEOLOGICAL SURVEYS

To investigate a possible relationship between Paleoindian land use and fluctuating lake levels, systematic surveys were performed in two separate regions at elevations ranging from about 1185 to 1235 m. The first area is that previously described at the north end of WDL (Figures 1, 2). The second area is located at the north end of the West Arm of the Black Rock Desert (Figure 1). Survey results for each of these areas are presented below.

Winnemucca Dry Lake

At the north end of WDL, we conducted an archaeological survey of beach ridges ranging in elevation from 1231 m down to 1185 m (Figure 2). To investigate whether humans ever utilized the Sehoo highstand beach-ridge sequence, we also surveyed the highstand beach ridge located about 7 km to the north at an elevation of 1338 m (Adams, Wesnousky, & Bills, 1999), as well as the next two lower features at 1333 m and 1329 m, respectively. The only archaeological remains discovered at these high-elevation beach ridges included three isolated Archaic-period projectile points, an Elko Corner-notched point (1338 m), a Rose Spring point (1333 m), and a Northern Side-notched point (1329 m).

Archaeological finds on the lower beach ridges consisted of prehistoric lithic artifacts that were observed on the surfaces of the surveyed beach features. Fifteen sites and five isolated finds were discovered on beach features between 1225 m and 1190 m (Figure 2). No cultural remains were discovered along the 1231 m beach ridge, but the 1225 m beach ridge yielded several isolated, non-diagnostic finds and a single late Archaic site.

The 1218 m beach ridge yielded several non-diagnostic sites, but one of the sites was found to be a new, previously unknown locus of the Coleman site—an extensive Great Basin stemmed point site that was first identified and recorded during the late 1950s by Tuohy (1970) and further documented by Graf (2001) (Figure 2). Artifacts found in this study closely match the type of artifacts found at the original Coleman site.

Four sites were found on the 1202 m beach, but only one contained diagnostic artifacts (early to middle Archaic) that place the age of occupation between about 8000 and 2000 14C B.P. (∼8900 and 1950 cal. B.P.) (Thomas, 1981). One large, early to middle Archaic site straddled both the 1202 m and 1194 m beach features.

The last beaches surveyed in our study include the closely associated 1190 m and 1185 m features, on which we found two middle and late Archaic sites (Figure 2). In addition, one highly weathered stemmed point was found on the larger of these sites. The presence of this point is interesting, but because the artifact was highly water-worn (similar to other rocks comprising the beach itself), its presence may suggest that it was reworked from an older beach and secondarily deposited in the beach gravels that formed the 1190–1185 m beaches. Middle and late Archaic artifacts from this beach are comparatively fresh and unweathered.

In sum, we have found numerous archaeological sites between the 1231 m and 1185 m beach ridges. Diagnostic archaeological remains found on the 1225 m beach suggest a late Archaic occupation of this feature between about 1300 and 700 14C B.P.
LATE PLEISTOCENE AND EARLY HOLOCENE LAKE-LEVEL FLUCTUATIONS

(~1260 and 660 cal. B.P.) (Thomas, 1981; Holmer, 1986). Extension of the Coleman Locality along the 1218 m beach, coupled with the lack of other diagnostic artifact types on this beach, suggest that humans occupied this geomorphic feature sometime between about 11,000 and 8500 ¹⁴C B.P. (~12,900 and 9510 cal. B.P.). We found archaeological evidence of early to middle Archaic occupation of both the 1202 m and the 1194 m beach ridges, suggesting that human occupation of these features occurred some time between 8000 and 2000 ¹⁴C B.P. (~8900 and 1950 cal. B.P.). The lower beach ridges surveyed, 1190 m and 1185 m, contain sites with both middle and late Archaic archaeological remains. Therefore, we can say that these beach features were occupied by humans sometime during the 4000 to 1000 ¹⁴C B.P. (~4470 to 930 cal. B.P.) period (Holmer, 1986).

West Arm of the Black Rock Desert

The Black Rock Desert (BRD) contains a large, very flat playa at an average elevation of about 1190 m. This feature represents the bed of Lake Lahontan and is occasionally flooded to shallow depths by local precipitation and discharge from the Quinn River and Mud Meadows Creek (MMC) (Figure 1). At the north end of the playa, the landscape gradually rises to an elevation of about 1225 m, where MMC becomes confined in a broad canyon likely cut through Pleistocene lacustrine deposits (Figure 6). In contrast to WDL, there are few well-developed shorelines in the elevation range of 1200 to 1230 m, even though a common lake surface would have connected these subbasins at all elevations above about 1200 m. Thus, lake-level fluctuations documented at Pyramid Lake and WDL for the elevation range of 1200–1230 m (Briggs, Wesnousky, & Adams, 2005) also apply to the BRD. Reasons for a lack of well-developed shorelines at MMC may include low sediment supply and low wave energy, due to a low gradient (0.0005). Despite the lack of well-defined beach ridges and possessing an overall low gradient, the area is characterized by numerous, isolated knobs and linear ridges. The sinuous linear ridges are oriented sub-parallel to the modern drainage and transverse to local slopes. Therefore, they are probably fluvial features deposited by MMC in an environment perhaps similar to that described by Oviatt, Madsen, and Schmitt (2003) for gravel paleochannels in the Bonneville basin.

In the BRD, our surveys were conducted primarily on parcels between 1200 and 1230 m, but we also surveyed parcels above and below this elevation range (Figure 6). In total, 79 open-air archaeological sites were identified. Thirty-five of these contain diagnostic artifacts and 44 are undiagnostic lithic scatters. Five isolated diagnostic artifacts also were recorded. These sites are summarized below.

Sixteen archaeological sites containing Paleoindian artifacts were recorded. Additionally, two isolated crescents—a diagnostic component of the Paleoindian toolkit in the region (Beck & Jones, 1997)—and one stemmed projectile point were recorded. Seven of the Paleoindian sites contained multiple stemmed points, concave-based points, and/or crescents, and nine sites contained single examples of these. All of the sites containing multiple Paleoindian artifacts also contained later Archaic
Figure 6. Map of the west arm of the Black Rock Desert along Mud Meadows Creek showing distribution of archaeological sites with respect to elevation. Survey boundaries are outlined in thin black lines. Most of the identifiable Paleoindian sites are found in the elevation range of from 1205 to 1225 m.
Two possibilities may account for this fact. First, the Paleoindian artifacts may have been collected by later groups in need of lithic raw materials and redeposited at these locations together with other lithic detritus—the implication of this possibility being that the sites containing Paleoindian artifacts may not actually date to the Pleistocene/Holocene transition but instead some time during the Archaic period. Second, later groups may have simply revisited the same landforms that Paleoindian groups occupied before them. Most of the sites containing early-period artifacts are situated on elevated landforms which would have afforded good vantage points overlooking the surrounding areas. To be sure, environmental conditions changed dramatically in the West Arm of the BRD across the Pleistocene/Holocene transition; however, these raised landforms would have continued to represent ideal overlooks throughout the Archaic period. Given that high-quality lithic raw materials (i.e., CCS and, to a lesser extent, obsidian) occur in the uplands and alluvial deposits surrounding the West Arm of the BRD (Elston & Davis, 1979; Moyer, 1999; Young, 2002; Smith & Goebel, 2003; David Valentine, pers. comm., 2005), the latter possibility—that later groups simply occupied the same landforms as earlier groups—is likely the most parsimonious explanation for why later Archaic artifacts frequently co-occur with Paleoindian artifacts.

Archaeological sites containing later Archaic projectile points (e.g., Large Side-notched, Humboldt, Gatecliff, Elko, Rose Spring, Desert Side-notched, and Cottonwood types) are ubiquitous throughout our study area. In fact, 33 of the 35 archaeological sites containing diagnostic artifacts contained later Archaic points. Based on these data, it appears that, like Paleoindians, later Archaic groups also frequented the West Arm of the BRD.

To investigate a possible relationship between Paleoindian artifacts and lake levels, we must first show that most sites containing early-period artifacts are located at specific elevations—namely within the range of shorelines formed from about 11,000–8000 \(^{14}C\) B.P. (~12,900–8930 cal. B.P.). In other words, do Paleoindian sites occur in high numbers around these features or are they instead scattered relatively uniformly across the landscape?

As Figure 6 illustrates, the bulk of Paleoindian sites (15 of 16 sites) and isolates (2 of 3) are located between 1205 and 1225 m in elevation. The one site containing a Paleoindian artifact is CrNV-22-8199, which is located outside of the elevation range transgressed by a lake between about 11,000 and 8000 \(^{14}C\) B.P. (~12,900 and 8930 cal. B.P.). It contained a single concave-based point and six later Archaic points and is located at 1255 m in elevation, about 6 km north of the 1225 m contour. Again, the concave-based point may have been collected by later groups and redeposited there, or later groups may have revisited the location after an initial Paleoindian occupation. In either case, this site is clearly not associated with any shorelines that formed during the Pleistocene/Holocene transition. The isolated Paleoindian artifact, a crescent, also was located outside of the 1205–1225 m elevation range at an elevation of 1195 m along the bank of one of the current channels of MMC. Although we cannot say for certain, it is possible that this artifact was removed from its primary context by natural or cultural processes and redeposited at that location. These data strongly suggest that early groups occupying the West Arm of the BRD displayed an affinity for...
the area within a particular elevation range, 1205–1225 m, and this could have been because of the presence of a shallow lake or marsh at or just below this elevation range.

DISCUSSION AND CONCLUSIONS

In the Lahontan basin, people were clearly present when lake levels were undergoing dramatic changes at the end of the Pleistocene and into the early Holocene. The question then becomes, did lake-level fluctuations control the spatio-temporal distribution of archaeological sites during this time frame? To address this question, we first developed lake-level chronologies for the western subbasins (Figure 3) and the Carson Sink (Figure 5) of the Lahontan system and then compared these to existing archaeological data as well as detailed field surveys in two regions (Figures 2, 6) that were inundated during the Younger Dryas period. Differences in the lake-level curves for the western subbasins and the Carson Sink may be related to differences in hydrology and hypsometry of the respective subbasins but are also likely due to insufficient data to draw these curves with more detail. Even though the lake-level curves may continue to evolve as more data are collected in the future, there appears to be a strong spatio-temporal correspondence between the physical record of paleoenvironmental change and where humans were focusing their activities. As Figure 7 shows, there appears to be an inverse relationship between lake level and frequency of \(^{14}C\)-dated archaeological events in the Lahontan basin. The finds from Handprint Cave, Pyramid Lake (the ivory point and bone harpoon), and Fishbone Cave may or may not represent human activity between about 12,150 and 13,200 cal. B.P.; however, even if they do, these finds seem to date to before the Younger Dryas highstand, during a relatively dry time when lake levels were lower than 1200 m. During the Younger Dryas highstand, when lake levels in the western subbasins rebounded to \(\sim 1230\) m (about 12,000–12,500 cal. B.P.), there is little dated evidence of humans in the Lahontan basin, but after the Younger Dryas, when lake levels dropped to as low as 1150 m (about 10,000 to 11,000 cal. B.P.), there is a sharp rise in the frequency of \(^{14}C\)-dated events (Figure 7). After this time, as lake levels gradually rose to (and fell from) the 1202 m shoreline, \(^{14}C\)-dated events continue, albeit at lower proportions than during the earlier episode of lowest lake levels. If these dates can serve as a proxy for frequency of human occupation of the region, then they suggest that late Pleistocene/early Holocene humans most frequently utilized the Lahontan basin not when deep, extensive lakes existed, but instead when shallow lakes and marshes characterized the playa floors. This interpretation is supported by our findings at the northern end of WDL and West Arm of BRD.

Our archaeological investigations at the northern end of WDL have shown that the beach ridges were occupied by humans throughout much of prehistory (Figure 2). Several of the sites contained diagnostic artifacts so that the surface archaeology can be generally dated. Clearly, as soon as a geomorphic feature was constructed it was available for human occupation. Given this, we can argue that the 1218 m beach, which contains Paleoindian artifacts, must have been constructed by 12,900–9500 cal. B.P., the time those humans were there. Although the Younger Dryas highstand likely reached about 1231 m (Briggs, Wesnousky, & Adams, 2005), the difference in age
between the 1231 and 1218 m beach ridges is probably minimal, reflecting rapid lake-level regression. This correlates well with the geomorphic work presented above. Because the Mazama and Tsoyawata tephras were identified in ponded sediments directly behind the 1202 m beach, we can be sure that this beach feature was constructed by about 7800 cal. B.P. Interestingly, the archaeology on this feature supports this interpretation in that the diagnostic artifacts are early to middle Archaic in

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**Figure 7.** Lake-level curves of the Pyramid–WDL basins and Carson Sink, superimposed on bar chart showing frequency of \(^{14}C\)-dated archaeological events in the Lahontan basin. Dated events are extracted from Table I. Individual artifacts or osteological remains are counted once; if multiple artifacts or osteological remains from the same site date to within the same 500-year interval, they are counted once. If an archaeological event does not fall within the 500-year intervals shown in the figure, they are split proportionally between the multiple 500-year intervals (for example, the mat from the entrance of Hidden Cave is scored 0.5 for the interval 10,000–10,500 cal. B.P. and 0.5 for the interval 10,500–11,000 cal. B.P.).
character and could very well date to and/or post-date the Mazama and Tsoyawata events. As discussed above, our archaeological data suggest that humans camped on the 1190 m and 1185 m beaches between about 4500 and 900 cal. B.P. These dates correlate well with the ages of these features, which were emplaced between about 3900 and 2750 cal. B.P. (Figure 2) (Briggs, Wesnousky, & Adams, 2005). The presence of a single, heavily water-worn stemmed point on the 1190 m beach does not conflict with this interpretation, in that we argue that the condition of the artifact suggests that it was reworked into the 1190 m beach from earlier deposits. The existence of the Coleman stemmed point site on beaches post-dating the Younger Dryas highstand indicates that humans occupied the 1218 m surface after 12,000 cal. B.P.

Our work in the West Arm of the BRD also has revealed a rich record of human occupation. There, diagnostic artifacts indicate that groups visited the area during an approximately 13,000-year period. Based on the distribution of sites containing these artifacts, two major inferences regarding the relationship between humans and changing hydrographic conditions can be made.

First, it appears that Paleoindians visiting the West Arm of the BRD focused intensively on the area between about 1205 and 1225 m in elevation. During the Younger Dryas highstand, this area was located below the point where MMC flowed into the lake, so it is likely that none of the sites date to this interval of time. Instead, the sites occur at elevations just below the Younger Dryas highstand, indicating that they likely date to a time immediately following the Younger Dryas, when a potentially rich deltaic environment existed. We still cannot discern, however, whether Paleoindians camped alongside a shallow lake or wetland charged by MMC and/or local springs. Because the sites mapped were exclusively surface scatters of lithic artifacts, lacking preserved faunal and floral remains, we cannot address whether Paleoindians were using lake, marsh, or terrestrial resources. Second, the ubiquity of Archaic sites indicates that later groups also occupied the West Arm of the BRD throughout the Holocene, long after the lake had receded from its Younger Dryas levels. These later sites also are distributed throughout much of the 1205–1225 m elevation interval in which almost all of the Paleoindian sites are located; however, they also occur in large numbers outside of this range. Clearly, later Archaic groups did not focus as intensely on one particular area (i.e., Younger Dryas shorelines) in the West Arm of the BRD as did Paleoindian groups. In sum, although the West Arm of the BRD lacks the well-developed shorelines present at WDL and elsewhere, there still appears to be a significant difference in distribution of Paleoindian and later Archaic sites. Paleoindian groups appear to have focused almost exclusively on the area situated between 1205 and 1225 m in elevation, while later Archaic groups did not possess an affinity for any particular elevation range. Therefore, as is the case at WDL, data from the West Arm of the BRD indicate that Paleoindian land use appears to have been linked closely to fluctuating lake levels in the Lahontan basin. Hattori (1982) and Hattori and Tuohy (1993) were the first to hypothesize that occupations of archaeological sites at the northern end of WDL were indicative of the presence of a lake in the basin. Our present study has added depth to this idea by independently establishing the age of shoreline features in the western subbasins and the Carson Sink and then comparing
these ages to the age and distribution of archaeological sites both on the ground and culled from the literature. Although no detailed surveys were performed in the Carson Sink for this study, linear distribution of Paleoindian artifacts along the 1235 m beach ridge at the Sadmat site in the western Carson Sink (Tuohy, 1988b) generally supports the conclusions reached for the western subbasins. Results of all of these comparisons indicate that during the late Pleistocene and into the early Holocene, lake-level fluctuations played a role in controlling the distribution of early archaeological sites.

This conclusion reiterates a strategy originally suggested by Campbell and Campbell (1937) for locating Paleoindian and early Archaic sites in lake basins. If the goal is to locate archaeological sites of a particular age in a lake basin, then detailed knowledge of past lake-level fluctuations can assist in delineating where sites will not be located (areas below lake level at a particular time) and where they may be concentrated (areas adjacent to the lakeshore at a particular time). For example, the highest concentration of Paleoindian sites in the Lahontan basin is likely to be found in the elevation range of 1200–1235 m, which is the maximum range of latest Pleistocene lake levels in the western subbasins and the Carson Sink (Figure 4). Humans may have been in the basin prior to the rise of the Younger Dryas lakes, but evidence for this is sparse. If they were present, there is a possibility that the earliest sites were at lower elevations and buried by sediments from the transgressing lake between 13,000 and 12,000 cal. B.P. Similarly, there is a high probability that sites dating from around 11,000 cal. B.P. in the Pyramid and WDL subbasins were submerged by a subsequent lake-level rise around 8000 cal. B.P. (Figure 3), which may have sealed their stratigraphic context.

Our findings are in line with current models of Paleoindian adaptation in the Great Basin (Grayson, 1993; Beck & Jones, 1997; Oviatt, Madsen, & Schmitt, 2003; Jenkins, Connolly, & Aikens, 2004), which are supported in part by early-period subsistence residues. Paleoindians obviously harvested marsh resources (Bedwell, 1973; Greenspan, 1994; Eiselt, 1997; Layton & Davis, n.d.), but they also regularly subsisted on terrestrial resources including artiodactyls, lagomorphs, birds (e.g., sage grouse), and possibly small seeds (Oetting, 1994; Pinson, 2004; Hockett, 2007; Rhode & Louderback, 2007). Thus, although it is possible the surface lithic scatters found during this study represent marsh-side occupations, they could also represent places where humans accessed terrestrial resources. Pinson (2008) has reported such a case in Dietz basin, south central Oregon, where a wet meadow appears to have been present during the Paleoindian stemmed-point occupation.

Continuing integration of detailed paleoenvironmental information at both local (pack rat middens, pollen cores, etc.) and regional (lake-level fluctuations, alluvial fan activity, etc.) scales with archaeological data will lead to a better understanding of how people interacted with their changing environments through time. This approach should prove useful in other locales in the Great Basin and elsewhere.

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ADAMS ET AL.

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LATE PLEISTOCENE AND EARLY HOLOCENE LAKE-LEVEL FLUCTUATIONS


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