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A Natural and Cultural History of Leonard Rockshelter, Nevada

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By

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ABSTRACT

Leonard Rockshelter (LRS) is located in Pershing County, Nevada. Robert Heizer excavated the site in 1950 and reported more than 2 m of stratified deposits from which he recovered a modest assemblage of perishable and lithic artifacts. Of interest to the University of Nevada Reno's Great Basin Paleoindian Research Unit (GBPRU) was Heizer's discovery of obsidian flakes in deposits dated to 11,199±570 ^{14}C BP (14,900-11,610 cal BP). This possibility of a stratified Pleistocene occupation prompted the GBPRU to return to LRS in 2018 and 2019 for additional work, which produced few artifacts but a sizeable small mammal assemblage. In this thesis, I test two hypotheses: (1) the small mammal assemblage provides a paleoenvironmental record that demonstrates changing local conditions during the Terminal Pleistocene and Holocene; and (2) the shelter contains evidence of human occupation dating to the Terminal Pleistocene. My results demonstrate that the Early Holocene and initial Middle Holocene were more mesic than later periods. They also suggest that people did not occupy LRS until the Early Holocene, after which time they periodically returned to the site.

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CHAPTER 1

Introduction

Our understanding of past conditions in the Great Basin is founded on the study of various proxies including relict lake features, pollen records, packrat middens, and small and large mammal remains. There have been numerous such studies in the Lahontan basin (Adams 1997, 2003; Adams and Rhodes 2019a, 2019b; Adams and Wesnousky 1999; Adams et al. 2008; Benson and Thompson 1987; Benson et al. 2002; Briggs et al. 2005; Byrne et al. 1979; Mensing et al. 2004, 2008; Morrison 1991; Nowak et al. 1994; Rhode 2003; Wigand and Mehringer 1985). While this work has produced a detailed history for Lake Lahontan, other aspects of environmental change remain less clear. Small mammal assemblages from Hidden Cave (Grayson 1985) and Lovelock Cave (Livingston 1988) have offered some insight into temperature and vegetation shifts during the Holocene, but they are neither as detailed nor as informative as similar studies carried out in the Bonneville Basin (Grayson 1998, 2000a, 2000b; Schmitt and Lupo 2005, 2012). Recent excavations at Leonard Rockshelter (LRS) in the Lahontan basin produced a stratified and dated small mammal assemblage. In this thesis, I present the results of my analysis of that assemblage and explore what it tells us about Holocene environmental change. I also present new radiocarbon dates from LRS, which offer insight into how and when humans used the site.

Research Background

Using Small Mammal Assemblages as a Proxy for Environmental Change

Many Great Basin caves and rockshelters contain stratified archaeological and paleontological deposits. They are also often home to roosting owls who deposit small mammal remains when they regurgitate pellets. Over time, this process can introduce large numbers of bones into cave and shelter deposits. Small mammal assemblages offer an opportunity to understand environmental change because different taxa have different ecological tolerances (Grayson 2000b; Lyman 2017). They also provide a high-resolution record because small mammals do not range very far. Their primary predators and agents responsible for depositing their remains, owls, also do not forage far from their roosts. For example, Great Horned Owls (*Bubo virginianus*) generally range ~4 km from their nest and only ~1 km during breeding season (Bennet and Bloom 2005). As such, small mammal assemblages are different from other paleoenvironmental proxies such as pollen records, which provide low-resolution regional records (Byrne et al. 1979; Wigand and Mehringer 1985). By looking at the different ecological tolerances of small mammals and observing shifts in the diversity, abundances, richness, and evenness of assemblages, researchers can identify local environmental shifts (Grayson 1981, 1983, 1984, 1985, 1998, 2000a, 2000b, 2006; Livingston 1988; Schmitt and Lupo 2005, 2012).

To date, the largest and most well-studied small mammal assemblage in the Great Basin comes from Homestead Cave (Grayson 2000b). Homestead Cave contained ~184,000 identified small mammal bones and teeth. Other well-studied small mammal assemblages from the Bonneville Basin include Camels Back Cave (CBC) and Bonneville Estates Rockshelter (BER), which produced 51,000 and 1,080 small mammal bones and teeth, respectively (Schmitt and Lupo 2005, 2012). These records contained several key taxa that researchers have used to investigate environmental change, including pygmy rabbits (*Brachylagus idahoensis*), meadow voles (*Microtus montanus*), sage voles (*Lemmiscus curtatus*), bushy-tailed woodrats (*Neotoma cinerea),* desert woodrats (*Neotoma lepida*), Great Basin pocket mice (*Perognathus parvus*), western harvest mice (*Reithrodontomys megalotis*), Ord's kangaroo rats (*Dipodomys ordii*), chisel-toothed kangaroo rats (*Dipodomys microps*), Botta's pocket gophers (*Thomomys bottae),* northern pocket gophers (*Thomomys talpoides*), hares (*Lepus* spp.), and cottontails (*Sylvilagus* spp.) (Grayson 1998, 2000a, 2000b; Schmitt and Lupo 2005, 2012). Of note, hares are challenging to identify to the species level and cottontails often make up only a small part of the faunal assemblages from caves, which limits the interpretive value of those taxa (Grayson 2000b). Although species identification and sample sizes often leave these two taxa difficult to interpret, researchers can interpret the changes in abundances from fewer cottontails to more hares as a shift to more open vegetation communities (e.g., from sagebrush to greasewood and shadscale) (Schmitt and Madsen 2005).

By looking at changes in the presence and abundances of these animals, Grayson (2000b) and Schmitt and Lupo (2005, 2012) argued that the Terminal Pleistocene and Early Holocene (TP/EH) (~16,000-8300 cal BP) were relatively cool and moist, with gradual warming beginning in the Early Holocene. The presence of mesic-adapted taxa such as pygmy rabbits, sage and meadow voles, bushy-tailed woodrats, and Great Basin pocket mice in TP/EH deposits from Bonneville basin cave and shelter deposits support this interpretation. Those animals likely enjoyed a dense cover of big sagebrush. By the onset of the Middle Holocene (~8300 cal BP), aridity peaked and several taxa including western harvest mice and bushy-tailed woodrats became locally extirpated in the Bonneville basin. A slight rebound in mesic-adapted taxa occurred at the onset of the Late Holocene (~5000 cal BP) but xeric-adapted taxa continued to dominate the record, as is the case today (Grayson 2000b; Schmitt and Lupo 2005, 2012).

Researchers have carried out similar although less extensive, and ultimately less productive, studies of small mammal records in the Lahontan basin. Hidden Cave and Lovelock Cave are two notable examples (Figure 1.1). Grayson (1985) analyzed the Hidden Cave fauna but was unable to provide a detailed record of environmental change due to: (1) unequal distributions of fauna throughout the strata; (2) the fact that many taxa could not be assigned to particular strata; and (3) at the time there were no other studies in the area with which to compare the Hidden Cave record. Given these limitations, he also examined changing relative abundances of hares, yellow-bellied marmots, and bushy-tailed woodrats. Hares steadily increased from the Terminal Pleistocene to the Late Holocene; however, given that the climate changed from cool and wet to warm and dry and back during the Holocene, he was unable to explain the steady increase. Marmots, which reflect mesic conditions, posed a similar problem because their abundances were consistent in Hidden Cave’s Terminal Pleistocene and Holocene deposits. As such, they offered few clues about environmental change. Furthermore, the presence of marmots suggested more mesic conditions throughout the Holocene, which directly contradicted Hidden Cave’s pollen record (Wigand and Mehringer 1985). Finally, while bushy-tailed woodrats also reflect mesic conditions, their changing abundances did not correspond closely to the pollen record. Because of the contradictory nature of Hidden Cave’s faunal and pollen records, Grayson (1985) limited his conclusions. He tentatively suggested that the Carson Desert fostered more mesic fauna in the past and that a transition to more xeric conditions happened within the past 1,500 years.

Located in the West Humboldt Range and overlooking the Humboldt Sink, Lovelock Cave also contained a small mammal record that Livingston (1988) analyzed (see Figure 1.1). Unfortunately, due to the coarse excavation methods of the early 20th century, which resulted in poor provenience information for most faunal remains (Loud and Harrington 1929), Livingston (1988) was even more limited in what she could infer. While she identified 1,251 mammal specimens and 3,512 bird specimens and provided descriptive summaries, she could not use them to reconstruct climate change. A lack of chronological controls led her to treat the Lovelock Cave sample, which almost certainly accumulated over many millennia, as a single analytical unit to which she compared assemblages from other Great Basin sites. Livingston (1988) argued that the numerous avian taxa showed that the Lovelock Cave assemblage was more like assemblages from open marsh sites than those from other caves. She suggested that during wet periods groups using Lovelock Cave harvested birds from marshes in the nearby Humboldt Sink.

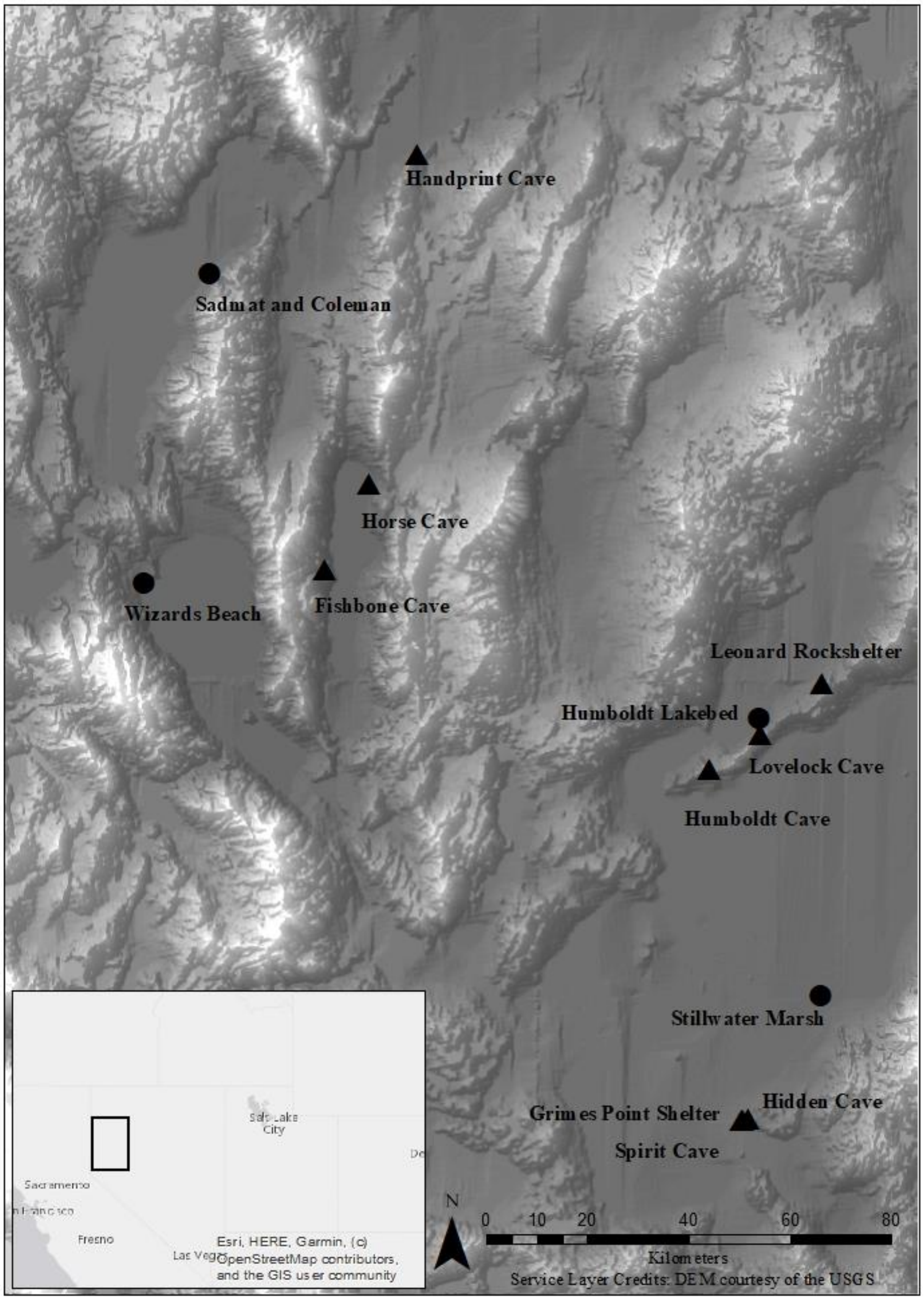

Figure 2.1 The Lahontan Basin with locations of key sites. Circles mark open sites and triangles mark cave and rockshelter sites.

The Natural and Cultural History of the Lahontan Basin

Sites like Hidden Cave and Lovelock Cave have provided some information about past conditions in the western Great Basin. They have also provided clues about how, when, and why humans used such places. We know that groups sometimes used caves and rockshelters as burial locations, places to cache gear, and short-term residential or logistical destinations (Kelly 1997; Thomas 1985). The Lahontan basin's caves and rockshelters have figured prominently in important debates about prehistoric lifeways. For example, they provided much of the evidence cited in support of Heizer and Napton's (1970) limno-sedentary and Thomas' (1985) limno-mobile models, which I outline below.

While caves and rockshelters sometimes offer stratified occupations that contain perishable artifacts and preserved food remains, they nevertheless provide an incomplete picture of past lifeways. Comparisons of open-air and cave/rockshelter assemblages have shown that the range of activities carried out in both settings likely differed and as such we should consider both records together (Wriston 2016). Finally, the paleoenvironmental records offered by caves and shelters allow us to understand the role of past climates in conditioning human adaptive strategies. In the remainder of this chapter, I draw from all three sources of information – paleoenvironmental records, cave and rockshelter occupations, and open-air sites – to review what we know about the Lahontan basin's natural and cultural history.

The Terminal Pleistocene/Early Holocene (16,000-8300 cal BP)

Most TP/EH paleoenvironmental records from the Lahontan basin come from lake level and pollen studies (Adams 1997, 2003; Adams and Rhodes 2019a, 2019b, Adams and Wesnousky 1999; Adams et al. 2008; Wigand and Mehringer 1985). Lakes were higher during the TP/EH than at any later time (Adams et al. 2008). After the last Sehoo highstand of ~1340 m ASL ~15,300 cal BP and a subsequent drop of 100+ m, Lake Lahontan again rose to 1230-1235 m ASL during the Younger Dryas (12,900-11,600 cal BP). At that level, lakes in the Smoke Creek, Black Rock, Winnemucca, and Pyramid basins coalesced (Adams et al. 2008).

We do not know much about lake levels in the Humboldt Sink during this time, but immediately to the southwest in the Carson Sink a lake reached 1205 m ASL ~13,200-12,260 cal BP (Adams et al. 2008; Benson et al. 1992; Currey 1990). At the Jessup Embayment in the northwestern Carson Sink and southwest of the Humboldt Sink, Adams and Wesnousky (1999) found evidence for a lake rise to 1235 m ASL after ~13,200-12,260 cal BP but that event remains undated. By the end of the Younger Dryas, Lake Lahontan had receded but again rose to 1204 m ASL by ~10,100 cal BP (Adams et al. 2008). In the southeastern Carson Sink along the Rainbow Mountain fault, Caskey et al. (2004) dated a beach ridge at 1228 m ASL to ~11,330-9000 cal BP (Adams et al. 2008). By the onset of the Middle Holocene, Lake Lahontan had receded to 1200 m ASL (Adams et al. 2008).

Miller et al.’s (2004) study of the middle Humboldt River, which drains into the Humboldt Sink, demonstrated that the Terminal Pleistocene culminated with an episode of fluvial aggradation by a sizeable meandering river which continued until ~10,800 cal BP. Miller et al. (2004) do not know when this aggradation began but prior to ~10,800 cal BP there was a large amount of deposition and meander belt migration with enhanced streamflow and sediment discharge. After ~10,800 cal BP, there was less floodplain aggradation with more valley-bottom stability and marsh deposition. Deposits along the river contained thin layers of black mud, which Miller et al. (2004) interpreted as reflecting reduced streamflow but generally wet conditions. This reduced but stable deposition continued until ~7600 cal BP.

Hidden Cave, located in the Carson Sink, showed high levels of pine (*Pinus*) and sagebrush (*Artemisia*) during the Terminal Pleistocene, suggesting a mesic climate, but sharply declining levels at the beginning of the Holocene, which corresponds to the diminution of Lake Lahontan (Wigand and Mehringer 1985). Textiles dated to ~10,800 cal BP at Grimes Point Burial Shelter in the Carson Sink demonstrate that lake levels were below 1200 m ASL before transgressing to 1200 m ASL by the onset of the Middle Holocene (Adams et al. 2008).

A few sites elsewhere in the Lahontan basin have produced Terminal Pleistocene dates, including Fishbone Cave, Handprint Cave, surface artifacts from Pyramid Lake, and LRS. These sites suggest that humans occupied the area fairly early. Fishbone Cave produced what some researchers have considered the earliest evidence of humans in the Lahontan basin. The cave contained two horse mandibles dated to 11,350±40 ^{14}C BP (13,300-13,130 cal BP) and 11,210±50 ^{14}C BP (13,215-12,980 cal BP) (Adams et al. 2008). Dansie and Jerrems (2005) argued that the mandibles exhibited cutmarks and impact fractures from human modification; however, Adams et al. (2008) noted that not all archaeologists agree that the modification is cultural.

Handprint Cave is located in the Black Rock Desert and produced one date of 10,740±70 ^{14}C BP (12,725-12,565 cal BP) on charcoal recovered beneath a stemmed point (Bryans 1988). It is unclear if the charcoal was in a primary context and in any case the dated sample can only provide a lower limiting age for the point (Adams et al. 2008). Furthermore, it now seems clear that the point is a younger Humboldt point and not an older Western Stemmed Tradition (WST) point (Goebel and Keene 2014). Two osseous points from an eroded surface near Pyramid Lake produced dates of 10,360±50 ^{14}C BP (12,410-12,010 cal BP) and 10,340±40 ^{14}C BP (12,390-12,005 cal BP) (Dansie and Jerrems 2005). The points may be made of mammoth ivory but their ages date the death of the animal, not the time of deposition (Adams et al. 2008; Dansie and Jerrems 2005). At LRS, Robert Heizer (1951) reported a date of 11,199±570 ^{14}C BP (14,900-11,610 cal BP) on guano associated with obsidian flakes. I discuss that date in greater detail in Chapter 2.

Sites that have produced Early Holocene dates are more common and include Spirit Cave, Grimes Burial Cave, Horse Cave, LRS, and, perhaps, Hidden Cave (see Figure 1.1) (Adams et al. 2008; Fowler et al. 2000; Heizer 1951; Rozaire 1974; Thomas 1985, Tuohy and Dansie 1997). Spirit Cave contained five human burials, two cremations, and 67 artifacts. The cave is best known for the burial of a 40-50-year-old male dated to 10,500 cal BP known as the Spirit Cave Mummy (Hockett and Palus 2018; Tuohy and Danise 1997). Textiles associated with the Spirit Cave Mummy were finely decorated. They may have been made on a loom, suggesting that people occupied a place long enough to gather raw materials and produce elaborate and decorated textiles (Fowler et al. 2000; Smith and Barker 2017). Fecal boluses from the mummy suggest that his last meal included small fish and bulrush seeds (Wigand 1997), which supports the idea that early groups spent at least some time near wetlands (Adams et al. 2008).

Directly dated textiles from Grimes Burial Cave, Horse Cave, and arguably Hidden Cave provide further evidence for Early Holocene occupations in the Lahontan basin (see Figure 1.1). Grimes Burial Cave contained a plain weave mat dated to ~10,880 cal BP, and textiles from Horse Cave dated to ~9400 cal BP (Rozaire 1974). A piece of warp-faced plain weave basketry from Hidden Cave returned a date of ~10,440 cal BP (Camp 2018; Connolly et al. 2016; Tuohy and Dansie 1997) but as Thomas (1985) has noted there is little other evidence for an Early Holocene occupation at the site.

Sites in the Lahontan basin dating to the TP/EH via radiocarbon dating or lithic cross-dating are concentrated along shorelines between 1200 and 1235 m ASL (Mohr 2018). The open-air Sadmat and Coleman sites both served as retooling stations (Graf 2001). Artifacts and human remains from Wizards Beach dated to the Early Holocene indicate that groups used sagebrush cordage and bone tools for fishing but there is no evidence that they were associated with a habitation site (Adams et al. 2008; Dansie and Jerrems 2005; Tuohy 1988). Like most early sites, these locations probably served as short-term stopovers where mobile groups exploited marsh resources rather than long-term residential camps.

The Middle Holocene (8300-5100 cal BP)

The Middle Holocene was characterized by prolonged periods of droughts and warm temperatures (Grayson 2011). Lakes in the Carson and Humboldt sinks disappeared and saltbush became the most prominent vegetation in the area (Byrne et al. 1979; Davis 1982; Wigand and Mehringer 1985). There were periods of intense aeolian activity in the Carson and Humboldt sinks, with as much as 2 km^3 of sediment deflated from the Carson Sink (Rhode et al. 2000). It is unknown how much deflation took place in the Humboldt Sink during this time but Byrne et al. (1979) discuss windblown silt in LRS as being evidence for deflation on the exposed basin floor. Lake levels from other Lahontan sub-basins such as Pyramid Lake and Winnemucca Dry Lake demonstrated a drop from ~1200 m ASL ~8000 cal BP to ~1155 m ASL during the Middle Holocene (Adams and Rhodes 2019b).

The Humboldt River experienced reduced streamflow during the Middle Holocene. Miller et al. (2004) found unconformities along the middle Humboldt River between ~7600 and 5500 cal BP. These unconformities indicated significantly reduced deposition of the river and increased deposition of windblown silt. The driest period along the Humboldt River began ~7600 cal BP, with a minimal amount of floodplain aggradation ending ~6300 cal BP.

Pollen records paint a picture similar to those provided by lake levels and river history. Pollen records from Hidden Cave (Wigand and Mehringer 1985) and LRS (Byrne et al. 1979) showed a rise in xeric adapted Cheno/Am ~7400 cal BP and ~6800-

4500 cal BP, respectively. Pollen from Pyramid Lake suggested that ~7600-6300 cal BP was one of the driest periods in the Lahontan Basin (Mensing et al. 2004).

These records show that the Middle Holocene was characterized by xeric conditions that were poorly suited for prolonged human occupation; however, a few sites show limited use during that period. Burnt organic debris from Hidden Cave dated to 5365±90 ^{14}C BP (~6205-5935 cal BP), foreshafts from LRS dated to 7038±350 ^{14}C BP (8610-7250 cal BP), and an infant burial associated with carbonized basketry from LRS dated to 5650±250 ^{14}C BP (7630-5915 cal BP) (Heizer 1951; Thomas 1985). These findings show that humans visited the area at least periodically. In general, though, the low number of dated Middle Holocene sites suggests that groups occupied the Lahontan basin to a lesser extent than during both earlier and later times (Louderback et al. 2010).

The Late Holocene (5100-150 cal BP)

The Late Holocene is best characterized as a time of frequent climatic oscillation with increased moisture coupled with recurrent droughts (Grayson 2011; Rhode et al. 2000). At Pyramid Lake, lake level data support the conclusion of increased moisture with recurrent droughts. The lake rose from ~1155 m ASL to ~1190-1195 m ASL during the Neopluvial Period (~4800-3400 cal BP) (Adams and Rhodes 2019b). The lake dropped again after the Neopluvial Period, between ~2800-1900 cal BP, with another transgression to 1190 m ~1200 cal BP. After ~1200 cal BP and up until 100 years ago, lake levels ranged from 1170 to 1182 m ASL. A pollen core from Pyramid Lake painted a similar picture and demonstrated distinct wet and dry phases between 5000 and 3500 cal BP (Mensing et al. 2004). The core did not contain data for the period between 3500 and 2500 cal BP but demonstrated that the past 2,500 years were times of reoccurring droughts with 18 wet/dry oscillations.

On the western edge of the Great Basin, montane forests around Lake Tahoe were inundated by the rising lake ~5500 cal BP, demonstrating increased precipitation by the end of the Middle Holocene. Walker Lake, the southernmost sub-basin of the Lahontan Basin, was a dry playa during the Middle Holocene but had refilled by ~4700 cal BP (Bradbury et al. 1989; Wigand and Rhode 2002). This refilling event could have been from increased precipitation but it may have also been the result of a shift in the river’s course from the Carson Desert to the Walker Lake Basin (Adams and Rhodes, 2019a).

At Hidden Cave, there is further evidence for higher lakes during the Neopluvial Period. The cave is located on a ridge of the Lahontan Mountains overlooking the Carson Sink and sits at ~1250 m ASL (Thomas 1985). Human coprolites demonstrated two main occupations: one during the Neopluvial highstand from ~4200 to 3650 cal BP and one from ~1800 to 1400 cal BP. Rhode (2003) identified cattail and bulrush in the coprolites, which demonstrate an emphasis on wetland resources. His argument is supported by the chronology of open-air sites in Stillwater Marsh, which sits at ~1180 m ASL (Kelly 2001; Thomas 1985). Times when Hidden Cave was most intensively used were times when Stillwater Marsh was not, suggesting that the marsh was inundated ~4200-3650 cal BP and ~1800-1400 cal BP. The lake levels during the Neopluvial Period in the Carson Sink demonstrated a rise ~1196 m ASL around ~3900-3700 cal BP (Adams and Rhodes 2019a). We also know that lake levels reached 1204 m ASL ~915-650 cal BP and 1198 m ASL ~1520-1310 cal BP (Adams 2003). During these Late Holocene highstands, Stillwater Marsh occupations were interrupted.

The middle Humboldt River also reflects increased moisture and recurrent droughts. The river experienced increased fluvial activity beginning ~5500 cal BP, with intermittent deposition occurring until ~3500 cal BP. After ~3500 cal BP, there was a period of lateral plantation, incision, and rapid floodplain aggradation from ~3200 to 2100 cal BP (Miller et al. 2004). After ~2100 cal BP and lasting until ~1100 cal BP, there was channel incision and lateral erosion of older floodplain deposits, with erosion likely driven by channel relocation. Floodplain aggradation occurred again between ~1100 and 650 cal BP, which could correspond with the transition to the Little Ice Age. Some floodplain abandonment and incision occurred after ~650 cal BP but floodplain aggradation began again ~550 cal BP and has continued to present day (Miller et al. 2004).

The increased moisture at the beginning of the Late Holocene led to higher human population levels (Louderback et al. 2010) and a possible shift in settlement strategies within the Lahontan basin. Investigations of Late Holocene cave and rockshelter occupations led researchers such as Heizer (Heizer and Napton 1970) and Thomas (1985) to argue for two different settlement strategies: limno-sedentary and limno-mobile. Heizer and colleagues put forth the limno-sedentary model after they studied coprolites from Hidden Cave and refined it based on further excavations at Lovelock Cave (Ambro 1967; Heizer and Napton 1970; Roust 1967). They argued that groups tethered their settlements to wetlands and the range of resources that such places provided (Heizer and Napton 1970; Rhode 2003). Heizer used accounts of ethnographic Töedokadö, Klamath, and Modoc lifeways to support the limno-sedentary model because those groups relied on wetlands (Rhode 2003).

Thomas (1985) excavated Hidden Cave and believed that it provided evidence for a limno-mobile strategy. This model involved shorter-term use of wetlands and nearby caves as part of a larger and more diverse seasonal round that incorporated a range of settings. It is important to note that researchers developed both hypotheses before surveys and excavations around Stillwater Marsh and further analyses of the Humboldt Lakebed sites (Kelly 2001; Livingston 1986, 1988). Today, archaeologists generally agree that the evidence from caves, rockshelters, and open-air sites in the Humboldt and Carson sinks are not wholly consistent with either fully sedentary or mobile lifeways (Hemphill and Larsen 1999; Kelly 1997).

While Thomas (1985) and Heizer (Heizer and Napton 1970) failed to provide evidence that fully supports either the limno-sedentary or the limno-mobile models, both caves/rockshelters and open-air sites have yielded a wealth of information about Late Holocene lifeways. Caves and rockshelters generally lack hearths and large quantities of debitage, suggesting that groups did not live in those places for extended periods (Kelly 1999). Instead, sites such as Lovelock Cave, LRS, Humboldt Cave, and Hidden Cave seem to have served as places to cache fishing and hunting gear for future use. Lovelock Cave is associated with the Lovelock Culture (~4500-600 cal BP), which is recognized by a suite of items made from tule and other marsh plants, and tools used to harvest lacustrine resources. Lovelock Culture artifacts include Lovelock Wickerware, large mortars, biconical pestles, L-shaped scapula awls, tule duck decoys, and zoomorphic figurines (Benson et al. 2006). Duck decoys, a well-known component of the Lovelock

Culture, signal a reliance on wetland resources and archaeologists have found them at both Lovelock and Humboldt caves (Heizer and Krieger 1956; Loud and Harrington 1929). Groups also used the caves for burials (except for Humboldt Cave) and diurnal waystations (Heizer 1951; Heizer and Krieger 1956; Heizer and Napton 1970; Livingston 1988; Loud and Harrington 1929; Thomas 1985).

We can better understand Late Holocene settlement strategies by comparing the records of caves/rockshelters and open-air sites; for example, by considering how groups used Lovelock Cave and the nearby open-air Humboldt Lakebed Site. The Humboldt Lakebed Site showed a pattern of groups seasonally exploiting wetlands (Kelly 1997). The site, which is only ~4 km from Lovelock Cave, contained houses and storage pits, both evidence of a fairly permanent settlement. The earliest radiocarbon date from the site is ~3200 cal BP (Livingston 1988). Increased use of the site began ~1300 cal BP. The numbers of shallower and larger houses suggest intensified use began 3,800 years later than intensified use of nearby Lovelock Cave began (~5100 cal BP). Groups used Lovelock Cave for caching before they intensively occupied the Humboldt Lakebed Site. This lag may reflect more sporadic use of wetlands before ~1300 cal BP. Because looting and erosion destroyed many of the later deposits, much information about the Humboldt Lakebed Site has been lost; however, it saw at least intermittent use until ~550 cal BP (Livingston 1988). Heizer and Napton (1970) interpreted Lovelock Cave as a satellite to the Humboldt Lakebed Site: the lakebed site was likely the primary residential locus whereas the cave served as a storage facility, cold-weather retreat, burial locale, and possibly a place for ceremonial activities.

Livingston (1988) proposed several alternatives to Heizer and Napton's (1970) conclusion regarding the link between Lovelock Cave and the Humboldt Lakebed Site. First, she suggested that the productivity of the pinyon nut harvest dictated groups' winter settlement patterns. When pinyon nuts were abundant, winter villages were situated in the mountains, and when pinyon nuts were less abundant, winter villages were situated near lake margins. This pattern is similar to that documented for the Northern Paiute and suggests that groups occupied the Humboldt Lakebed during years of low pinyon productivity. Second, Livingston (1988) suggested that groups may have determined winter village locations based on the abundance of marsh resources rather than pinyon or other mountain resources – a pattern that the Modoc practiced (Livingston 1988). Finally, the first people to use Lovelock Cave may not have focused on lacustrine resources; however, as time went on, groups settled into the area, adopted a settlement pattern focused on wetlands, and diversified or intensified their subsistence strategies during times of stress (Livingston 1988). Resource intensification contradicts Thomas' (1985) limno-mobile hypothesis, which states that groups exploited a range of resources as a buffer against the failure of any one resource patch. It is hard to know for certain which of these scenarios' best captures Late Holocene human behavior in the Lahontan Basin; however, it seems likely that given the proximity of the two locations groups using Lovelock Cave also used the Humboldt Lakebed Site (Livingston 1988).

While LRS is reasonably close to both Lovelock Cave and the Humboldt Lakebed Site, its modest artifact assemblage lacks Lovelock Wickerware, duck decoys, and other Lovelock Culture artifacts (Anna Camp, personal communication, 2019). Radiocarbon dates on fiber, wooden artifacts, textiles, and the presence of a Cottonwood Triangular point suggest that groups used LRS throughout the Holocene, a topic that I return to in later chapters.

Humboldt Cave is located a few kilometers southwest of Lovelock Cave. The cave's deposits were mostly disturbed and there is only one radiocarbon date (~2000 cal BP) from the site. Nevertheless, Heizer and Krieger (1956) reported 31 caches of wetland-oriented personal gear such as a fisherman's cache and Lovelock Wickerware, which suggests that Humboldt Cave likely played a similar role as Lovelock Cave. Heizer and Krieger (1956) also recovered large fishhooks, which Thomas (1985) argued were too large for the small fish endemic to the Humboldt and Carson sinks. He suggested that whomever used the hooks likely traveled 50+ km to either Pyramid or Winnemucca lakes where larger fish were available. If viewed in that way then Humboldt Cave might reflect a settlement pattern where groups returned seasonally to the Humboldt Sink after fish spawning runs in deep water lakes (Thomas 1985). Given that there is only one radiocarbon date from Humboldt Cave, and without an understanding of the cave's stratigraphy, it is hard to know exactly how or when groups used the cave.

Excavations at Hidden Cave produced 22 caches, eight hearths, and a few lithic artifacts. The limited evidence for long-term occupations led Thomas (1985:391) to conclude that Hidden Cave was a "prehistoric warehouse," or a place where people stored their personal gear to be retrieved later, a conclusion that agreed with his limno-mobile hypothesis. As mentioned above, Rhode (2003) analyzed coprolites from Hidden Cave and demonstrated two main occupations: (1) 4200-3650 cal BP; and (2) 1800-1400 cal BP. He concluded that groups mostly used Hidden Cave when Stillwater Marsh was flooded and unavailable for residential occupations. Artifacts from the cave support

Rhode's conclusions and suggest intermittent use of wetlands before ~1500 cal BP and more residential use of Stillwater Marsh during drier times (Kelly 1997; Mensing et al. 2008).

Stillwater Marsh was historically home to the Töedokadö band of Northern Paiute (Kelly 2001). The marsh contained a record of human occupation ranging from ~3000 to 650 cal BP, with most radiocarbon dates falling between ~1500 and 750 cal BP. Sites there seemed to be residential and although men may have hunted large game in the surrounding mountains, women's foraging opportunities around the marsh seemed to have dictated site location. This scenario is supported by the fact that the Stillwater Range rarely witnessed residential occupations (Kelly 1999; Zeanah 2004), perhaps because pinyon pine did not reach the region until after 1500 cal BP. Analyses of skeletal remains from Stillwater Marsh established that pinyon nuts were never a prominent part of the diet (Larsen and Hutchison 1999; Wigand 1990).

There were no prepared hearths or house pits at residential sites in Stillwater Marsh, which supports the idea that groups did not live there year-round (Kelly 1999). Instead, people may have been more sedentary in times of droughts when resources were scarce and less sedentary during wetter periods when resources were abundant (Kelly 2001). Kelly's (2001) model supports Livingston's (1988) hypothesis that during hard times groups diversified and intensified their subsistence pursuits instead of moving to new resource patches.

Human use of Hidden Cave ended ~800 cal BP and by 500 cal BP groups seem to have stopped living in and around Stillwater Marsh (Kelly 2001; Thomas 1985); however, Desert Side-notched points do occur on the valley floor around the marsh suggesting that groups did not completely abandon the Carson Sink. Reduced use of the marsh and Hidden Cave may be tied to the Numic Spread and a corresponding shift in land-use patterns, *in-situ* groups merely focusing on other resource patches during prolonged droughts, post-depositional processes such as site burial or erosion, or a combination of these processes (Adams and Rhodes 2019a; Kelly 1999; Mensing et al. 2008).

In sum, Late Holocene sites in the Lahontan basin show that groups exploited marsh resources when they were available and occupied wetlands for at least part of the year. Cached duck decoys, fishhooks, and items used to harvest wetland resources show a commitment to marshes; however, the very act of caching also suggests that there was periodic or seasonal abandonment of such places (Kelly 2001). Furthermore, groups did not always use caves and rockshelters for caching. They also used them as places to bury the dead and/or short-term logistical destinations. Given that wetland resource abundance can change drastically over a short amount of time (Kelly 2001) and archaeological and paleoenvironment data are generally unable to provide fine-grained chronological information (e.g., decadal or better), it is important to recognize that current interpretations of wetland use and how it changed over time are fairly general.

CHAPTER 2

Materials and Methods

Materials

Previous work at Leonard Rockshelter

Leonard Rockshelter (LRS) is located in the Humboldt Sink ~27 km south of Lovelock, NV (Figure 2.1). The rockshelter sits at 1224.5 m ASL, not 1272.5 m ASL as Heizer (1951) and Byrne et al. (1979) initially reported. Later in this chapter, I discuss the significance of this discrepancy. The rockshelter lies below a north-facing vertical extrusive rock dike. It is one of many wave-cut caves and shelters in the area, including Lovelock and Humboldt caves. The rockshelter is covered in calciferous tufa deposited during Lake Lahontan's final highstand ~15,300 cal BP (Adams et al. 2008). Initially visited by Euro-Americans in 1936 for its rich bat guano deposits, miners quickly discovered a modest but diverse collection of artifacts including a complete atlatl dart and string of *Olivella* shell beads, which prompted a visit by archaeologist Robert Heizer. Heizer and a small crew from the University of California, Berkeley (UCB) recovered an obsidian blade fragment and three additional foreshafts from the guano deposits during the visit (Heizer 1938, 1951).

In 1949 Heizer returned to LRS to collect several pounds of bat guano at the approximate level from which the miners recovered the complete atlatl for radiocarbon dating. The bat guano produced two dates: 8443±510 ^{14}C BP (11,065-8315 cal BP) and 8820±400 ^{14}C BP (11,130-9005 cal BP) (Table 2.1).[1] Heizer believed the bat guano dates to be too old and submitted three atlatl foreshafts from the same deposits for dating. The combined foreshafts produced a single date of 7038±350 ^{14}C BP (8610-7250 cal BP) (see Table 2.1). Given these fairly old dates, Heizer (1951:89) believed that the site "fell into the category of early man" and excavated much of the rockshelter's deposits in the summer of 1950.

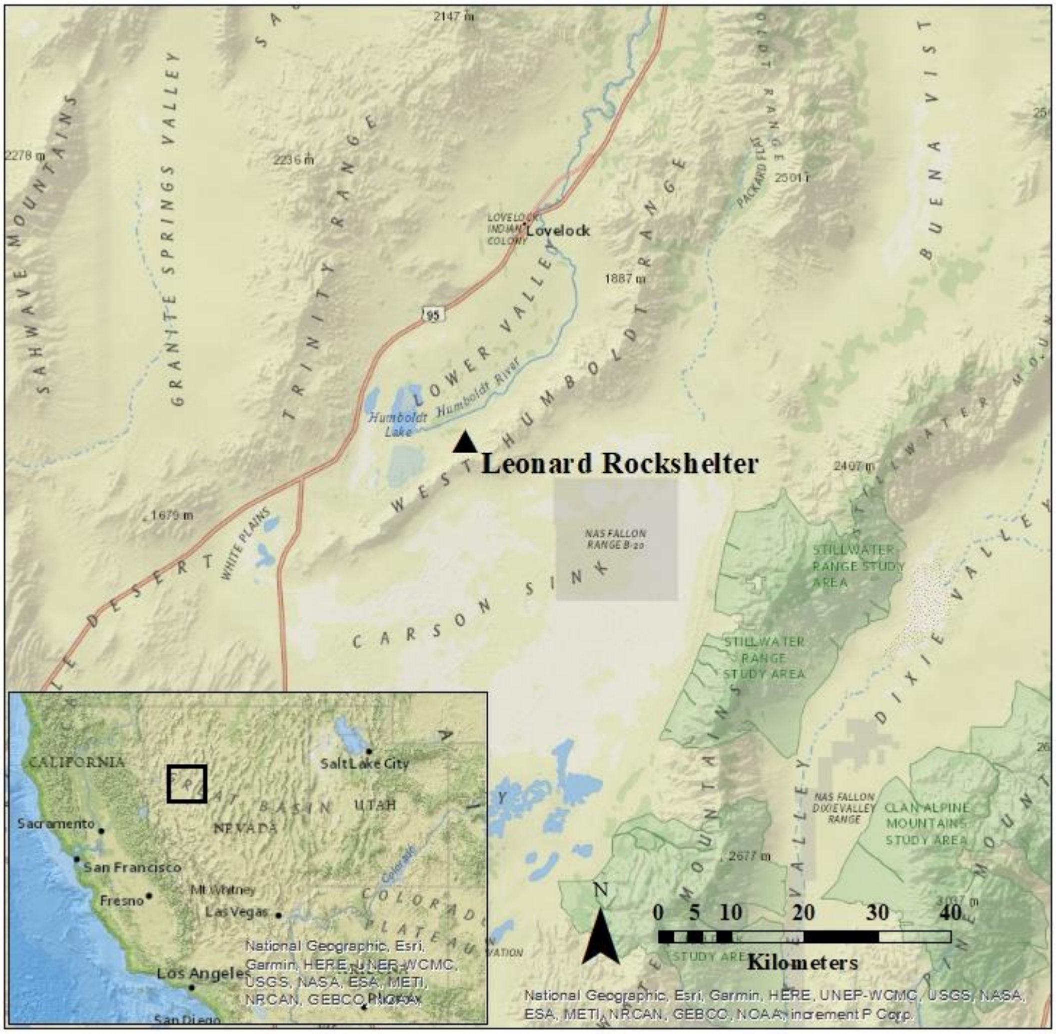

Figure 2.1 Location of Leonard Rockshelter.

Table 2.1 Radiocarbon Dates on Materials Recovered During Heizer's 1950 Excavations.

Sample ID	^{14}C Date	Material	2σ cal BP	Area	Unit	Provenience	Reference
L-281	8443±510	Unburned guano	11,065-8315	B	D	Unburned guano layer containing wood artifacts	Arnold and Libby (1950)
L-281b	8820±400	Unburned guano	11,130-9005	B	D	Unburned guano layer containing wood artifacts	Arnold and Libby (1950)
Average of L-281 and L-281b	8860±300	Unburned guano	10,515-9005	B	D	Unburned guano layer containing wood artifacts	Arnold and Libby (1950)
GBPRU's average of L-281 and L-281b	8830±315	Unburned guano	10,765-9120	B	D	Unburned guano layer containing wood artifacts	
L-298	7038±350	3 greasewood foreshafts	8610-7250	B	D	Top of guano layer	Arnold and Libby (1950)
L-554 Rejected sample	2736±500	1 lb. of crushed carbonized basketry	4235-1705	C	B	Base of Unit B	Arnold and Libby (1950); Heizer (1951)
L-554	5779±400	1 lb. of crushed carbonized basketry	7880-5750	C	B	Base of Unit B	Arnold and Libby (1950); Heizer (1951)
L-554	5694±325	1 lb. of crushed carbonized basketry	7280-5760	C	B	Base of Unit B	Arnold and Libby (1950); Heizer (1951)
GBPRU's average of L-554	5650±250	1 lb. of crushed carbonized basketry	7630-5915	C	B	Base of Unit B	
None provided	11,199±570	Bat guano	14,900-11,610	D	D/E	Immediately lying upon lake gravels (Unit E)	Heizer (1951)

Heizer's Excavations

Heizer excavated four areas (A-D) and reported 2+ m of stratified deposits (Figure 2.2). He placed Area A at the east end of the shelter, east of a steep mound. Area B, located west of the mound, had five trenches numbered A-E, with Trench B having three units numbered 1-3 (Figure 2.3). Areas C and D (Figures 2.4 and 2.5) were located ~5 and 12 m west of Area B, respectively. Areas C and D were situated against the wall of the shelter but did not have numbered trenches as far as I can tell. The excavators dug beneath the tufa face toward the rear of the shelter ~0.6-1.22 m in areas C and D (Heizer 1951).

Heizer (1951) recovered a modest but diverse collection of artifacts including textiles, cordage, two projectile points, a tan flint blade, two flakes, two *Olivella* shell beads, a greasewood arrow foreshaft, and fragments of cane arrow shafts. He did not recover any milling stones but did find desiccated fish and pinenut shells. The crew recovered the tan flint blade, two shell beads, and pieces of nets and cordage from the same guano layer (Stratum D, see below) from which Heizer and the guano miners recovered the string of 50 *Olivella* beads, complete atlatl dart, and three foreshafts a decade earlier. The foreshafts and bat guano from Area B dated to 7038±350 (8610-7250 cal BP) and 8830±315 (10,765-9120 cal BP) respectively. The crew also recovered two flakes from the bottom of the bat guano layer, one in Area C and one in Area D, from which Heizer obtained a date of 11,199±570 ^{14}C BP (14,900-11,610 cal BP) on bat guano.[2]

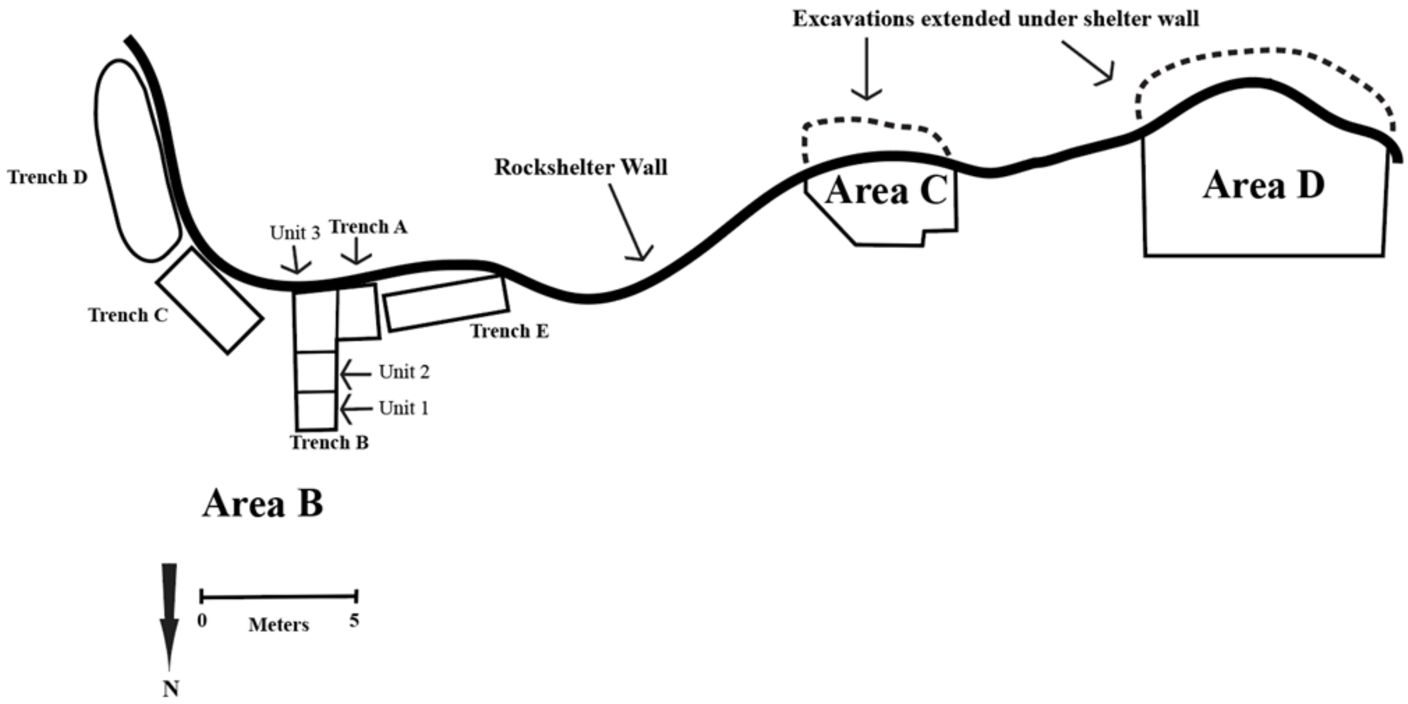

Figure 3.2. Modified planview map of Leonard Rockshelter showing Heizer’s 1950 excavation areas. Adapted from Byrne et al. (1979).

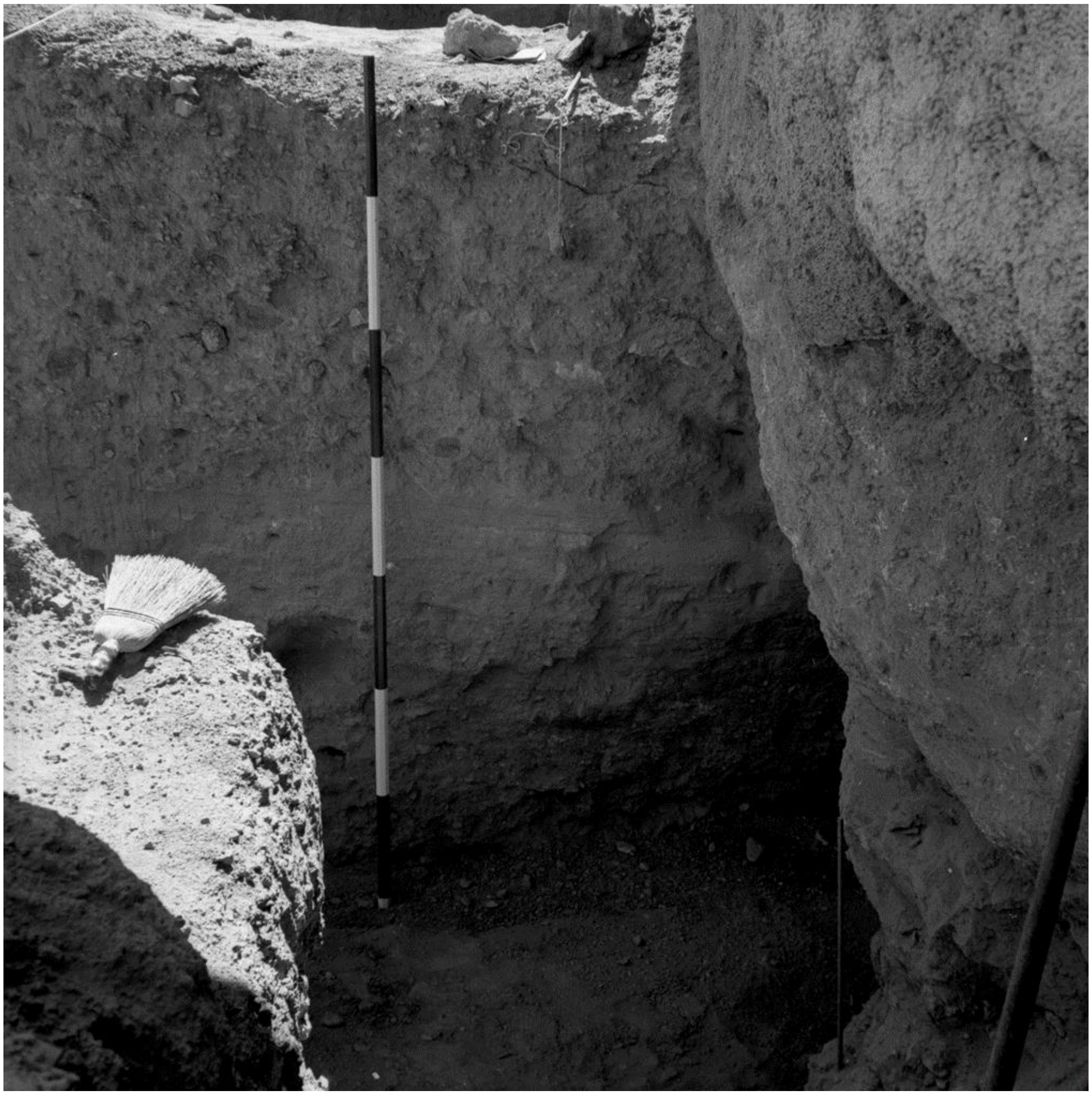

Figure 3.3. Heizer's Area B, Trench B, Unit 3 facing east. This photo likely shows the same profile depicted in Byrne et al.'s (1979) Figure 2.2. UCB Photo No. 2261 courtesy of Phoebe Hearst Museum.

Figure 3.4. Heizer's excavation areas C (foreground) and D (background), view west. UCB Photo No. 2276 courtesy of Phoebe Hearst Museum.

Figure 3.5. Excavations in Heizer's Area C, view southwest. UCB Photo No. 2280 courtesy of Phoebe Hearst Museum.

In Area C, the crew uncovered an infant burial directly below carbonized basketry. Heizer (1951) submitted 1 lb. of the basketry for radiocarbon dating and obtained a date of 2736±500 ^{14}C BP (4235-1710 cal BP) (see Table 2.1). Heizer rejected that date, believing that it was too young. Arnold and Libby (1950) accounted for the erroneous date as an error in the identification of the sample or insufficient washing of the sample. Heizer submitted an additional 2 lbs. of the carbonized basketry, which returned dates of 5779±400 ^{14}C BP (7880-5750 cal BP) and 5694±325 ^{14}C BP (7230-5760 cal BP) (see Table 2.1). Based on the two new dates on the carbonized basketry, Heizer argued that the burial was placed in the rockshelter 400 years before or after 5785 ^{14}C BP (~6500 cal BP).

Heizer recognized five stratigraphic units, labeling them units A-E (Table 2.2). Unit A consisted of windblown sand and silt, tufa rockfall, bat guano, and packrat nest material (Byrne et al. 1979). There were no radiocarbon dates from Unit A, but according to Heizer and Napton (1970) artifacts found within it were similar enough to those from dated contexts in Lovelock Cave to suggest that Unit A at LRS spanned from ~4500 ^{14}C BP (~5000 cal BP) to contact (Byrne et al. 1979). Unit B was comprised of stratified gray sand and silt, likely blown in from the Humboldt Sink (Byrne et al. 1979). A date on the carbonized basketry found immediately above the burial within Unit B led Byrne et al. (1979) to argue that Unit B spanned from ~6500 to 4500 ^{14}C BP (~7400-5100 cal BP). Unit C was comprised of fine sand intermixed with angular rock fragments and contained no artifacts or radiocarbon dated items (Byrne et al. 1979). Unit D consisted of bat guano and tufa rockfall. The bat guano returned dates of 11,199±570 ^{14}C BP (14,900-11,610 cal BP), 8443±510 ^{14}C BP (11,065-8315 cal BP), and 8820±400 ^{14}C BP (11,130-9005 cal

BP). The date of 7038±350 ^{14}C BP (8610-7250 cal BP) on the three greasewood foreshafts recovered in 1949 was from the guano layer as well. The basal layer, Unit E, consisted of Lake Lahontan gravels and did not contain artifacts or produce any radiocarbon dates.

Table 3.2. Stratigraphic Units Reported by Heizer (1951).

Stratigraphic Units	**Description**	**Reference**
A	Mixture of windblown sand and silt, tufa rockfall, bat guano, and packrat nest material	Byrne (1979)
B	Stratified whitish gray sand and silt. Sediments are the same as sediments from Humboldt Lake. They contain diatoms and ostracods, indicative of a lacustrine origin	Byrne (1979)
C	Above basal guano layer, fine sand intermixed with angular rock fragments. Rock fragments account for 20-30% of total deposit	Byrne (1979)
D	Bat guano layer lying on top of beach gravels	Byrne (1979)
E	Lake Lahontan beach gravels	Byrne (1979)

Given that Unit A contained artifacts similar to those recovered from Lovelock Cave, Heizer (1951) attributed that stratum to the Lovelock Culture, although there is no Lovelock Wickerware at LRS (Anna Camp, personal communication, 2019). He stated that people likely used the rockshelter as a temporary retreat from enemies or harsh weather. Heizer (1951) assigned Unit B to the Leonard Culture, stating that the burial and carbonized basketry were the only evidence of a Middle Holocene occupation in the Humboldt Sink. Unit C had no evidence of human occupation or radiocarbon dates, but the dates of 5779±400 ^{14}C BP (7880-5750 cal BP) and 5694±325 ^{14}C BP (7280-5760 cal BP) from Unit B and 7038±350 ^{14}C BP (8610-7250 cal BP) and 11,199±570 ^{14}C BP

(14,900-11,610 cal BP) from Unit D suggested that Unit C could date to the beginning of the Middle Holocene (Heizer 1951). Using the dates of 8830±315 ^{14}C BP (10,765-9120 cal BP) on bat guano and 7038±350 ^{14}C BP (8610-7250 cal BP) on the foreshafts, Heizer (1951) assigned Unit D to the Humboldt Culture/Early Holocene; however, he suspected a Terminal Pleistocene occupation given the date of 11,199±570 ^{14}C BP (14,900-11,610 cal BP) from the bottom of the bat guano layer in association with the obsidian flakes in areas C and D.

Figure 2.6 shows a summed probability distribution (SPD) of Heizer's four dates. The peaks represent long durations of time due to the typical large errors of dates run in the 1950s. The SPD shows that LRS could have been occupied as early as ~15,000 cal BP with several troughs and peaks throughout the Early and Middle Holocene and no occupations after ~5200 cal BP. The SPD probably does not accurately track human use of LRS though because Heizer recovered artifacts from Unit A, which he estimated spanned the Late Holocene. Given the small number of dates and their large associated errors, the SPD is limited in what it can tell us about human use of LRS. Later in this thesis, I present new dates on fiber artifacts to address this issue.

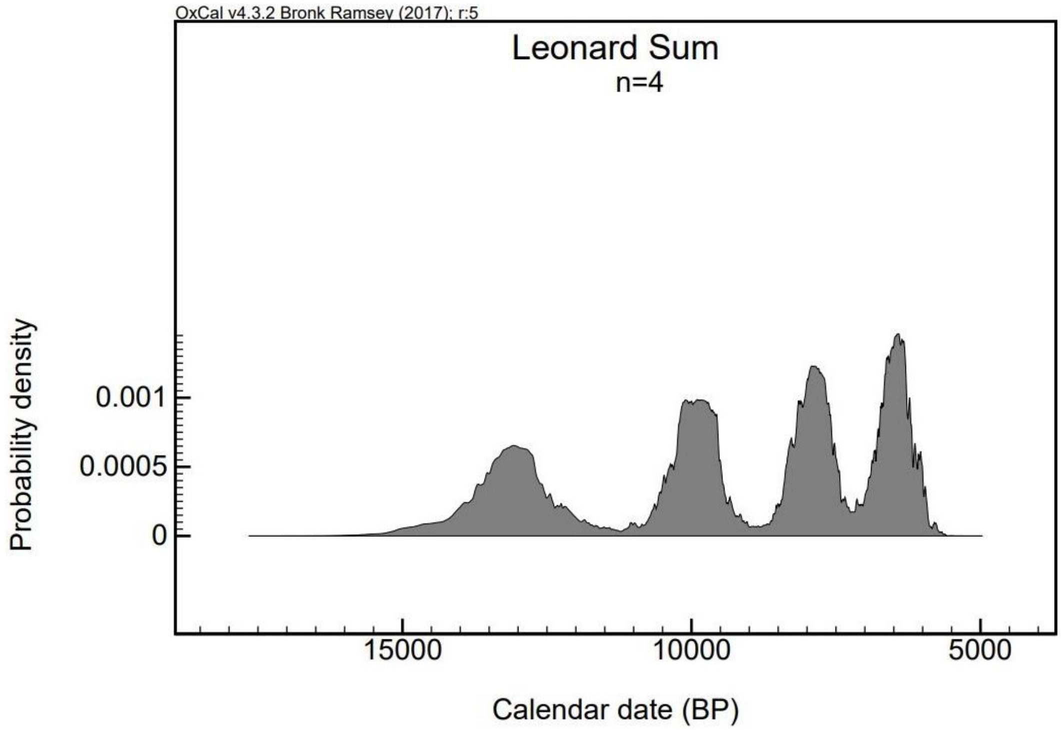

Figure 3.6. Summed probability distribution of Heizer's (1951) radiocarbon dates.

Byrne et al.'s Pollen Study

Byrne et al. (1979) analyzed pollen from sediment samples that Heizer collected in 1950. The samples came from areas B and C but did not have exact provenience information. Byrne et al. (1979) failed to recover pollen from the lower bat guano layer (Unit D) and the sediment samples from Area C only included Unit B. The truncated record from Area C was likely because excavations there extended under the rockshelter's overhang and the sediment sample was taken from that interior location where the full stratigraphic sequence was not present (Byrne et al. 1979).

Given the truncated sequence and lack of precise locations for sediment samples, Byrne et al. (1979) kept their interpretations of climate change broad. The lower levels of the pollen sample from Area B had higher pine levels, indicating a more mesic environment, and likely correspond to stratigraphic Unit C, which Heizer (1951) initially interpreted as dating to the dry Middle Holocene. Above the pine levels were high levels of Cheno/Am, indicating a more xeric environment and a “pine minimum” from 6000 to 4000 ^{14}C BP (~6800 to ~4500 cal BP) (Byrne et al. 1979:288). The pine minimum likely corresponds to stratigraphic Unit B (windblown silt). Lower lake levels in the Humboldt Sink corresponding to the pine minimum likely exposed the lake floor and led to increased Cheno/Am vegetation, pollen from which was blown into the rockshelter. Unit A had relatively high pine levels, suggesting a cooler climate than was reflected in Unit B; however, because no pine trees grow near LRS today and probably did not during much of the Holocene, Byrne et al. (1979) warned that the pine pollen in the sediment samples could only demonstrate regional and not local conditions.

Summary

Heizer and colleagues’ work at LRS has played an important role in understanding prehistoric lifeways of the Western Great Basin. The site produced a sizeable textile assemblage, numerous *Olivella* beads, and a Terminal Pleistocene/Early Holocene radiocarbon date purportedly associated with obsidian flakes. Heizer (1951) briefly discussed the basketry in his preliminary report, stating that close and open-twined basketry were present, but not Catlow Twine. He also stated that there was no Lovelock Wickerware, which is unusual given its proximity to Lovelock Cave (Heizer

1951). Dr. Anna Camp (Nevada State Museum) is currently analyzing the textiles from LRS and confirms that no Catlow Twine or Lovelock Wickerware are present.

The *Olivella* beads from LRS were instrumental in Bennyhoff and Hughes' (1987) interpretations of western Great Basin shell bead exchange. Based on the frequency of radiocarbon dates associated with *Olivella* beads, they argued that the western Great Basin likely served as a major shell redistribution center beginning as early as ~8000 cal BP (Bennyhoff and Hughes 1987). The Terminal Pleistocene/Early Holocene date associated with two flakes provided tenuous evidence for early human occupation of the Humboldt Sink, a claim that ultimately led the GBPRU to revisit LRS in 2018 and 2019.

Return to Leonard Rockshelter

The GBPRU returned to LRS in 2018 and 2019 to evaluate Heizer's (1951) claim of an early Paleoindian occupation. We established a 1-m grid across Heizer's Area B and placed a permanent datum in the ground at an arbitrary location designated N500 E500 and 100 m elevation. We excavated three 1x1 m test units (N498 E497, N495 E500, and N494 E500) (Figures 2.7-2.9). We placed the units in Heizer's Area B in an attempt to locate an intact profile that we could use to gain a better understanding of the site's stratigraphy and chronology. In 2018, we excavated units N498 E497 and N495 E500 in arbitrary 10-cm levels. In 2019, we excavated N494 E500 in arbitrary 5-cm levels. We excavated using trowels and passed sediment through 1/8th-inch screens. We collected numerous charcoal and macrobotanical samples for radiocarbon dating and plotted artifacts *in-situ* when we encountered them. We recovered bones, debitage, and other items from the screens and bagged them by level. Units N495 E500 and N494 E500 crosscut the eastern profile of Heizer’s Unit 3 in Trench B (Figure 2.10), which means that sediment in the eastern portion of those units was presumably intact whereas sediment in the western portion of those units was almost certainly disturbed. We do not know if Heizer backfilled Trench B; therefore, the disturbed deposits from those units could either represent excavated sediments used to backfill the trench or intact and/or excavated sediments that gradually infilled Heizer’s trench over the past 70 years. In any case, we excavated and screened the intact and disturbed deposits separately.

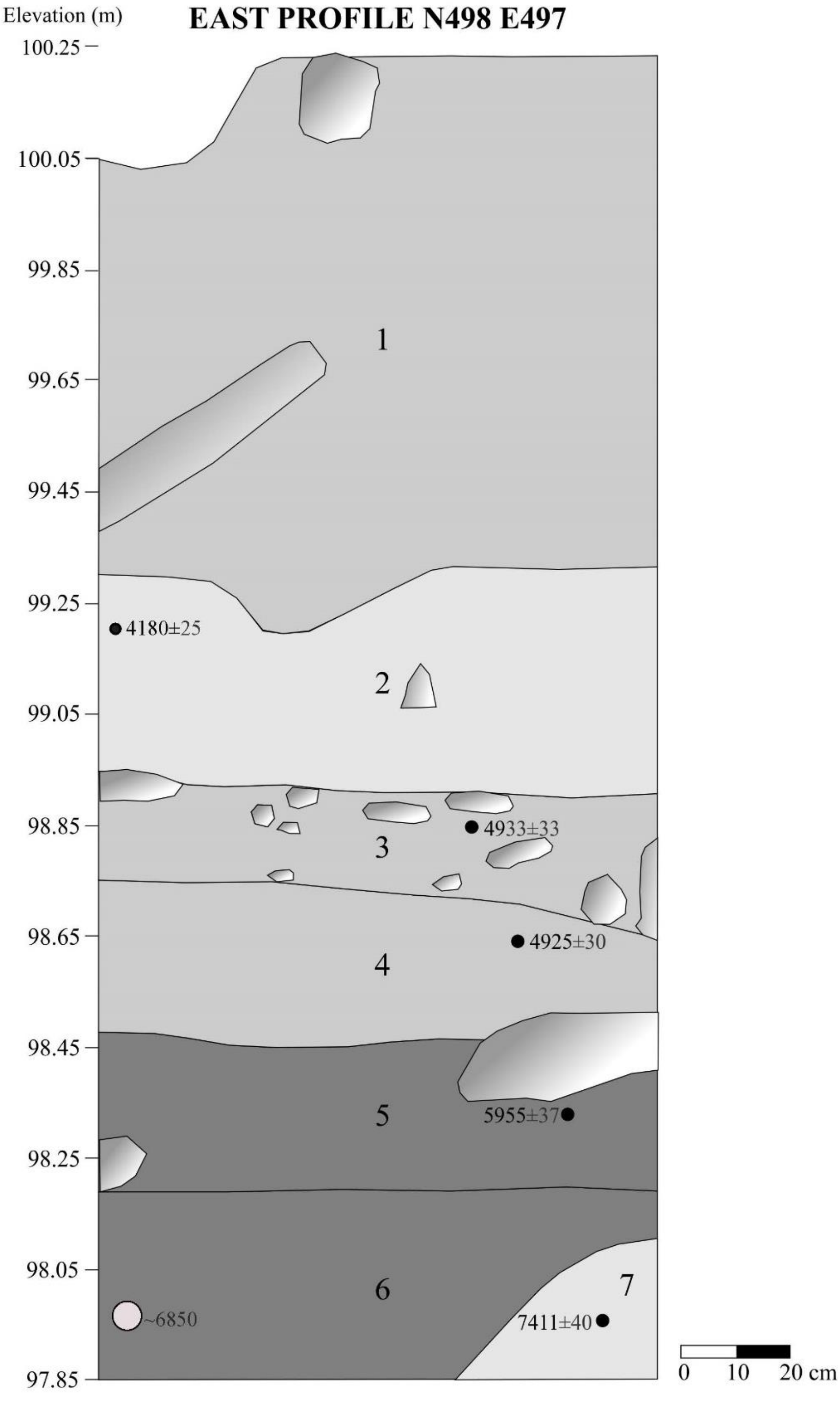

Figure 3.7. East profile of Unit N498 E497. Grey circle on lower left marks location of Mt. Mazama tephra.

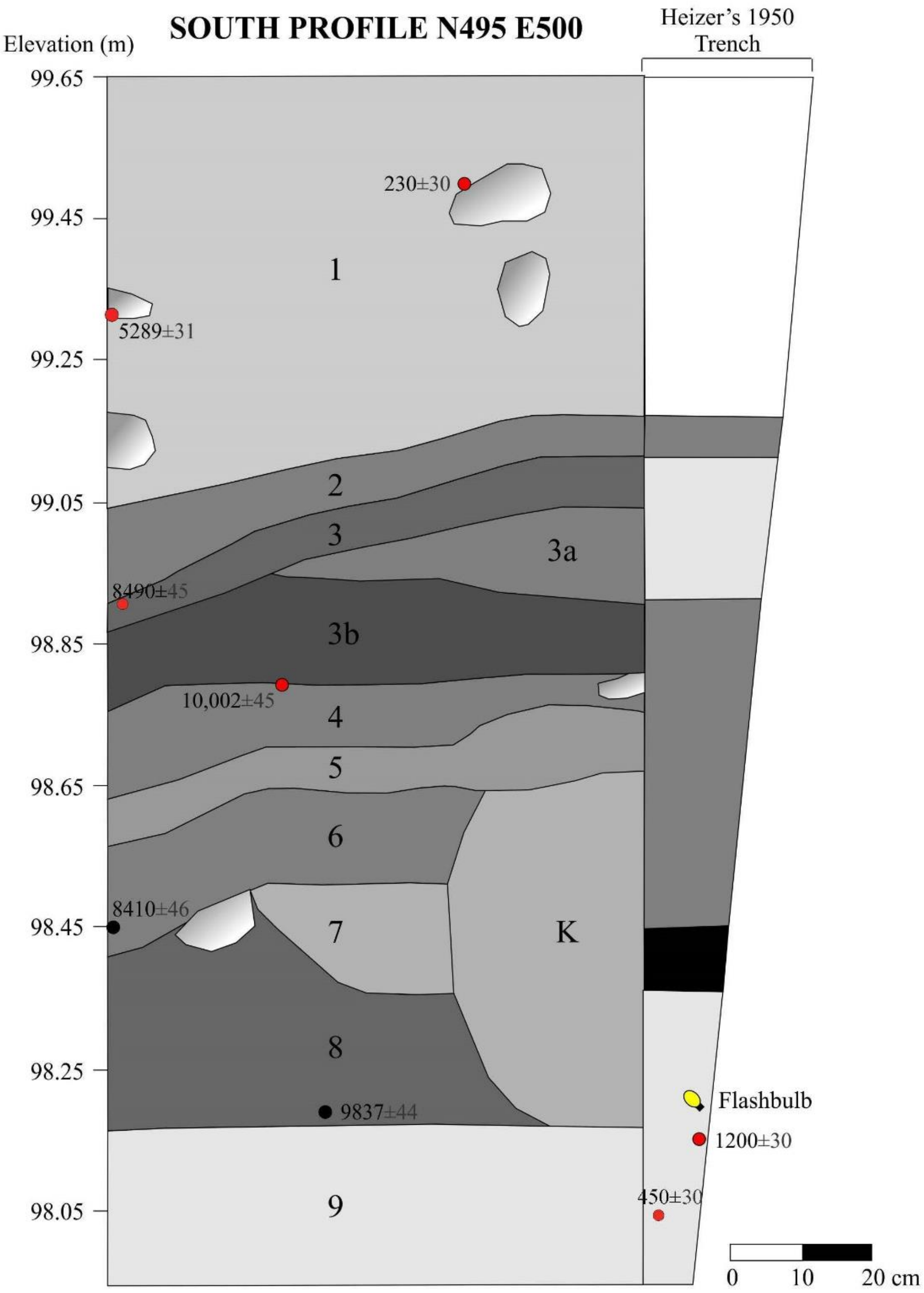

Figure 3.8. South profile of Unit N495 E500. Dates shown in red are suspect.

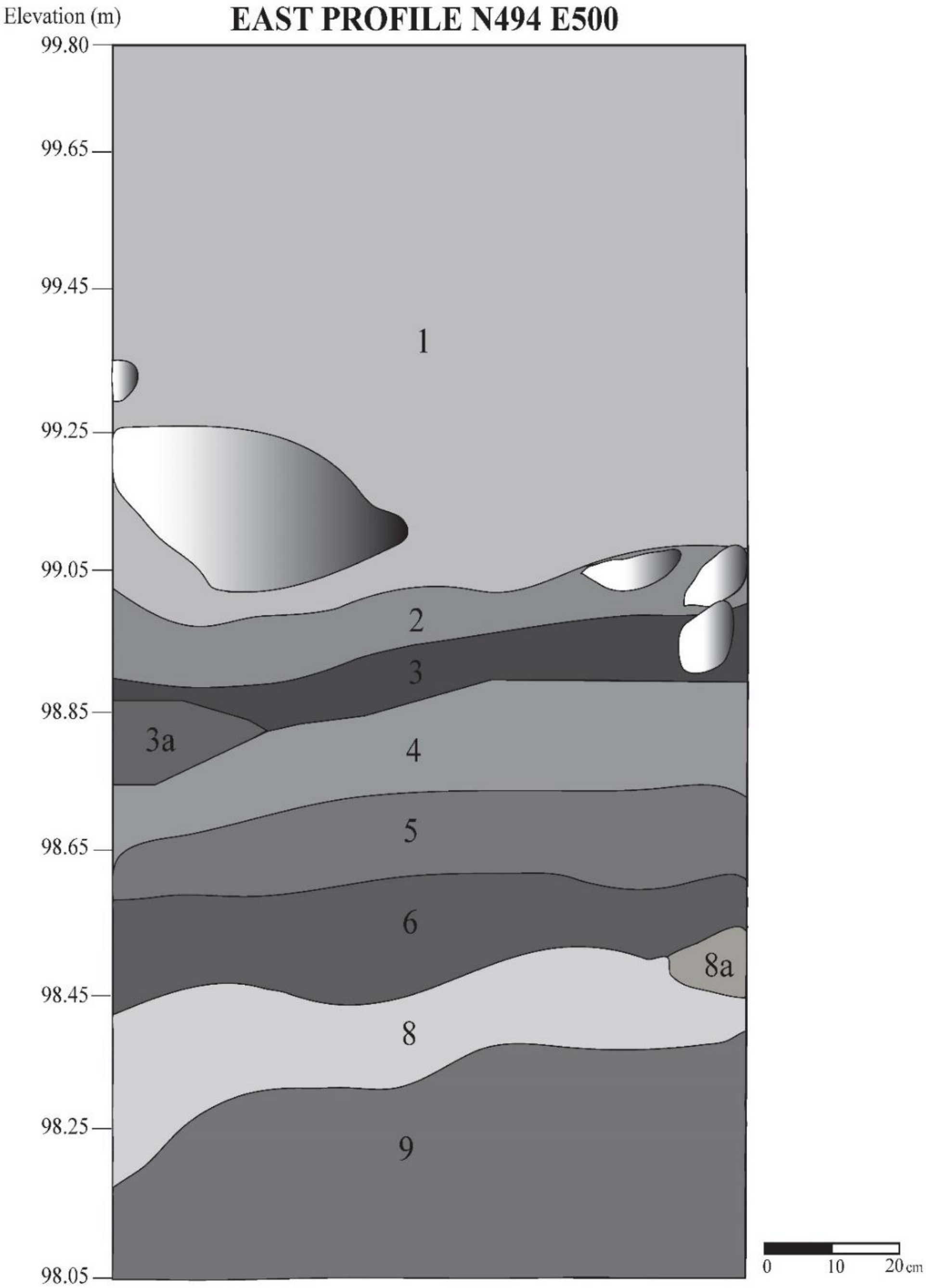

Figure 3.9 East profile of Unit N494 E500.

Figure 3.10. Planview of Unit N495 E500 showing the intact and disturbed deposits. The boundary between the two likely marks the location of the profile illustrated in Byrne et al.’s (1979) Figure 2.2.

We recovered a well-preserved small mammal record throughout the deposits, which is the primary focus of my thesis, but only a few artifacts (Table 2.3). In Unit N498 E497, we recovered metal wire, three metal shell casings, two *Olivella* beads, and a piece of possible ochre from the upper and almost certainly disturbed levels of what we called Stratum 1 (see below). In Unit N494 E500, we recovered an *Olivella* bead with cordage threaded through it and two pieces of cordage. Again, these almost certainly came from Heizer's excavated deposits and not primary contexts. We also found two pieces of debitage in Stratum 2, one piece of debitage in Stratum 3B, and an obsidian biface fragment in Stratum 8. In Unit N495 E500, we found two flakes in Stratum 1 and one flake in Stratum 7. We also recovered two *Olivella* beads in the upper and most likely disturbed levels of Stratum 1.

Table 3.3. Artifacts Recovered from GBPRU Excavations.

Unit	**Description**	**FS**	**n**	**Elevation (m)**	**Stratum**
N495 E500	Flake	n/a	1	99.45-99.35	1
N495 E500	*Olivella* bead	n/a	2	99.35-99.25	1
N495 E500	Flake	n/a	3	99.35-99.25	1
N495 E500	Flake	n/a	1	99.25-99.15	1
N495 E500	Flake	n/a	1	99.05-98.95	1/2
N494 E500	*Olivella* bead with cordage	n/a	1	99.30-99.25	1
N494 E500	Cordage	n/a	1	99.30-99.25	1
N498 E497	Metal wire	n/a	1	100.47-100.05	1
N498 E497	Metal shell casing	n/a	3	100.47-100.05	1
N498 E497	*Olivella* bead	n/a	2	100.47-100.05	1
N498 E497	*Olivella* bead	n/a	1	100.05-99.95	1
N498 E497	Ochre	n/a	1	99.85-99.75	1
N494 E500	Flake	n/a	2	98.95-98.90	2/3
N494 E500	Flake	n/a	1	98.80-98.75	3b/4
N495 E500	Flake	n/a	1	98.35-98.25	7
N494 E500	Reworked biface	72	1	98.44	8

We recovered three textile fragments and a flashbulb from the disturbed deposits in Unit N495 E500, which again marked Heizer's infilled Trench B (Table 2.4). We initially believed that the textiles were archaeological so we submitted them for radiocarbon dating. They returned a range of aberrant ages. One piece found at an elevation of 99.48 m returned an age of 230±30 ^{14}C BP (420 cal BP-present) and is clearly very young. Another piece found at an elevation of 98.14 m and next to the flashbulb returned a date 1200±30 ^{14}C BP (1235-1010 cal BP). A final piece found at an elevation of 98.05 m returned a date of 450±30 ^{14}C BP (535-470 cal BP). Anna Camp, Pat Barker, and Gene Hattori (Nevada State Museum) – leading textile researchers – examined the pieces and ultimately concluded that they are degraded burlap likely introduced during Heizer's excavations and not Native American basketry. The wide range of dates obtained on what is almost certainly modern material is likely a function of a petroleum-based contaminant on the burlap.

Table 3.4. Artifacts Recovered from Heizer's Trench B Unit 3.

Description	**FS**	**Elevation (m)**	**Sample ID**	**^{14}C Date**	**2σ cal BP range**
Textile	12	98.05	18P/0918	450±30	535-470
Textile	27	98.14	18P/08115	1200±30	1235-1010
Textile	33	99.48	18P/08113	230±30	420-Modern
Flashbulb	26	98.19	n/a	n/a	n/a

In the intact deposits of N494 E500 we recovered a heavily reworked obsidian biface fragment *in-situ* within Stratum 8 at an elevation of 98.44 m (Figure 2.11). It is made of Bordwell Spring/Pinto Peak/Fox Mountain obsidian, which occurs across a fairly large area in northwestern Nevada ~180 km from Leonard Rockshelter. A radiocarbon date of 9835±45 ^{14}C BP (11,325-11,190 cal BP) from Stratum 8 suggests that the biface is quite old but it lacks heavy edge grinding and collateral flaking typical of Western Stemmed Tradition (WST) points. Regardless, the association between the biface and date indicates that groups visited LRS during the Early Holocene and as such solidifies

LRS’s position on the list of archaeological sites that immediately postdate the Younger Dryas in the Lahontan basin (Adams et al. 2008).

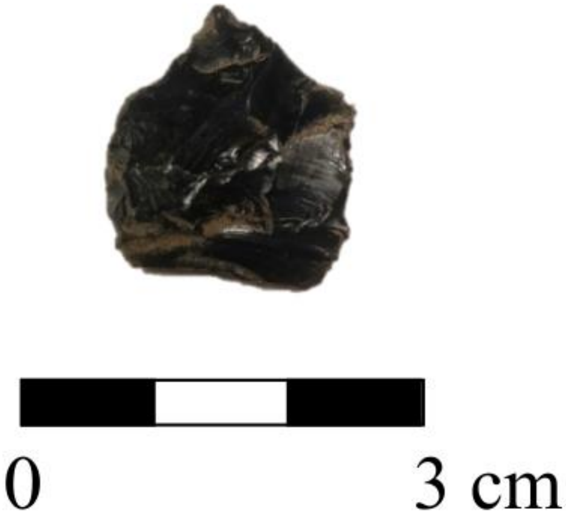

Figure 3.11. Obsidian biface from Stratum 8 in Unit N495 E500.

With the help of Dr. Ken Adams (Desert Research Institute), we recorded nine major stratigraphic units in our three exaction units (Table 2.5). This contrasts with the five strata that Heizer recognized. Stratum 1 consisted of poorly-sorted gravelly silt with angular to sub-rounded clasts. We obtained a date of 5290±30 ^{14}C BP (6180-5950 cal BP) on plant material collected *in-situ*. The age of that sample is not in accordance with radiocarbon dates from the underlying strata. Stratum 2 consisted of well-sorted fine sandy silt with pockets of organic material. We obtained a radiocarbon date of 4180±25 ^{14}C BP (4835-4620 cal BP) on collagen from a small mammal bone selected from the 99.25-99.15 m level bag.

There was an abrupt boundary between strata 2 and 3, the latter of which consisted of fine sandy silt, pieces of plant material, and sporadic angular gravel. We recorded two sub-strata with Stratum 3: (1) Stratum 3A, which was similar in texture and color to Stratum 4 but located stratigraphically above it and separated from the other sub-stratum; and (2) Stratum 3B, a continuous band of angular gravel. Stratum 3 has two contradictory radiocarbon dates. The first, 4935±35 ^{14}C BP (5730-5600 cal BP), was obtained on a charcoal sample collected *in-situ*. The second date, 8490±25 ^{14}C BP (9950-9840 cal BP), was obtained on collagen from a small mammal bone selected from the 98.95-98.85 m level bag. This latter date probably does not reflect the true age of the deposits from which we recovered the bone. Unit N495 E500 contained disturbed deposits and it is possible that some of them were screened together with intact deposits. We also submitted a charred *Sylvilagus* sp. maxilla from the boundary between strata 3B and 4 for radiocarbon dating. It lacked sufficient collagen and produced a clearly erroneous date of 10,000±45 ^{14}C BP (11,665-11,270 cal BP).

Stratum 4 consisted of well-sorted gravel with sandy silt and several angular clasts. A charcoal sample collected *in-situ* provided a date of 4925±30 ^{14}C BP (5715-5560 cal BP). Stratum 5 had a distinct dark grey color with well-sorted fine sandy silt and an abrupt boundary with the underlying Stratum 6. A radiocarbon date on collagen from an *Aves* sp. bone collected *in-situ* from Stratum 5 returned a date of 5955±35 ^{14}C BP (6885-6670 cal BP). Stratum 6 was also fine sandy silt but the sediment was yellowish-brown and contained some coarse sand. In Unit N498 E497, we encountered Mt. Mazama tephra at 97.95 m. The eruption of Mt. Mazama occurred ~7600 cal BP. We submitted a piece of a desert shrub (*Amaranthaceae* sp.) recovered from an elevation of 98.45 m in

Stratum 6 for radiocarbon dating and it returned a date of 8410±45 ^{14}C BP (9525-9365 cal BP). This date is problematic given that it does not align with Stratum 6 in N498 E497. Of note, we observed what is likely a large infilled krotovina that may have disturbed portions of strata 6-8 in units N495 E500 and N494 E500; however, the dated piece of vegetation from Stratum 6 in N495 E500 came directly from the east wall of the intact deposits and is likely reliable. Stratum 7 was well-sorted fine sandy silt and contained several small clasts. A piece of a desert shrub (*Amaranthaceae* sp.) collected *in-situ* at an elevation of 98.01 m in Stratum 7 provided a date of 7410±40 ^{14}C BP (8340-8170 cal BP). Water-rounded clasts began to appear in Stratum 8 together with fine sandy and silty gravel. We obtained a date of 9835±45 ^{14}C BP (11,325-11,185 cal BP) on charcoal collected from the bottom of Stratum 8. Stratum 9 was the lowest stratum that we encountered and it consisted of beach gravels with fine sandy gravel deposited when Lake Lahontan reached the elevation of LRS for the last time.

Table 3.5. GBPRU Stratigraphic Units.

Strata	**Description**
Stratum 1	Poorly-sorted gravelly silt with angular to sub-rounded clasts
Stratum 2	Well-sorted sandy silt with pockets of organic material
Stratum 3	Fine sandy silt with several pieces of organic material and sporadic angular gravel
Stratum 3A	Well-sorted gravel with sandy silt and several angular clasts
Stratum 3B	Angular gravel
Stratum 4	Well-sorted gravel with sandy silt and several angular clasts
Stratum 5	Dark grey sediment with well-sorted fine sandy silt
Stratum 6	Yellowish-brown sediment with fine sandy silt and coarse sand
Stratum 7	Well-sorted fine sandy silt with several small clasts
Stratum 8	Fine sandy silt with gravel and water-rounded clasts
Stratum 9	Fine sand with Lake Lahontan gravels

The elevation of LRS and the presence of Lahontan gravels in the shelter are critical to understanding when humans could have first visited the site. Heizer (1951) reported an early date of 11,199±570 ^{14}C BP (14,900-11,610 cal BP) associated with obsidian flakes, which suggests that the initial occupation might be among the oldest in the Great Basin. Based on his understanding of the elevation of the rockshelter (1272.5 m ASL) and what was known in the mid-20th Century about Lake Lahontan’s history, Heizer (1951) concluded that the site was likely dry and available for occupation as early as ~13,000 cal BP. Put another way, Heizer thought that after ~13,000 cal BP the lake never again flooded LRS.

We know now that Heizer's interpretations are based on an incorrect elevation for LRS, which has changed the likelihood that the site contains evidence of a Terminal Pleistocene occupation. We remeasured the elevation of the Lahontan gravels in the site using both a total station shot from the site to a USGS turning point shown on the 1:24,000 *Wild Horse Pass* Quadrangle (2018) topographic map and double-checked the elevation of that point using a Trimble Nomad map-grade GPS unit with decimeter accuracy. Both methods confirmed that LRS sits at 1224.5 m ASL, not 1272.5 m ASL as shown on the map and used by Heizer (1951) and, later, Byrne et al. (1979) to determine the site's elevation. The fact that the USGS map is wrong may be because the shelter sits beneath a very steep and overhanging rock outcrop, which likely complicated efforts to record the local topography. The change in site elevation is significant because based on what we now know about Lake Lahontan's history (Adams et al. 2008) and the date of 9835±45 ^{14}C BP (11,325-11,190 cal BP) that we obtained from charcoal sitting immediately above the rounded gravels in Stratum 9, it is clear that those gravels were deposited during the Younger Dryas (12,900-11,600 cal BP) and not an earlier highstand (Figure 2.12). In other words, LRS was last inundated much later than Heizer (1951) believed. We did not reach bedrock in our excavation units so we cannot rule out the possibility that the site contains evidence of a pre-Younger Dryas occupation; however, given that Lake Lahontan flooded the site after that time with enough force to deposit a large quantity of gravel we suspect that if humans did use the site before the Younger Dryas any traces of such visits were likely destroyed by the lake.

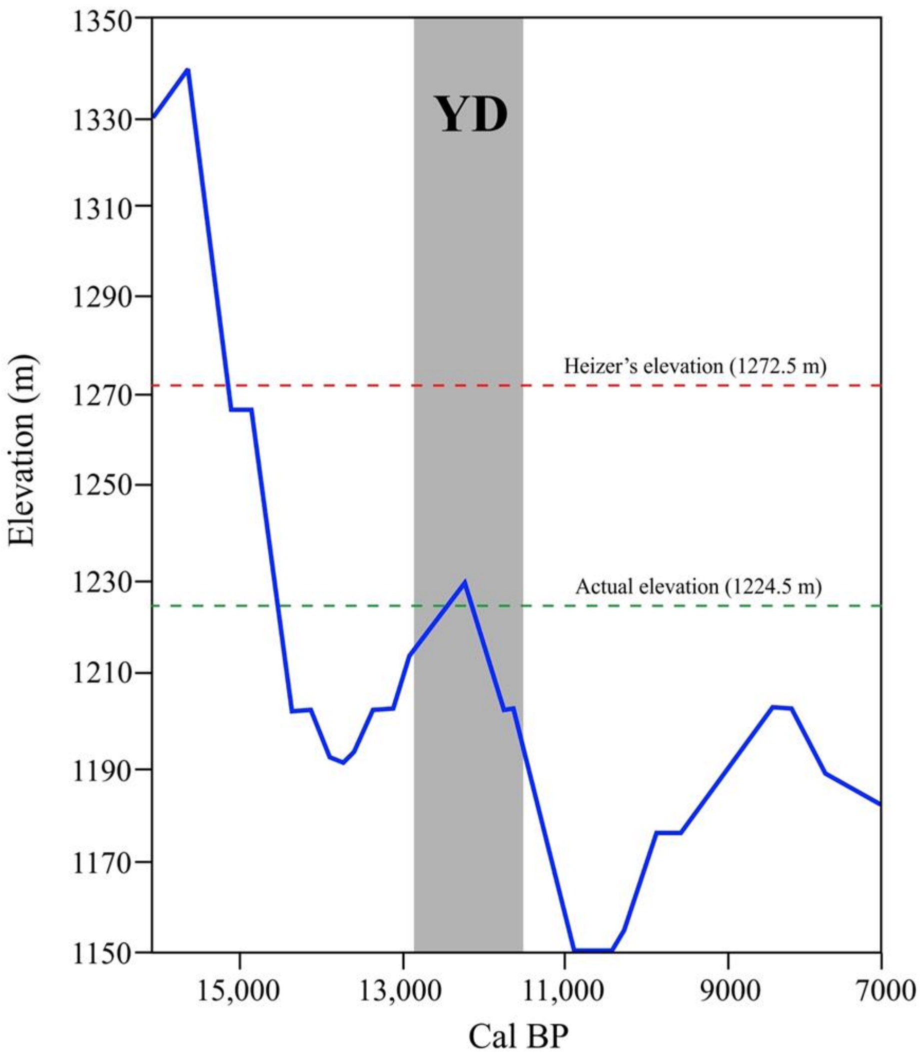

Figure 3.12. Lake curve for Lake Lahontan during the terminal Pleistocene/early Holocene (adapted from Adams et al. 2008). The gray band marks the Younger Dryas. The upper dashed line marks Heizer's erroneous elevation for LRS. The lower dashed line marks the correct elevation for LRS and demonstrates that the lake rose above that level during the Younger Dryas and flooded the shelter.

Correlating Heizer's and the GBPRU's Stratigraphy

We defined nine major strata in the same area where Heizer (1951) and Byrne et al. (1979) defined five (units A-E). Correlating these sequences proved to be challenging.

I am confident that Heizer’s Unit E correlates to our Stratum 9, as both contained beach gravels. I am also confident that our Stratum 1, described as poorly-sorted gravelly silt, correlates to Heizer’s Unit A, which Byrne et al. (1979) describe as a mixture of windblown sand and silt with tufa rockfall, bat guano, and packrat nest material. By looking at photos of Heizer’s excavations on file at UCB, we realized over the course of our excavations that his crew removed the top ~75 cm of deposits where we placed units N495 E500 and N494 E500 during their 1950 excavations. Using a large crack in the rockshelter’s tufa-covered wall visible in the photographs as a guide, we located the approximate elevation of the top of the shelter’s deposits prior to Heizer’s excavations: they rested at ~100.41 m, or ~41 cm above our datum (Figure 2.13). When we began excavating, the surface of N495 E500 was 99.65 m and the surface of N494 E500 was 99.75-99.81 m. The ~75 cm difference means that our Stratum 1 is a truncated version of Heizer’s (1951) Unit A, and that our excavations likely did not encounter many Late Holocene deposits in those units.

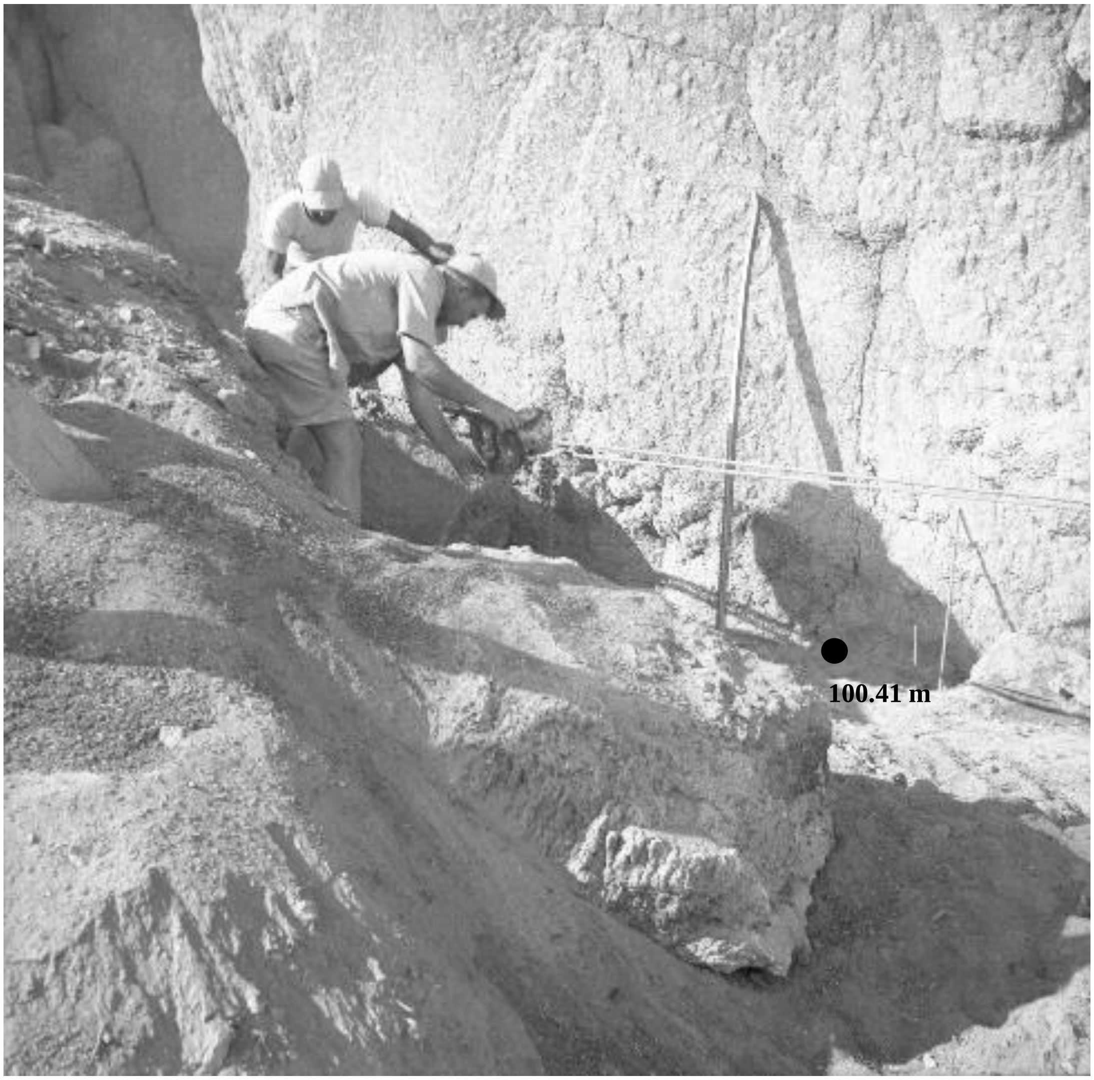

Figure 3.13. Excavators in Area B. The crack in tufa to the right of the rod provided a reference point with which we could correlate the elevations of Heizer's excavations and our test pits. UCB Photo No. 2288 courtesy of Phoebe Hearst Museum.

The correlations of Heizer's units B-D and our strata 2-8 are less clear. Heizer's Unit B consisted of stratified gray sand and silt, which is likely what we called strata 2, 3, and 3A. We defined strata 2, 3, and 3A as sandy silt with more angular clasts in strata 3 and 3A. Even though these stratigraphic units are likely the same, the gray sand and silt described by Byrne et al. (1979) was not noted in our stratigraphic descriptions. Instead, we called it dark yellowish-brown (10 YR 5/4 and 10 YR 3/4).

Our strata 3B and 4 contained a higher amount of angular gravel than the strata above or below them, with Stratum 3B consisting of a continuous band of angular gravel. Byrne et al. (1979) described Unit C as fine sand intermixed with angular rock fragments. Given the presence of angular gravel in our strata 3B and 4, I correlated them to Heizer's Unit C. Heizer (1951) and Byrne et al. (1979) stated that Unit D was comprised of solid bat guano lying atop of beach gravels (Unit E). We did not find bat guano during the 2018 and 2019 excavations; therefore, I correlated our strata 4-8 to Heizer's Unit D.

Summary

Our renewed excavations at LRS did not produce evidence of the Terminal Pleistocene occupation that Heizer (1951) believed was present based on the association between the obsidian flakes and dated bat guano. Also, the SPD of Heizer's (1951) radiocarbon dates and its lack of accordance with his reporting of artifacts from the different strata indicate that his sample of dates does not faithfully record when people visited LRS. We did find an obsidian biface fragment (see Figure 2.11) in a stratigraphic and dated context that suggests humans first visited the site during the Early Holocene; however, we did not find any other traces of human activity at that depth so LRS may not have seen heavy use early. That seems to be the general trend for the site across time: Heizer (1938, 1951) reported a diverse collection of finished basketry, weapon parts, and shell beads, but just a few stone tools, almost no debitage, and few animal bones that could be attributed to human activity. Our limited excavations produced a meager artifact assemblage: just a handful of flakes and shell beads, often intermixed with modern debris, mostly in the disturbed surface deposits. Based on these trends, it appears that LRS served as a place where people periodically visited to cache items but rarely occupied it for any significant amount of time. I return to this topic later to place LRS within the broader context of western Nevada prehistory and address the shortcomings of Heizer's sample of radiocarbon dates by presenting new dates on fiber artifacts.

Although we found little cultural material, we did recover abundant small mammal remains from throughout the deposits. Because small mammals need specific local environmental conditions to live, researchers can use their remains to learn about changing climatic conditions. Specifically, by recognizing the ecological tolerances of different taxa, we can interpret decreases and increases in their abundances as evidence of extirpation or colonization events, which in turn can provide clues about environmental change (Grayson 1998, 2000a, 2000b, 2006; Schmitt and Lupo 2005, 2012). Since our excavations at LRS provided a large assemblage of small mammal remains from stratified and dated deposits, I elected to analyze the shelter's fauna to understand local conditions in the Humboldt Sink and how they changed during the Holocene. Researchers have conducted similar studies in the Bonneville Basin – for example; Grayson's (2000), and Schmitt and Lupo's (2005, 2012) work at Homestead Cave, CBC, and BER– but to date there has been little done in the Lahontan Basin.

Methods

Faunal Analysis

I analyzed the fauna from the three 1x1-m units we excavated in 2018 and 2019. We recovered virtually all of the bones from sediment sifted using 1/8th-in. screens. I processed the level bags from which the bulk of my sample originated in the GBPRU Lab at UNR. The radiocarbon dates I described above provided some degree of temporal control for my sample.

Based on the number of well-preserved small mammal bones throughout the deposits with bits of fur and other materials still adhering to many of those bones, we know that most or all of the remains were likely deposited by owls who roost in the shelter today and apparently did so in the past. Accumulative mechanisms and damage present on most bones further attest to this fact (Hockett 2007). Some of the bones also showed evidence of chemical attrition, polish, pitting, staining, and rounding, which suggests that a minority of them were deposited in coyote scat (Andrews 1990; Schmitt and Lupo 2012).

The most diagnostic bones of small mammals are the crania and mandibles (Grayson 1983) and I relied on those elements for species identification. I began my analysis by isolating crania and mandibles from the other bones in the level bags. In the case of loose molars for *Arvioclinae* I used the lower M_1 and upper M_3 for identification. I identified 149 *Arvioclinae* using only loose molars. For leporids, in addition to the crania and mandibles, I also separated other diagnostic elements such as the sacrum, humerus, radius, ulna, acetabulum, femur, tibia, and vertebrae.

After collecting the diagnostic elements, I washed them to remove any sediment and owl pellet residue adhering to them. I placed them in a fine mesh sieve and submerged them in water for several seconds. I did not shake the sieve during washing and laid out the bones in a single layer on trays to air dry. Once they were completely dry I lightly brushed off any remaining sediment with a toothbrush.

My species identifications were based on crania and mandible morphology, tooth morphology (specifically, the occlusal surfaces), specimen size, and measurements of tooth rows when needed. I relied on both comparative collections and reference manuals. My comparative collections included specimens housed in UNR's Natural History Museum and Bryan Hockett's (Bureau of Land Management) personal collection. To identify leporids, I also used collections housed at the Nevada State Museum. For reference manuals, I used Hall's (1995) *Mammals of Nevada*, Elbroch's (2006) *Animal Skulls: A Guide to North American Species,* and Nagorsen's (2002) *An Identification Manual to the Small Mammals of British Columbia*. These manuals aided me in making taxonomic determinations, and although Nagorsen's (2002) manual is for British Columbia it nevertheless contained useful information on some mesic adapted mammals in the Great Basin.

I inspected most mandibles under 10× to 60× power using a binocular microscope in the UNR Natural History Museum and GBPRU Lab. I used mandibular and maxillary alveolar lengths to identify the species of woodrats and pocket gophers in my sample. I used differences in the morphologies of the mandibles and maxillae together with the comparative collections to distinguish between pocket gophers and woodrats. For woodrats, I used the shape of the first molars and the alveolar lengths for species designations. The species that I identified as desert woodrats had mandibular alveolar lengths of ≤8.7 mm and maxillary alveolar lengths between 7.8 mm and 8.6 mm. I assigned mandibles with alveolar lengths of >9.3 mm and maxillary alveolar lengths between 9.4 mm and 11.4 mm to bushy-tailed woodrats (Grayson 1985; Livingston 1988). I assigned mandibles with alveolar measurements between 8.8 mm to 9.2 mm and maxillary alveolar measurements between 8.7 mm to 9.3 mm to the more general woodrat genus because Grayson's (1985) statistical analysis of specimens between the two measurements were ambiguous.

For pocket gophers, I used the morphology of the rostral and lower fourth premolar to differentiate Botta's pocket gophers from northern pocket gophers (there were ultimately no northern pocket gophers in the sample). The occlusal surface of Botta's pocket gopher's premolar is oriented nearly perpendicular to the occlusal surface of the tooth, which leads the ventral surface of the maxillary to abruptly arch in front of the upper molars, distinguishing it from the northern pocket gopher (Thaeler 1980). Thaeler (1980) did not discuss a method to distinguish between Botta's pocket gopher and Townsend's pocket gopher; therefore, to differentiate between Botta's pocket gopher and Townsend's pocket gopher I used the alveolar length of the mandibles and maxillae. I assigned mandibular alveolar lengths between 4.7 mm and 6.3 mm and maxillary alveolar lengths between 6.8 mm and 8.1 mm to Botta's pocket gopher. I assigned mandibular alveolar lengths between 6.4 mm and 7.8 mm and maxillary alveolar lengths between 8.2 mm to 10.4 mm to Townsend's pocket gopher (Grayson 1983, 1985; Livingston 1988).

There are two genera of voles in the Great Basin: *Lemmiscus* sp. and *Microtus* sp. (Hall 1995). To distinguish them, I used the lower M_1 and upper M_3 morphologies in conjunction with a comparative collection (Barnosky and Rasmussen 1988). In the case of edentulous mandibles, I used the placement of the mandibular foramen to distinguish the genera. For *Microtus,* the mandibular foramen is on or adjacent to the ridge of the bone that encapsulates the base of the incisor, and one can see it when the disarticulated half of the mandible is laid on its buccal surface. For *Lemmiscus,* the mandibular foramen is on the anterior-cranial wall of the ridge and cannot be seen when the disarticulated half of the mandible is laid on the buccal surface (Grayson 1983). I identified other species based on their occlusal surface morphology and how favorably they compared to the collection of known species.

Our excavations reached a maximum depth of 1.7 m and included 17 arbitrary levels. We recorded nine distinct strata. I analyzed the fauna by level and analyzed changes in their character within the levels and strata. The assemblage spans ~11,325-4720 cal BP. The lack of substantial Late Holocene deposits is due to Heizer's removal of those deposits in our excavation areas. Once I assigned the small mammals to the genus or species level, I used the assemblage from LRS to investigate the nature and timing of climatic change in the Humboldt Sink.

For Unit N498 E497, I did not include the top 30 cm of mixed deposits (99.55-99.35 m) in my climatic interpretations. The intact deposits from Unit N498 E497 span the beginning of the Early Holocene, the Middle Holocene, and beginning of the Late

Holocene (Figure 2.14). For units N495 E500 and N494 E500, I have a low degree of confidence that the small mammals from strata 1-5 were from intact deposits given the multiple erroneous radiocarbon dates discussed above. I used strata 6-9 (98.55-97.95 m) from units N495 E500 and N494 E500 for my climate interpretations. The intact deposits from these two units span the Early Holocene (see Figure 2.14).

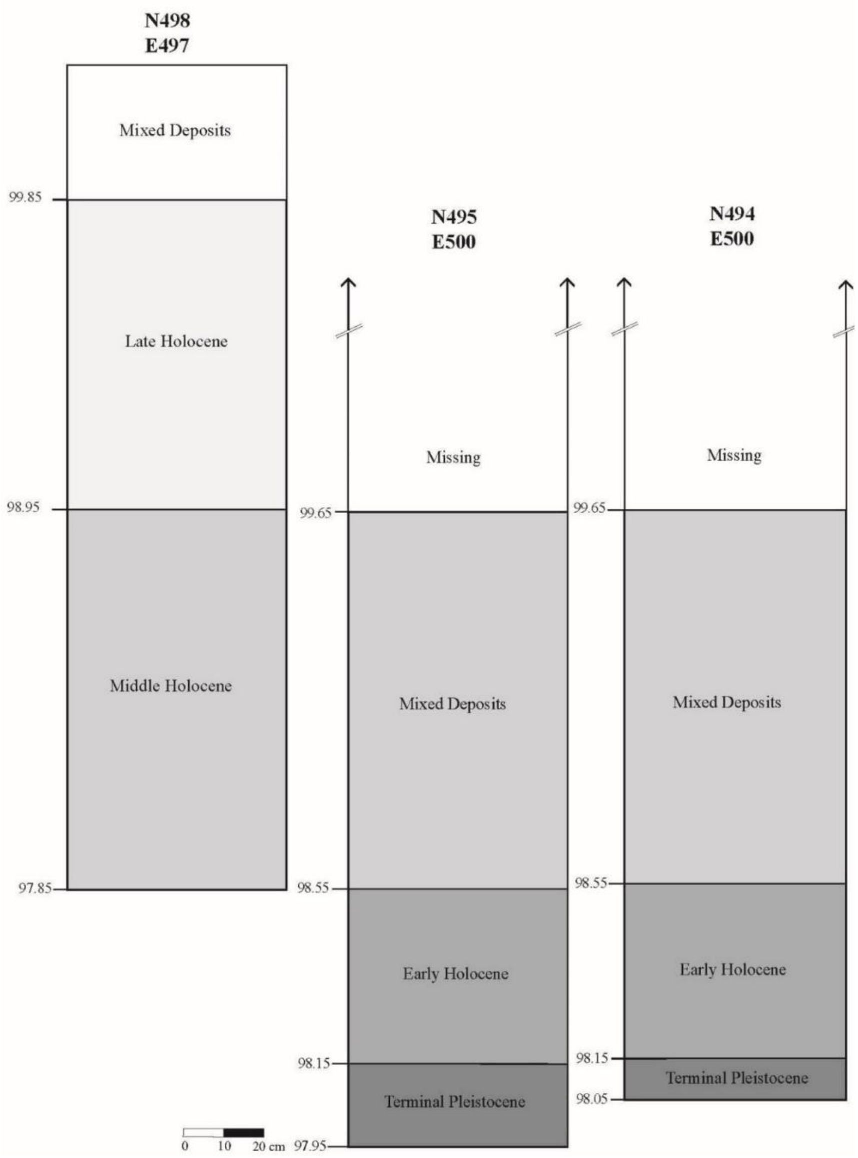

Figure 3.14. Elevations and ages of the deposits in our test pits.

To investigate changes in the assemblage, I considered the abundance, relative abundance, richness, diversity, and evenness of the LRS small mammal record across time, as well as the presence and absence of mesic and xeric adapted species. Abundance is simply the number of identified specimens (NISP) per species. Relative abundance measures the evenness of distribution among species, and richness is the number of species represented in a community (Grayson 1984). I used the Shannon-Weaver (S-W) diversity index to measure biodiversity throughout the strata because the index considers species richness and relative abundance. The S-W index is calculated using the following formula:

$$H' = -\sum_{i=1}^{s} (p_i * \ln p_i)$$

where H' is the measure of diversity, $\sum$ is the sum of the calculations, s is the number of species, p_i is the proportion of individuals of a particular species, and *ln* is the natural log. The H_{max}, which is the maximum diversity possible, can be calculated by taking the natural log (*ln*) of the number of species (s) present in the sample. To calculate the evenness of a sample, I divided H' by H_{max}, which gives a value range between 0 and 1, with 1 being complete evenness.

I used NISP to quantify my results because it is not affected by aggregation (Grayson 1984). Minimum number of individuals (MNI) is another common way to measure abundance but it is prone to effects of aggregation as the aggregation method an analyst chooses will affect any significance test applied to the data. For example, MNI can be calculated in several ways: (1) calculating the MNI for each stratum; (2) calculating the MNI for a site overall; or (3) calculating the MNI based on arbitrary measurements, such as 10 cm levels. These methods leave analysts without a way to know whether the represented taxa are showing the actual composition or if they show biases related to collection methods (Grayson 1984). A counterargument for using MNI over NISP is that MNI can control for fragmentation of bones, especially from larger mammals (animals whose bones people often processed for marrow). Because my sample is comprised almost exclusively of small mammal remains deposited by owls and there is not a high degree of fragmentation, NISP is the most suitable means to measure the relative abundances of taxa at LRS.

LRS Collection at the UCB

In addition to my faunal analysis, I also examined Heizer's LRS collection at UCB and selected several items for radiocarbon dating. I did so because the sizeable collection of fiber artifacts offered the best opportunity to address unresolved questions about when people used the site. Because our 2018 and 2019 excavations were in Heizer's Area B, I selected two pieces of cordage, one piece of worked wood, one wood fragment, and a feather fragment from the atlatl dart recovered in 1937 from Area B for dating (Table 2.6). With the guidance of Dr. Anna Camp, I also selected several pieces of diagnostic basketry to add to the record of directly dated textiles in western Nevada; these include matting, a sandal fragment, a diagonally-twined winnowing tray, coiled basketry, a cradle basket, and an open-twined basket (see Table 2.6).

Table 3.6. Dates on Items in the LRS Collection at the University of California, Berkeley.

Artifact ID	**Lab Number**	**^{14}C Date**	**Material**	**2σ cal BP**	**Area**	**Unit**	**Heizer's Provenience Information**	**Reference**
2-21936	D-AMS 037412	7020±30	Feather from atlatl	7936-7792	B	Unknown	Guano layer	Heizer (1938)
2-26574	D-AMS 037413	1950±25	Matting	1969-1825	D	Unknown	Pit 2E	UCB Catalog
2-26640	D-AMS 037414	7015±35	Worked wood	7939-7764	B	Trench D	In upper portion of pure guano layer, possible shaft	UCB Catalog
1-50590	D-AMS 037415	2825±25	Sandal fragment	2996-2862	Unknown	Unknown	Pit 1 (1938) 30" depth	UCB Catalog
1-50596	D-AMS 037416	2825±25	Possible cradle basket	2996-2862	Unknown	Unknown	Pit 1 (1938) 30" depth	UCB Catalog
1-21549	D-AMS 037417	250±25	Winnowing tray	423-151	Unknown	Unknown	"On surface at base of a cliff ca. 400 ft. above Humboldt Lake" (Loud 1912)	UCB Catalog
2-26678	D-AMS 037418	7505±35	Cordage	8392-8205	B	Trench D	Found in pure guano layer	UCB Catalog
2-26734	D-AMS 037419	8350±35	Wood fragment	9466-9291	B	Trench D	Below pure guano layer	UCB Catalog
2-26704	D-AMS 037420	1925±25	Coiled basketry	1932-1829	D	Unknown	Pit 3A	UCB Catalog
2-26677	D-AMS 037421	7210±35	Cordage	8156-7958	B	Trench D	Found in pure guano layer	UCB Catalog
2-26695	D-AMS 037422	2105±25	Cradle basket	2141-2002	D	Unknown	Pit 3A; 1'7" W/ 11'3" S of Datum D; 39" d. Found directly under piece #2 of cache lined with basketry	UCB Catalog
1-50595	D-AMS 037423	1765±40	Open-twined basket	1810-1569	Unknown	Unknown	Pit 3 (1938)	UCB Catalog

Summary and Expectations

Our work at LRS generated a small mammal assemblage that had the potential to add to our understanding of conditions in the Humboldt Sink during the Holocene. Given the absence of some Late Holocene deposits, I am unable to make interpretations of the environment postdating 4180±25 ^{14}C BP (4835-4620 cal BP). The visit to UCB also produced a suite of new radiocarbon dates on artifacts that allows me to better understand when people visited LRS. Using the methods and materials discussed in this chapter, I developed two hypotheses: (1) LRS possesses a paleoenvironmental record that demonstrates changes in local conditions throughout the Holocene; and (2) LRS possesses a record of human occupation spanning the Holocene.

My expectations for Hypothesis 1 are that the small mammals should be more abundant, richer, more even, more diverse, and include more mesic adapted species such as the meadow vole, Ord's kangaroo rat, and the Townsend's pocket gopher during the Early Holocene. There should be an overall decline in abundance, richness, evenness, diversity and mesic adapted species during the Middle Holocene and beginning of the Late Holocene, with xeric adapted species such as the desert woodrat, chisel-toothed kangaroo rat, and Botta's pocket gopher comprising the deposits. I also expect the small mammal record to align with Byrne et al.'s (1979) pollen study. Specifically, the fauna should reflect a shift from mesic adapted small mammals to xeric adapted small mammals during the "pine minimum" (~6800-4500 cal BP).

My expectation for Hypothesis 2 is that directly dated artifacts and artifacts from dated strata should span the Holocene. Given the paucity of flakes, bones deposited by humans, and features, like Heizer (1951) I believe that people never intensively used LRS. Having said that, given the range of Heizer's dates and the depths from which he recovered artifacts, I expect that human use of the shelter, however sporadic, spanned many millennia. In the next chapter, I present the results of my analysis of the small mammals from LRS and new radiocarbon dates on artifacts from the site.

CHAPTER 3

Results

In this chapter, I present the results of my analysis of the small mammal record from LRS and the climatic interpretations that it provides. First, I present the NISP and discuss species richness throughout the deposits. Second, I demonstrate the changing abundances of mesic and xeric adapted taxa. Third, I present the abundances of meadow voles, Townsend's pocket gophers, Botta's pocket gophers, desert woodrats, bushy-tailed woodrats, and chisel-toothed kangaroo rat. Fourth, I present the results of my calculations of diversity for the small mammals throughout the deposits. Finally, I present an updated SPD for LRS that incorporates new radiocarbon dates on fiber artifacts and/or dated deposits with associated artifacts.

NISP and Richness of Small Mammals

I identified 2,284 small mammal bones from intact deposits within units N498 E497, N495 E500, and N494 E500 (Table 3.1) (see Appendix 1). I restricted 907 of my vole classifications to the subfamily level, *Arvioclinae*, because many specimens lacked lower M_1s, upper M_3s, or mandibular foramina. I excluded voles identified only to subfamily from further analyses due to their limited utility in climatic interpretations. With that group removed, my sample was reduced to 1377 small mammals with which to investigate changing climatic conditions (Table 3.2).

Table 4.1. Total NISP (including *Arvioclinae*) from Intact Deposits.

Stratum	**Unit**	**Age (cal BP)**	**NISP**
1	N498 E497		1416
1/2	N498 E497		71
2	N498 E497	~4725	97
2/3	N498 E497		112
3	N498 E497	~5665	94
3/4	N498 E497		155
4	N498 E497	~5635	127
4/5	N498 E497		64
5	N498 E497	~6775	13
6	N498 E497	~7600	9
6/7	N498 E497	~8250	29
5/6	N495 E500		19
6/7	N495 E500	~9445	44
7/8	N495 E500		18
8	N495 E500		13
8/9	N495 E500	~11,250	3

Table 4.2. Total NISP (excluding *Arvioclinae*) from Intact Deposits.

Stratum	**Unit**	**Age (cal BP)**	**NISP**
1	N498 E497		879
1/2	N498 E497		38
2	N498 E497	~4725	42
2/3	N498 E497		63
3	N498 E497	~5665	43
3/4	N498 E497		88
4	N498 E497	~5635	82
4/5	N498 E497		33
5	N498 E497	~6775	10
6	N498 E497	~7600	8
6/7	N498 E497	~8250	19
5/6	N495 E500		14
6/7	N495 E500	~9445	30
7/8	N495 E500		15
8	N495 E500		10
8/9	N495 E500	~11,250	3

First, I calculated richness, which is simply the number of species throughout the strata (Figure 3.1). A Spearman’s Rho correlation coefficient demonstrates that the number of species present (richness) and the NISP (sample size) are not significantly correlated (r_s=0.34, p=0.18), meaning that changes in richness throughout the strata are not merely a function of sample size. Species richness was variable throughout the strata, with increases throughout the Early Holocene, decreases towards the end of the Early Holocene, and a significant decrease after Mt. Mazama tephra was deposited ~7600 cal BP. In the Middle Holocene deposits above a bone directly dated to ~6775 cal BP, there is a slight increase with another decrease in the Late Holocene deposits associated with a bone directly dated to ~4725 cal BP, followed by another increase.

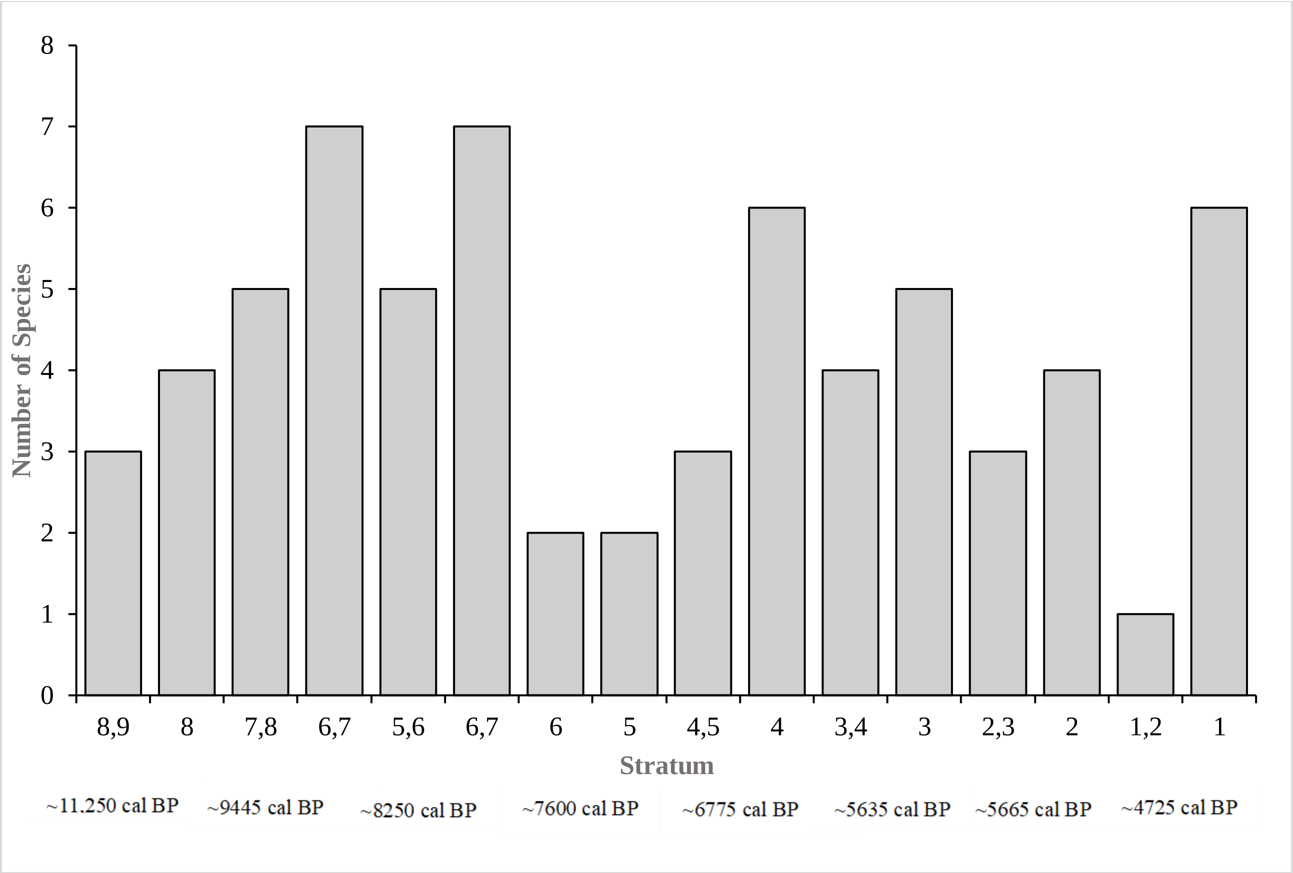

Figure 4.1. Species richness of the assemblage through time.

Relative Abundances

Next, I investigated the changing relative abundances of mesic and xeric adapted small mammals. Mesic adapted taxa included meadow voles, Townsend’s pocket gophers, bushy-tailed woodrats, Ord’s kangaroo rats, and western harvest mice (Table 3.3). The relative abundances of mesic adapted small mammals are variable throughout the Early Holocene deposits but lower than at any time after, with high abundances persisting throughout the Middle Holocene and at least the beginning of the Late Holocene (Figure 3.2); however, meadow voles, a mesic adapted taxon, dominated the sample. I initially suspected that their high occurrence throughout the deposits might have inflated the relative abundances of mesic adapted taxa; therefore, I removed meadow voles from my counts and calculated the relative abundances again. Without the meadow voles, the relative abundances demonstrated that there were no mesic adapted taxa in the sample after ~8250 cal BP, roughly the onset of the Middle Holocene. These results did not align with the high abundance of mesic adapted taxa throughout the Holocene when meadow voles were included (Figure 3.3). With the exception of the meadow voles, there were no mesic adapted small mammals in the assemblage after ~8250 cal BP.

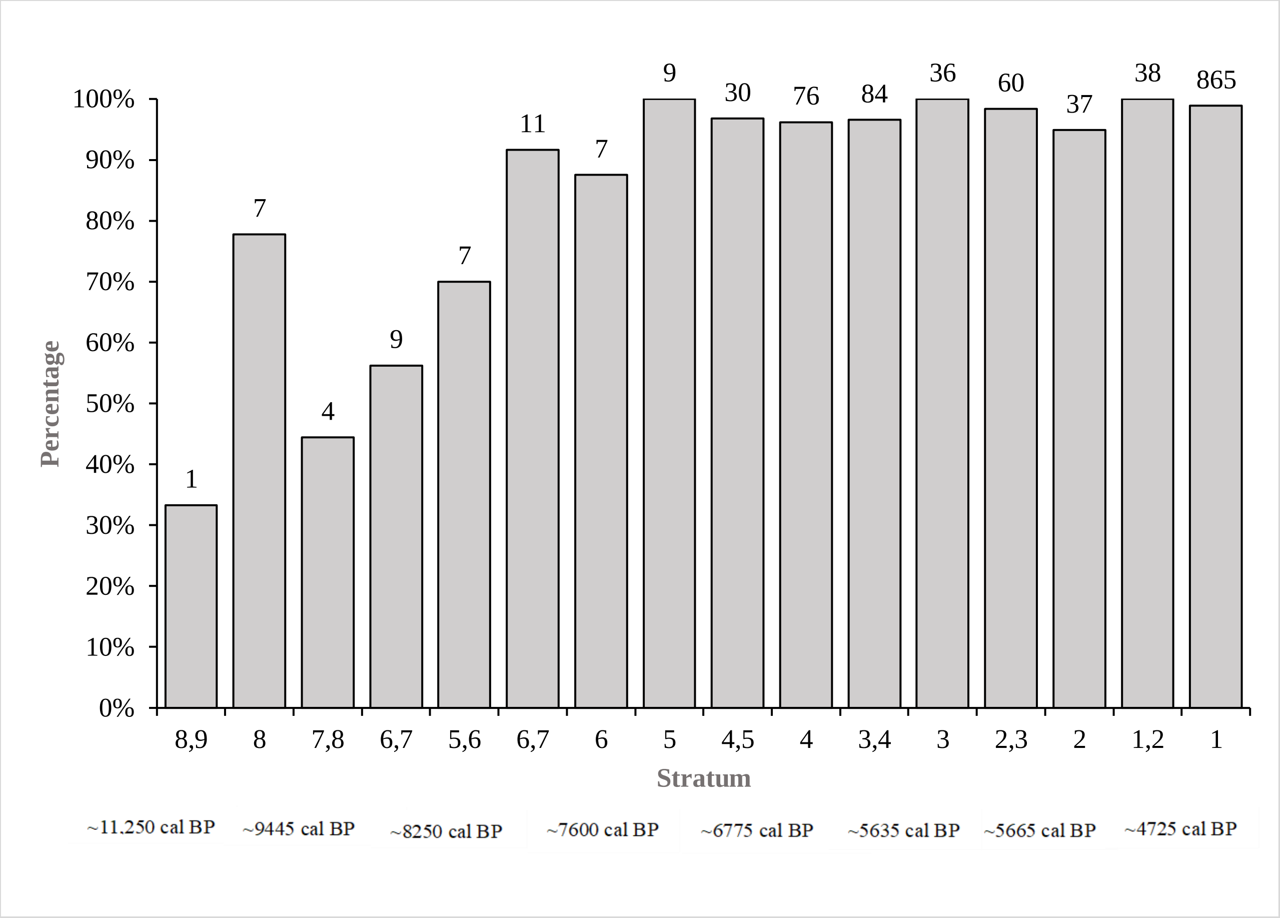

Figure 4.2. Abundances of mesic adapted species through time. The numbers atop each bar represents the NISP of mesic adapted small mammals in each stratum.

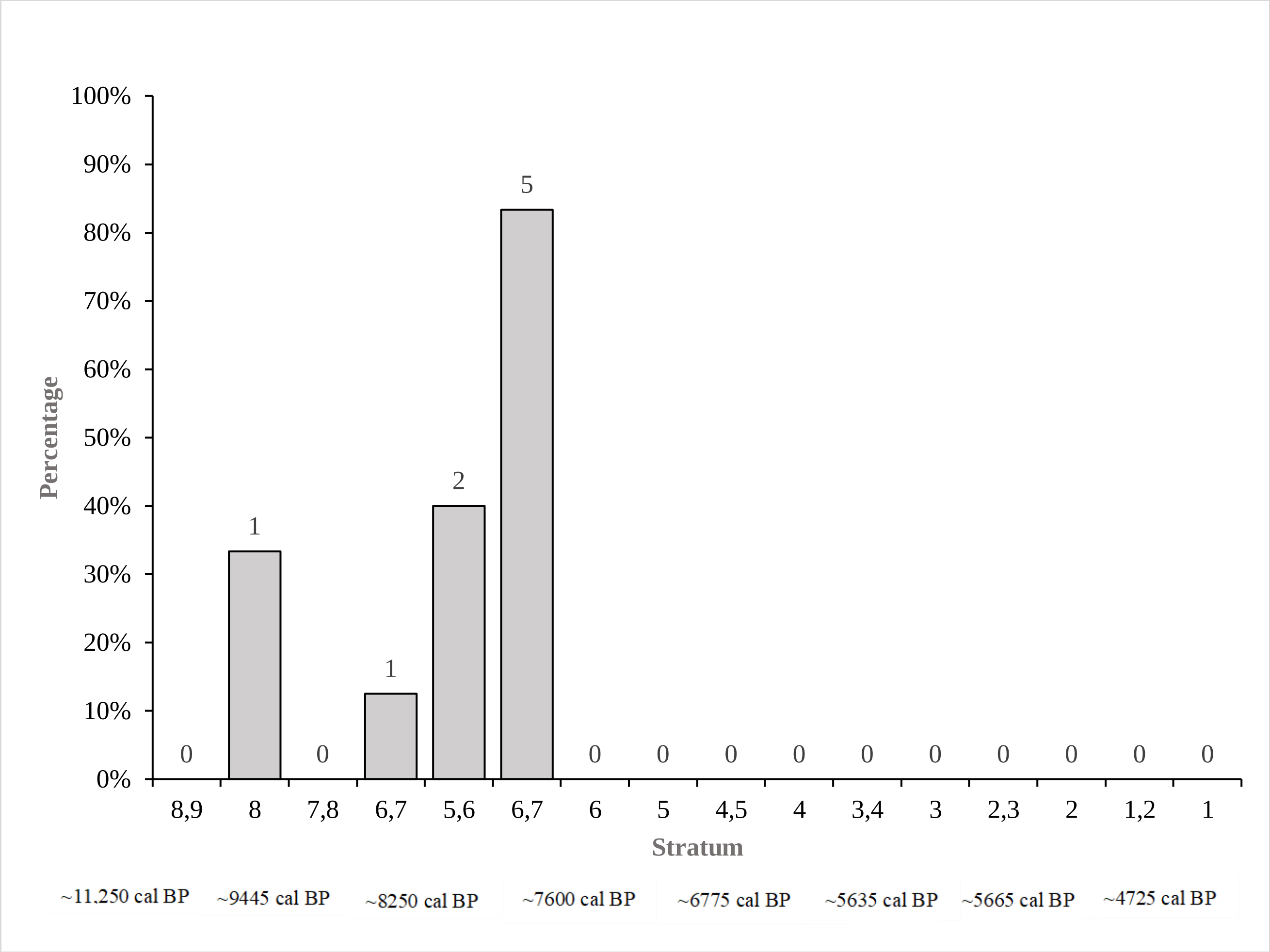

Figure 4.3. Abundances of mesic adapted species through time, excluding *Microtus* sp. The numbers atop each bar represents the NISP of mesic adapted small mammals in each stratum.

Table 4.3. Mesic Adapted Species Identified in the LRS Assemblage.

Species	**Common Name**
Microtus sp.	Meadow vole
Neotoma cinerea	Bushy-tailed woodrat
Thomomys townsendii	Townsend's pocket gopher
Dipodomys ordii	Ord's kangaroo rat
Reithrodontomys megalotis	Western harvest mouse

Xeric adapted taxa consisted of Merriam's kangaroo rats, chisel-toothed kangaroo rats, black-tailed jackrabbits, Desert woodrats, and Botta's pocket gophers (Table 3.4). Just as the mesic adapted small mammals demonstrated high relative abundances throughout the Middle and beginning of the Late Holocene, the xeric adapted mammals had low relative abundances throughout the Middle and beginning of the Late Holocene (Figure 3.4). The relative abundances of xeric adapted small mammals were higher during the Early Holocene than during any subsequent period, with low abundances throughout the Middle Holocene and beginning of the Late Holocene. Given that meadow voles dominated the assemblage and the low NISP in the Early Holocene, the relative abundances are of little interpretive value.

Table 4.4. Xeric Adapted Species Identified in the LRS Assemblage.

Species	**Common Name**
Dipodomys merriami	Merriam's kangaroo rat
D. microps	Chisel-toothed kangaroo rat
Lepus californicus	Black-tailed jackrabbit
Neotoma lepida	Desert woodrat
Thomomys bottae	Botta's pocket gopher

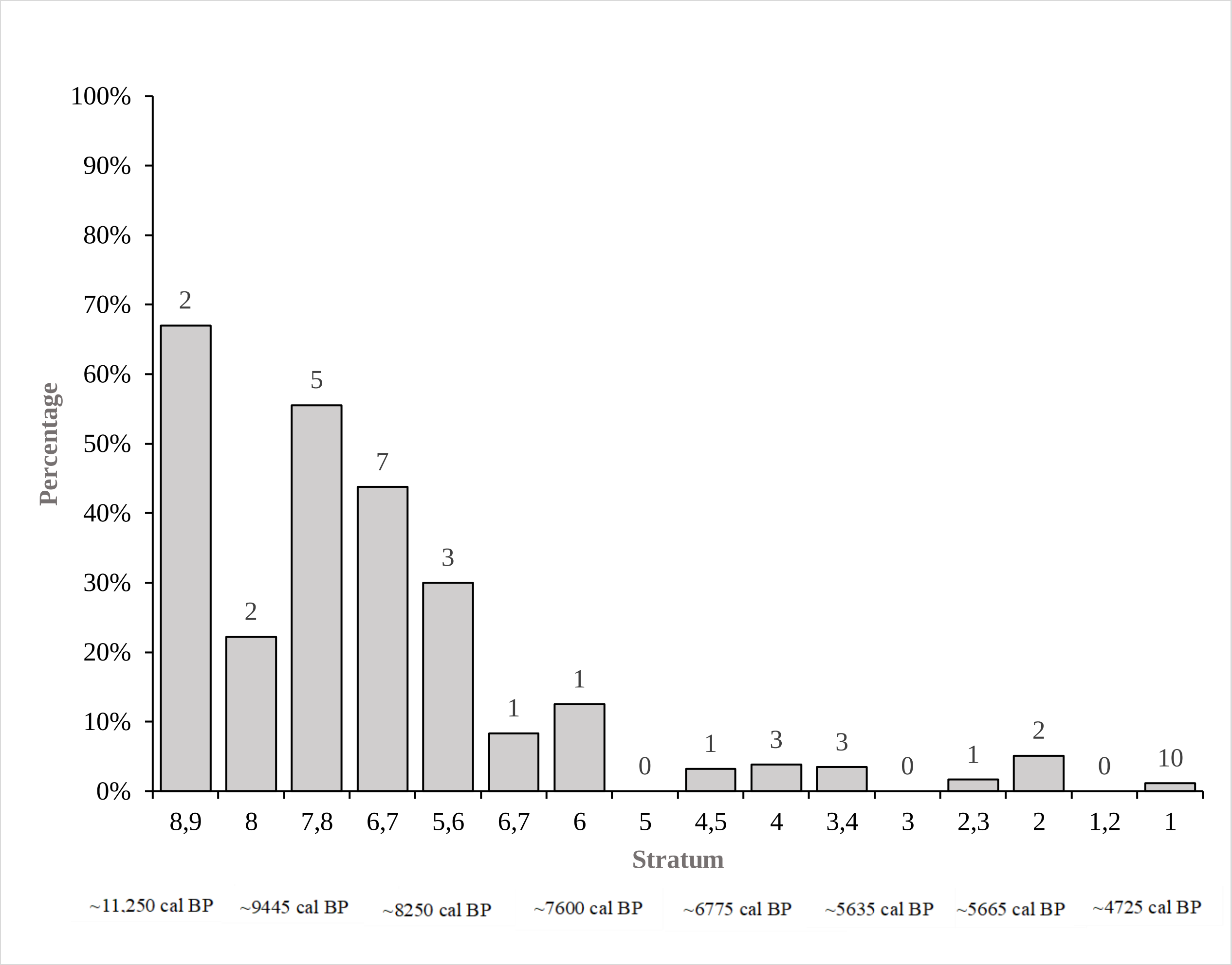

Figure 4.4. Abundances of xeric adapted species through time. The numbers atop each bar represents the NISP of mesic adapted small mammals in each stratum.

I investigated the changing relative and absolute abundances of several species to see if I could detect individual responses to climate change. I calculated the absolute and relative abundances of meadow voles, Townsend’s pocket gophers, Botta’s pocket gophers, chisel-toothed kangaroo rats, desert woodrats, and bushy-tailed woodrats. Meadow voles, a mesic adapted taxon, comprise the majority of the NISP identified in each stratum and their abundances are the highest of any species throughout the LRS deposits (Figure 3.5).

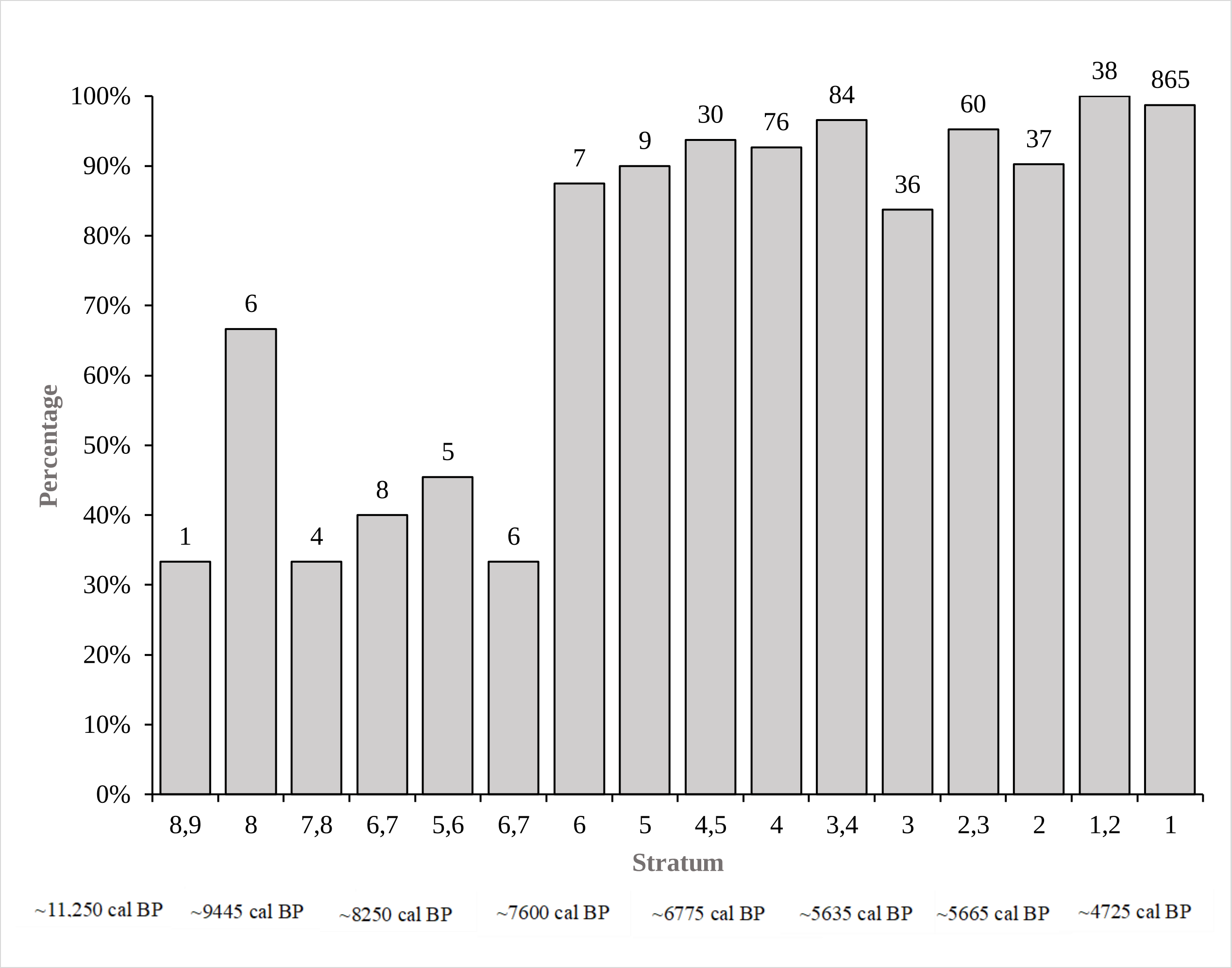

Figure 4.5. Abundance of *Microtus* sp. through time. The numbers atop each bar represents the NISP of *Microtus* sp. in each stratum.

Townsend’s pocket gophers are adapted to deep soils such as those found along the Humboldt River below LRS. They were present in low numbers during the Early Holocene but absent after ~8250 cal BP (Table 3.5). Botta’s pocket gophers, a xeric adapted taxon, were not present until the terminal Middle Holocene, ~5665 cal BP (Table 3.6). Their absolute abundance was highest during the Late Holocene, post-4725 cal BP, with three identified specimens in Stratum 1.

Table 4.5. Abundances of Townsend’s Pocket Gopher Through Time.

Relative Abundance of *Thomomys townsendii*	**Absolute Abundance of *Thomomys townsendii***	**Age of Deposits (cal BP)**
10%	1	~11,250 cal BP
14%	2	~9445 cal BP
14%	2	~8250 cal BP

Table 4.6. Abundances of Botta’s Pocket Gopher Through Time.

Relative Abundance of *Thomomys bottae*	**Absolute Abundance of *Thomomys bottae***	**Age of Deposits (cal BP)**
2%	1	~5665
2%	1	~4725
0.3%	3	Post-4725

Desert woodrats, a xeric adapted taxon, had relatively consistent but low abundances throughout the LRS deposits, with the highest abundance occurring during the Early Holocene (Table 3.7). Interestingly, I identified only one bushy-tailed woodrat, a mesic adapted taxon, in the Early Holocene deposits (~9445 cal BP). I am confident in my identification of the specimen because I used the alveolar lengths to speciate woodrats and the length of the maxillary alveolar length was 10.06 mm, well within the range of bushy-tailed woodrats (>9.3-11.4 mm) (Grayson 1985).

Table 4.7. Abundances of Desert Woodrat Through Time.

Relative Abundance of *Neotoma lepida*	**Absolute Abundance of *Neotoma lepida***	**Age of Deposits (cal BP)**
33%	1	~11,250
27%	4	-
17%	5	~9445
14%	2	-
1%	1	~5665
0.2%	2	Post-4725

Chisel-toothed kangaroo rats are a xeric adapted taxon known for their distinctive incisors (Hall 1995). I identified one chisel-toothed kangaroo rat specimen in roughly half of all strata spanning the Early to Late Holocene deposits (Table 3.8). I also identified single examples of Ord’s kangaroo rat and western harvest mouse from the stratum 6/7 deposits, which date to the onset of the Middle Holocene (~8250 cal BP). Ord’s kangaroo rats are adapted to an arid climate but often occupy sagebrush habitats. Western harvest mice also occupy arid climates but are mostly restricted to habitats with thick grass understories near water (Hall 1995; Schmitt and Lupo 2012). Except for meadow voles, none of the individual species occurred in high enough abundances to investigate their individual responses to climate change.

Table 4.8. Abundances of Chisel-toothed Kangaroo Rat Through Time.

Relative Abundance of *Dipodomys microps*	**Absolute Abundance of *Dipodomys microps***	**Age of Deposits (cal BP)**
33%	1	-
11%	1	~11,250
6%	1	~9445
10%	1	-
8%	1	~8250
1%	1	~5635
1%	1	-
0.11%	1	Post-4725

Shannon Weaver Diversity Index

Given the low absolute and relative abundances of the climate indicative species described above, I employed the S-W Index, which calculates diversity to investigate changes in the assemblage composition through time. The diversity values (*H'*) were higher in the Early Holocene deposits (~11,250 cal BP) and initial Middle Holocene deposits (~8250 cal BP) than at any time after (Table 3.9). After Mt. Mazama tephra fell ~7600 cal BP, there was a pronounced decrease of diversity, with a value of 0.37. Low diversity values continued throughout the Middle Holocene, with a slight increase of 0.65 ~5665 cal BP and remained consistently low throughout the initial Late Holocene deposits.

The S-W Index can also measure evenness (H'/H_{max}), which I used to investigate the changes in biotic communities through time. By tracking the evenness of the assemblage, I was able to investigate the decreases of species in the ecosystem better than by examining absolute and relative abundances alone (Hillebrand et al. 2008). The evenness values, much like the diversity values, are high within the Early Holocene and initial Middle Holocene (see Table 3.9). After Mt. Mazama tephra was deposited, evenness also decreased sharply and generally stayed low throughout the Middle and Late Holocene, except ~5665 cal BP when there was a slight increase of evenness, followed by another decrease for the beginning of the Late Holocene.

Table 4.9. Shannon Weaver Diversity Index and Evenness Values Through Time.

H’	**Evenness**	**Period**	**Age of Deposits (cal BP)**
0.087	0.048		
0.000	0.000	Late Holocene	
0.421	0.304		
0.222	0.202		~4725
0.652	0.405		
0.248	0.136		~5665
0.376	0.210		
0.405	0.252	Middle Holocene	~5635
0.325	0.469		~6775
0.377	0.544		~7600
1.754	0.901		~8250
1.414	0.727		
1.597	0.821		
1.445	0.898	Early Holocene	~9445
1.003	0.723		
1.099	1.000		~11,250

Revised SPD for LRS

To address the shortcomings of Heizer’s radiocarbon date sample, I combined his dates on fiber and wood artifacts with the 12 dates I recently obtained on artifacts stored in UCB’s Phoebe Hearst Museum (see Table 2.6.). Figure 3.6 presents a revised SPD for LRS based almost exclusively on directly dated artifacts; it also includes a date of

9835±45 ^{14}C BP (11,325-11,190 cal BP) associated with the obsidian biface from Stratum 8. The revised SPD demonstrates that there were several peaks during the Early Holocene and suggests that people visited LRS as early as ~11,300 cal BP and again ~9500 cal BP. It also demonstrates several peaks and troughs beginning ~8500 cal BP and concluding ~7800 cal BP. According to the SPD, there was a hiatus in occupation ~6000-3000 cal BP. There is a peak ~3000 cal BP. After ~3000 cal BP, several peaks suggest repeated visits to the site, mostly between ~2500 and ~1500 cal BP, with one also occurring just before Euro-Americans arrived in the region.

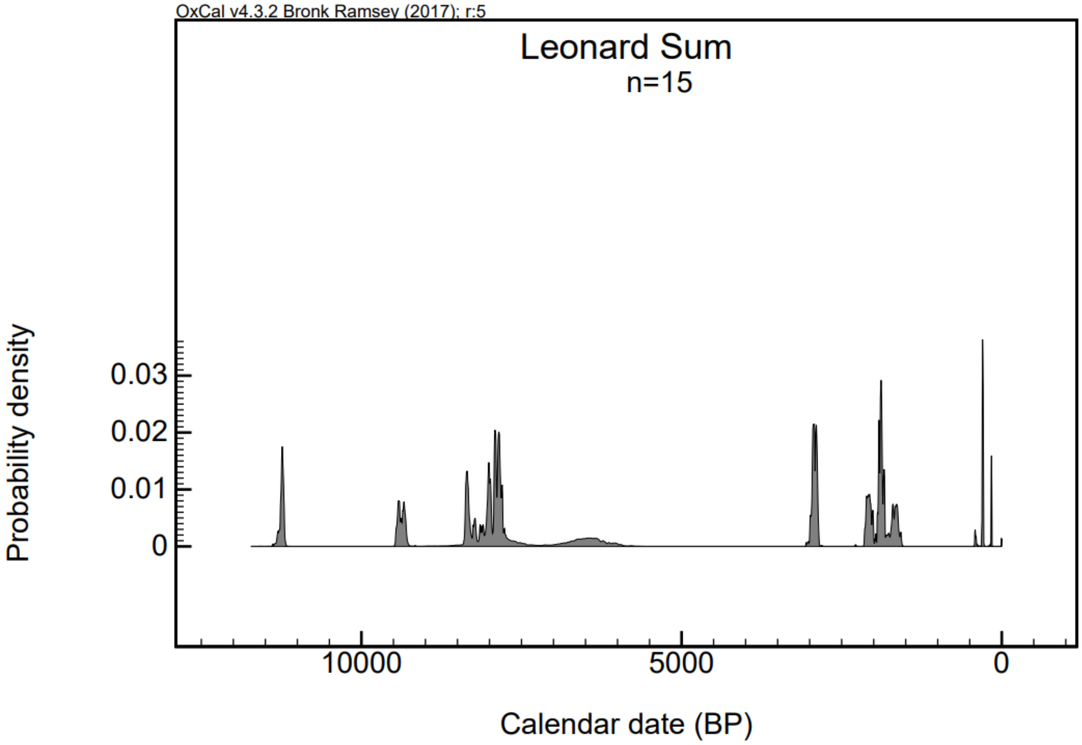

Figure 4.6. Updated summed probability distribution of radiocarbon dates obtained on fiber artifacts (*n*=14) or strata associated with artifacts (*n*=1). Sample includes two dates that Heizer obtained on artifacts (7038±350 and 5650±250 ^{14}C BP).

CHAPTER 4

Discussion

This study explores how the small mammal record from LRS adds to our understanding of changing conditions in the Humboldt Sink. It also adds to our understanding of how and when humans used the site. In this chapter, I discuss my results and how they relate to the following hypotheses:

(1) LRS possesses a paleoenvironmental record that demonstrates changes in local conditions throughout the Holocene;

and

(2) LRS possesses a record of human occupation spanning the Holocene

The Small Mammal Record at LRS

Species richness in the Early Holocene deposits demonstrated increasing values from ~11,250 cal BP to ~9445 cal BP, with gradual decreases by the onset of the Middle Holocene (8300 cal BP) (Table 4.1). A marked decrease did not occur until Mt. Mazama tephra was deposited ~7600 cal BP, suggesting that the xeric conditions that characterized the Middle Holocene (Grayson 2011; Louderback et al. 2010) did not begin until ~700 years after the onset of that period. Richness increased slightly after ~6775 cal BP and remained fairly consistent until the Late Holocene.

Table 5.1. Hypothesis, Expectations, Analyses, and Results.

Hypothesis	**Expectations**	**Analysis**	**Met?**
H1: LRS possesses a paleoenvironmental record that demonstrates changes in local conditions throughout the Holocene	Small mammal sample will have high richness in the Early Holocene, with low richness in the Middle and Late Holocene	Richness	Yes
	High diversity and evenness values in the Early Holocene with decreases in the Middle and Late Holocene	Shannon-Weaver Index	Yes
	High abundance of mesic adapted fauna in the Early Holocene and more xeric adapted fauna in the Middle and Late Holocene	Relative and Absolute Abundance	No
	Small mammal sample will align with Byrne et al.'s (1979) pollen record	NA	Yes
H2: LRS possesses a record of human occupation spanning the Holocene	Directly dated artifacts and artifacts from data strata will span the entire Holocene	SPD	Yes

In Stratum 1/2, dated to ~4700 cal BP, I identified only one species, the meadow vole, which produced the lowest richness of any stratum. The overlying Stratum 1 showed a marked increase with six identified species. The sudden decrease followed by a significant increase could reflect the variable climate of the Late Holocene (Adams 2003; Benson et al. 2002; Mensing et al. 2004; Stine 1994); however, intact Late Holocene deposits, which LRS generally lacked in our excavation area, are needed to further investigate this possibility.

The evenness and diversity values in the Early Holocene deposits fluctuated, with *H'* values between 1 and 1.6, which are higher than any time after the deposition of Mt. Mazama tephra. Interestingly, diversity was highest in the deposits dating to the initial Middle Holocene (~8250 cal BP) with an *H'* value of 1.75, but it decreased to 0.38 by the time Mt. Mazama tephra fell. Unsurprisingly, evenness was also high in the Early Holocene, with values ranging from 0.72 to 1, with 1 being complete evenness. Low evenness continued throughout the Middle and Late Holocene.

There was one significant increase in diversity (*H'*=0.65) after ~5665 cal BP. It may be the result of intermittent floodplain aggradation along the Humboldt River that occurred between ~5500 and 3500 cal BP (Miller et al. 2004), which may have made the valley floor below LRS more favorable to more taxa, at least in the short-term.

The relative abundance of mesic adapted mammals in the Early Holocene deposits demonstrated a different pattern than the richness and diversity values. Their relative abundance increased from 33% to 79% ~11,250 cal BP and decreased to 44% directly after that time. By ~9445 cal BP, the relative abundances of mesic adapted species began to increase again. They continued to have high relative abundances throughout the Middle and initial Late Holocene deposits, with values ranging from 88% to 100%. I expected the relative abundances of mesic adapted species to be higher in the Early Holocene than subsequent periods; however, this was not the case. There were consistently higher relative abundances of mesic adapted mammals throughout the Middle and Late Holocene deposits, with lower and more variable relative abundances during the Early Holocene.

The relative abundances of the LRS small mammals suggest that the Early Holocene was more xeric than the Middle and Late Holocene, which counters our current understanding of Early Holocene conditions in the Lahontan basin (Adams et al. 2008; Byrne et al. 1979; Grayson 2011; Wigand and Mehringer 1985). Furthermore, they do not align with the higher richness, diversity, and evenness values for that period discussed above. As I noted in the preceding chapter, I suspected that the dominance of meadow voles in the assemblage inflated the relative abundances of mesic adapted taxa. This pattern was not unexpected since meadow voles are a primary component of owls' diets (Livingston 1988) and the LRS small mammal sample is largely or wholly derived from owl pellets. When I removed the meadow vole from my calculations, there was no discernable pattern of changing relative abundances throughout the deposits. The absence of patterning likely means that the overrepresentation of mesic adapted species in the Middle and initial Late Holocene deposits can be attributed to the abundance of meadow voles in assemblage. Given that meadow voles dominate the sample, there is little to no interpretive value of relative abundances for the LRS assemblage.

Along with the meadow voles, I identified four other mesic adapted species in the Early Holocene deposits: (1) Townsend's pocket gopher (*n*=3); (2) bushy-tailed woodrat (*n*=1); (3) western harvest mouse (*n*=1); and (4) Ord's kangaroo rat (*n*=2). None of these mesic adapted mammals occurred in the Middle and initial Late Holocene deposits. The Townsend's pocket gopher is restricted to lacustrine deposits along the Humboldt River corridor, with soil depth being the most critical factor (Hall 1995). Given that I only identified Townsend's pocket gopher in the Early Holocene deposits, it may be that conditions were most optimal along the Humboldt River during that period. It is important to note, however, that my sample of Townsend's pocket gophers is extremely small.

Today, bushy-tailed woodrats mostly occupy the Boreal Zone and are only found in cool environments at lower elevations, usually among dense shade near water (Hall 1995). I identified only one bushy-tailed woodrat in the LRS sample. The bushy-tailed woodrat's sole occurrence in the Early Holocene deposits could suggest that the climate was cooler during this time; however, again my sample size was very small. I also only identified one western harvest mouse in the LRS sample. The western harvest mouse prefers moist habitats that have a thick grass understory (Hall 1995; Webster and Jones 1982), which further suggests that the environment in the Humboldt Sink during the Early Holocene provided a somewhat favorable climate for the mesic adapted taxa.

Kangaroo rats are adapted to arid settings, which means that the Ord's kangaroo rat habitat is less tied to a mesic environment (Hall 1995). However, unlike the chisel-toothed kangaroo rat, with their distinctive incisors used to shave off the saline faces of shadscale leaves, the Ord's kangaroo rat is primarily a granivore and is more common in mesic, sagebrush habitat (Grayson 2000a; Hall 1995; Hayssen 1991). I only identified two Ord's kangaroo rats and given that they can also tolerate arid environments, their presence in the Early Holocene deposits suggests that the climate was not as cool as the other small mammals discussed above suggest. Furthermore, I also identified several xeric adapted chisel-toothed kangaroo rats in the Early Holocene deposits, which suggests that there were shadscale communities near LRS during the Early Holocene. Nevertheless, the occurrence of the Ord's kangaroo rat suggests an Early Holocene habitat around LRS that contained more sagebrush than today, which the Hidden Cave pollen record also implies (Wigand and Mehringer 1985).

I also identified three xeric adapted species in the Middle and Late Holocene deposits: (1) Botta's pocket gopher (*n*=5); (2) desert woodrats (*n*=15); and (3) chisel-toothed kangaroo rats (*n*=8). The Botta's pocket gopher is a xeric adapted taxon tolerant of high temperatures and today is most common in lower valleys (Hall 1995). I identified Botta's pocket gophers in the terminal Middle and initial Late Holocene deposits. Although they occur in low numbers throughout those deposits, they were absent in the Early Holocene deposits and did not appear until ~5665 cal BP. This suggests a more xeric environment around the shelter during the Middle and Late Holocene, which supports my first hypothesis.

The desert woodrat is also a xeric adapted taxon. It displayed relatively consistent but low abundances throughout the deposits, with the highest abundance (*n*=5) occurring during the Early Holocene ~9445 cal BP. Although desert woodrats are xeric adapted, they can occupy the same areas as bushy-tailed woodrats if there is enough water and cover for the latter (Hall 1995). Given the presence of both species in the Early Holocene deposits, the local environment was likely amenable to both desert and bushy-tailed woodrats, but perhaps only for a short time since I only identified one bushy-tailed woodrat.

The xeric adapted chisel-toothed kangaroo rat is present throughout the LRS deposits, suggesting a somewhat hot and arid climate throughout the Holocene, a possibility that is also supported by the presence of desert woodrats. This does not mean that the Early Holocene was less mesic than later times but may indicate that some xeric adapted plants and animals were able to occupy the area around the shelter during the Early Holocene. The richness, diversity, evenness, and presence of xeric adapted species in the Middle and Late Holocene deposits demonstrated that the climate shifted after ~7600 cal BP. Increased temperatures and aridity continued throughout the Middle and Late Holocene, which is in line with my first hypothesis.

I also expected the signature provided by the small mammal record to align with that provided by Byrne et al.'s (1979) pollen study, which pointed to a more mesic Early Holocene, xeric Middle Holocene, and mesic Late Holocene. Their work showed that the lower levels of the pollen sample had more pine, indicating a more mesic environment in the Early Holocene, contradicting what Heizer (1951) initially interpreted as the dry Middle Holocene; however, given that Byrne et al.'s (1979) pollen sample did not extend into Heizer's stratigraphic Unit D (see Chapter 2), and our radiocarbon dates from directly dated artifacts from Unit D date to the Early Holocene and initial Middle Holocene (see Table 2.6), the lower levels of the pollen sample likely mark the Middle Holocene. This means that Heizer's original interpretation of Unit C being of Middle Holocene age is correct and Byrne et al.'s (1979) pollen study cannot tell us about Early Holocene conditions. It is possible that the higher pine pollen levels in the Middle Holocene deposits mark the time before Mt. Mazama's eruption – a period that the small mammal record suggests was relatively mesic.

Byrne et al. (1979) described a "pine minimum" characterized by increased Cheno/Am pollen ~6000-4000 ^{14}C BP (~6800-4500 cal BP). Although Byrne et al. (1979) stated that the Cheno/Am dominance began ~6800 cal BP, they acknowledge that that date was just a rough approximation. Based on the small mammal record at LRS, the "pine minimum" more likely began closer to ~7600 cal BP when Mazama tephra was deposited. Unfortunately, given that I was unable to confidently correlate the majority of Heizer's (1951) strata on which Byrne et al. (1979) based their study, I cannot explore this possibility further.

After the pine minimum, pine levels increased, suggesting a return to more mesic conditions. Unfortunately, due to the removal of Late Holocene deposits at LRS during Heizer's excavations, the small mammal record cannot address this topic. Our excavations did include deposits dating to the initial Late Holocene, but the fauna from those levels did not indicate a return to more mesic conditions. Instead, they more closely conform to the pollen sequence from Hidden Cave, which showed unchanging shadscale dominance since 7000-6000 cal BP (Wigand and Mehringer 1985).

The LRS Fauna in a Broader Context: The Paleoenvironmental Record of the Lahontan Basin

Numerous paleoenvironmental studies have demonstrated that conditions were variable in the Lahontan Basin over the past ~15,000 years (Adams 1997, 2003; Adams et al. 2008; Adams and Rhodes 2019a, 2019b; Adams and Wesnousky 1999; Benson and Thompson 1987; Benson et al. 1992; Briggs et al. 2005; Byrne et al. 1979; Mensing et al. 2004, 2008; Morrison 1991; Nowak et al. 1994; Rhode 2003; Wigand and Mehringer 1985). My analysis of the LRS small mammal assemblage was aimed at contributing our understanding of changing conditions in Humboldt Sink. While some of the interpretations I provide here are tenuous due to sample size issues, they nevertheless add to the bigger picture.

The small mammal record from LRS does not provide information on Terminal Pleistocene conditions because Lake Lahontan inundated the rockshelter during the Younger Dryas; however, our work identified that Heizer's estimate of site elevation and, in turn, the age of the beach gravels within LRS was incorrect. The inundation of LRS during the Younger Dryas signifies a time of high lake levels (1230-1235 m ASL) and more moisture than later periods (Adams et al. 2008). Other records paint a similar picture. Along the middle Humboldt River, the Terminal Pleistocene sequence contained cross-bedded meander-belt gravels indicative of a large meandering river, which continued until ~10,800 cal BP (Miller et al. 2004).

At the TP/EH boundary, pollen from Hidden Cave provided evidence of changing conditions. The record shows that there was a decline in pine and sagebrush pollen, signaling increasing temperatures – a shift that occurred across the Great Basin (Mehringer 1977). Lake levels decreased to ~1200 m ASL after the Younger Dryas highstand of 1230-1235 m ASL (Adams et al. 2008). They further transgressed below ~1200 m ASL at least once during the Early Holocene as evidenced by preserved textiles dated to ~10,800 cal BP at Grimes Point (Adams et al. 2008). The middle Humboldt River witnessed slow aggradation during the Early Holocene, which suggests a persistent moist environment that likely continued to support mesic adapted mammals such as Townsend's pocket gopher (Miller et al. 2004).

The LRS fauna demonstrate that both xeric adapted species (e.g., desert woodrat and chisel-toothed kangaroo rat) and mesic adapted species (e.g., Townsend's pocket gopher, bushy-tailed woodrat, western harvest mouse, Ord’s kangaroo rat) lived in the Humboldt Sink during the Early Holocene. Their coexistence suggests that there was a mosaic of drought-tolerant shadscale communities and sagebrush steppe within a few kilometers of LRS at that time. This variation in vegetation communities may have been primarily along an elevational grade, with shadscale occurring more on the valley floor and sagebrush occurring more in the West Humboldt Range, or along a horizontal grade, with sagebrush being more common along the Humboldt River and shadscale being more common elsewhere.

The onset of the Middle Holocene is often placed at ~8300 cal BP (e.g., Grayson 2011); however, the LRS fauna do not demonstrate a marked shift to xeric conditions at that time. Stratum 6/7, dated to ~8250 cal BP, possessed the highest diversity value in my sample (H'=1.75). A sharp decrease in diversity, which may signal a shift to drier conditions, did not occur until ~7600 cal BP (H'=0.38). Other records from the Lahontan basin support the possibility of a delayed shift to more xeric conditions (Byrne et al. 1979; Miller et al. 2004; Wigand and Mehringer 1985). The Hidden Cave pollen record showed fairly consistent amounts of sagebrush throughout the Early Holocene and until at least 6500 ^{14}C BP (~7400 cal BP) (Wigand and Mehringer 1985). After that time, shadscale increased around Hidden Cave. As I outlined earlier, Byrne et al. (1979) argued that a “pine minimum” took place ~6800-4500 cal BP; however, our work suggests that the deposits in which that event is represented may actually date to as early as ~7600 cal BP. The middle Humboldt River experienced its driest period beginning ~7600 cal BP, with a period of minimal floodplain aggradation ~6300 cal BP (Miller et al. 2004). Finally, the pollen record from Pyramid Lake suggests that 7600-6300 cal BP was an especially dry period (Mensing et al. 2004). Together, these lines of evidence suggest that the Lahontan basin, particularly the Humboldt and Carson sinks, did not witness a shift to xeric conditions until ~7600 cal BP, 700 years or so after researchers generally place the start of the Middle Holocene.

The LRS fauna show one significant increase in diversity (*H’*=0.65) near the end of the Middle Holocene, ~5665 cal BP. This value is lower than the Early Holocene values and it may correspond to increased fluvial activity along the Humboldt River ~5500-3500 cal BP (Miller et al. 2004) and a more general move away from dry conditions in the region suggested by the Pyramid Lake pollen record (Mensing et al. 2004). The LRS sample shows that shortly after 5665 cal BP, diversity decreased to (*H’*=0.22), rebounded slightly (*H’*=0.42), and then decreased again (*H’*=0). This variability in diversity suggests that the LRS small mammal record does not clearly reflect a major decrease in aridity and increase in moisture between ~5500 and 3500 cal BP. Instead, it only suggests more mesic conditions ~5665 cal BP.

Because our excavation area lacked the majority of the Late Holocene record, the LRS fauna cannot provide information about most of that period. The latest date for my sample is ~4725 cal BP. In the deposits directly post-dating ~4725 cal BP, the diversity value was 0.00 and meadow voles were the only identified taxon. Species richness is variable, with five species in the deposits dating to ~4725 cal BP and one species (meadow vole) identified in the deposits immediately postdating ~4725 cal BP. The uppermost Stratum 1 contained six species. The low diversity values and variable species richness in the initial Late Holocene deposits may demonstrate variable local conditions but it is hard to know for certain with such a limited sample.

The Place of LRS in Lahontan Basin Prehistory

Heizer never published a complete report of his excavations at LRS despite recovering a diverse collection of basketry, shell beads, and obtaining a Terminal Pleistocene radiocarbon date on deposits purportedly containing artifacts. Over the years, LRS has featured prominently in various studies including broad treatments of lake histories, the peopling of the Lahontan basin (e.g., Adams et al. 2008), and shell bead exchange (Bennyhoff and Hughes 1987); however, the lack of detailed reporting and nature of the radiocarbon dates from the site (a few dates possessing large errors obtained on less-than-ideal samples) has made placing LRS into a broader context difficult. As part of my work, I directly dated a range of perishable items housed at UCB in addition to organic materials recovered during our excavations (see Table 2.6). The new dates provided an opportunity to gain a better understanding of when people occupied the rockshelter and it fits into the archaeological record of the region.

Given the range of items that Heizer (1951) reported and present in the UCB collection, I hypothesized that LRS contained a record of human occupation that spanned the Holocene. Our 2018 and 2019 excavations demonstrated that people likely did not occupy LRS during the Terminal Pleistocene because the rockshelter was inundated during the Younger Dryas. Heizer’s (1951) radiocarbon dates on bat guano associated with artifacts, three dart foreshafts, and carbonized basketry (see Table 2.1) suggest that people occupied the site during the Early and Middle Holocene, although their very large errors made knowing precisely when difficult. While Heizer did not obtain any radiocarbon dates for his uppermost stratum, Unit A, he recognized that the artifacts contained within it were similar to those from Lovelock Cave and as such likely postdated ~5000 cal BP.

Our new radiocarbon dates fill in the gaps in LRS's record of human occupation. The directly dated textiles and the date associated with the reworked obsidian biface from Stratum 8 indicate that people visited the site several times during the Early Holocene beginning as early as ~11,300 cal BP. These new dates demonstrate that the Early Holocene pattern at LRS fits current models of Early Holocene prehistory in the Lahontan basin. Given the corrected elevation of LRS (1224.5 m ASL) and presence of the obsidian biface in deposits dated to ~11,300 cal BP, LRS joins the list of TP/EH sites that fall between 1200 and 1235 m ASL (Mohr 2018). The obsidian biface is made of obsidian that originated 180 km to the northwest, which supports current models of TP/EH lifeways that stress high mobility (Smith and Barker 2017 and references therein). Finally, the apparently ephemeral nature of the earliest visits to LRS similarly support the idea that early populations were mobile.

Several items including a complete atlatl dart, a piece of cordage, and a piece of worked wood returned dates around the Early-to-Middle Holocene transition. Of note, in addition to recovering the complete atlatl dart which we recently dated, guano miner Tom Derby also recovered a string of 50 *Olivella* shell beads from the guano layer. Our new direct radiocarbon date on cordage from the same guano layer suggests that the shell beads also date to ~8000 cal BP. If that is indeed the case, then it supports Bennyhoff and Hughes' (1987) argument that the western Great Basin served as a major shell redistribution center beginning as early as ~8000 cal BP. Furthermore, it adds to the list sites containing early shell beads in the Great Basin (Fitzgerald et al. 2005; Smith et al. 2016).

None of the artifacts that we submitted for dating returned Middle Holocene ages later than ~7700 cal BP; however, the carbonized basketry from Unit C that Heizer (1951) submitted for radiocarbon dating returned a date of 5650±250 ^{14}C BP (7630-5915 cal BP). Given the date's large error, it is hard to know the artifact's true age. If it dates to the early end of the two-sigma range, then it corresponds with other directly dated artifacts. Conversely, if it dates to the middle or later end of the range, that is significant because there are currently no other directly dated artifacts between ~7700 and ~3000 cal BP (see Table 4.1). Regardless, the carbonized basketry dates to the Middle Holocene, which makes it somewhat of an outlier. Only Heizer's carbonized basketry date suggests that humans visited LRS during the Middle Holocene.

Of note, the revised SPD for LRS has a small number of radiocarbon dates (*n*=15), and it may be missing occupations from the Middle Holocene. However, Middle Holocene deposits are not missing from LRS, as Byrne et al. (1979) stated that the windblown silt in the rockshelter's deposits were likely blown in from the deflated Humboldt Sink sediment during the Middle Holocene. This means that LRS contains Middle Holocene deposits and the gap in occupation during the Middle Holocene is likely a factor of groups not visiting the site. This fact fits well with Louderback et al.'s (2010) study of radiocarbon date frequencies, which point to very low human population levels at that time. Frequencies of time-sensitive projectile points at sites around LRS also suggest that this was the case (Table 4.2): Northern Side-notched and Gatecliff points are fairly rare whereas Rosegate and Desert Series points are fairly abundant. The

LRS small mammals and other paleoenvironmental records from the Lahontan basin suggest that the Middle Holocene may have been especially hard times for groups in the region (Grayson 2011; Louderback et al. 2010).

Table 5.2. Projectile Point Frequencies at Sites within 20 km of LRS. Date Ranges Adapted from Thomas (1981, 2013).

Point Type	**Age Range (cal BP)**	**N**
Northern Side-notched	7650-5700	1
Gatecliff Series	6000-3500	75
Humboldt Series	5000-1300	191
Elko Series	3500-1000	142
Rosegate	1300-700	754
Desert Series	Post-700	435

Seven of the recently dated artifacts postdate ~3000 cal BP, suggesting that the most intensive occupation at LRS occurred during the Late Holocene. The abundance of Late Holocene dates at LRS generally corresponds to the archaeological record of the Lahontan basin. The earliest radiocarbon date from the nearby Humboldt Lakebed Site is ~3200 cal BP, roughly the same time that people started to use LRS more frequently or more intensively. The Humboldt Lakebed Site saw increased use ~1300 cal BP, which Livingston (1988) argued was due to groups more intensively occupying wetlands around that time. Stillwater Marsh contains a record of human occupation dating to ~3000-650 cal BP (Kelly 2001). The first occupations took place roughly around the same time that people returned to LRS and occupations began at the Humboldt Lakebed Site. Increased use of Stillwater Marsh began ~1500 cal BP, with most dates falling between ~1500 and 750 cal BP. The marsh likely housed residential sites, although there were few prepared hearths or houses, suggesting that groups did not live there year-round. Rhode's (2003) coprolite study demonstrated that groups used Hidden Cave at times when Stillwater Marsh was inundated, primarily to cache equipment.

These open-air and cave sites provide a framework within which to understand LRS in a regional context. They demonstrate that groups likely began to casually exploit marsh resources and establish temporary residential occupations around these locations ~3000 cal BP. Based on directly dated artifacts, groups seem to have started to visit LRS more frequently. Like other caves and shelters in the area, LRS may have seen groups cache their gear during periods when it was not needed; however, it differed in at least one important way. LRS lacks tools like duck decoys, nets, fishhooks, and other tools clearly tied to lake or marsh resource exploitation. This difference may be related to the fact that LRS is located high on the north side of the West Humboldt Range and a considerable and difficult walk from the nearest wetland. After ~1500 cal BP, when groups began to focus more on wetlands in the Lahontan Basin, groups generally seem to have visited LRS far less frequently.

CHAPTER 5

Conclusions

Heizer (1951) presented an early radiocarbon date of 11,199±570 ^{14}C BP (14,901-11,610 cal BP) in association with obsidian flakes in his preliminary report on LRS. He stated that this early date might be evidence of a Terminal Pleistocene occupation at LRS. In 2018 and 2019, the GBPRU returned to LRS to explore this possibility. During our excavations we discovered that the rockshelter sits at a lower elevation than Heizer and colleagues believed. This discrepancy means that the rockshelter was inundated during the Younger Dryas. If there was any evidence of a Terminal Pleistocene occupation, it was likely washed away during the last highstand.

Our excavations uncovered few artifacts but produced an extensive small mammal assemblage, which adds to our understanding of changing conditions in the Humboldt Sink throughout the Holocene. My analysis of the small mammal record demonstrates that the climate was more mesic during the Early Holocene and onset of the Middle Holocene than later periods. Following the eruption of Mt. Mazama ~7600 cal BP, the composition of the assemblage shifted to taxa adapted to more xeric conditions. While my sample lacked a substantial Late Holocene component because Heizer's excavations removed most of those deposits, it did include some remains from the initial Late Holocene. My analysis suggests that there was not an immediate or marked transition to more mesic conditions at the end of the Middle Holocene, as other paleoenvironmental and archaeological records have suggested (Adams and Rhodes 2019a, 2019b, Byrne et al. 1979; Kelly 1997, 1999, 2001; Livingston 1988; Louderback et al. 2010; Mensing et al. 2004, 2008; Miller et al. 2004, Nowak et al. 1994; Rhode 2003; Stine 1994; Thomas 1985).

The new suite of radiocarbon dates on fiber artifacts supplements and refines our understanding of when people visited LRS. An obsidian biface recovered just above the Younger Dryas beach gravels indicates that people most likely first visited the site during the Early Holocene, not the Terminal Pleistocene as Heizer suggested long ago. Groups appear to have revisited the site periodically throughout the Early Holocene, and at least once during the Middle Holocene. This period corresponds with the hot and dry Middle Holocene when, overall, human populations seem to have been low in the Western Great Basin (Louderback et al. 2010).

Numerous dates after 3000 cal BP suggest a renewed use of LRS, with a period of relatively heavy use between 3000 and 1700 cal BP. None of the artifacts are clearly attributable to the Lovelock Culture. Together, the lack of debris signaling prolonged human occupations and sporadic radiocarbon record suggests that groups used the rockshelter to periodically cache important items but never as a place to live. After ~1500 cal BP, as use of nearby wetlands intensified, LRS may have largely been abandoned.

NOTES

[1] I calibrated all radiocarbon ages in the text to 2σ using OxCal 4.3 online program (Bronk Ramsey 2009) with the IntCal13 curve (Reimer et al. 2013). I rounded all new dates to the nearest five years (Stuiver and Polach 1977) but did not round Heizer's (1951) dates to avoid confusion.

[2] Byrne et al. (1979:284) incorrectly reported the flakes from areas B and C.

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APPENDIX 1

Identified Fauna from Unit N494 E500

Stratum	1										
m	99.81-99.60	99.60-99.55	99.55-99.50	99.50-99.45	99.45-99.40	99.40-99.35	99.35-99.30	99.30-99.25	99.25-99.20	99.20-99.15	99.15-99.10
Level	1	2	3	4	5	6	7	8	9	10	11
Neotoma sp.	0	0	0	0	0	0	0	2	11	0	8
Neotoma lepida	1	1	0	0	1	1	0	2	4	0	12
Neotoma cinerea	0	0	0	0	0	0	0	0	1	0	1
Leporidae	1	0	0	0	0	0	0	1	0	0	0
Sylvilagus sp.	0	0	0	0	1	1	0	1	1	2	0
Lepus sp.	0	0	0	0	0	0	1	1	0	0	0
Lepus californicus	0	0	0	0	0	0	2	2	1	3	0
Arvicolinae	0	32	18	6	22	22	6	25	17	0	7
Microtus sp.	0	46	21	7	46	46	18	30	31	0	19
Dipodomys sp.	2	0	0	0	0	0	0	1	1	1	1
Dipodomys microps	0	0	0	0	0	0	1	0	0	0	1
Dipodomys ordii cf.	1	0	0	0	0	0	0	0	0	0	0
Unidentified Mouse	0	0	2	0	0	0	0	0	0	0	0
Microdipodops sp.	0	1	0	0	0	0	0	0	0	0	0
Perognathus longimembris	2	0	0	0	1	1	0	0	1	0	0
Perognathus parvus	0	0	0	0	0	0	0	0	1	0	0
Peromyscus sp.	1	1	0	0	0	0	0	0	0	0	0
Thomomys sp.	0	0	0	0	0	0	0	0	1	2	2
Thomomys townsendii	7	1	0	0	0	0	1	0	0	0	2
Thomomys bottae	1	0	0	0	0	0	0	0	0	0	0
Sciuridae	2	0	0	0	0	0	0	2	0	0	0
Urocitellus sp.	0	0	0	0	0	0	0	0	0	0	2

Stratum	1/2		2/3		3/3b/4	3b/4		4	5	
m	99.10-99.05	99.05-99.00	99.00-98.95	98.95-98.90	98.90-98.85	98.85-98.80	98.80-98.75	98.75-98.70	98.70-98.65	98.65-98.60
Level	12	13	14	15	16	17	18	19	20	21
Neotoma sp.	3	10	10	6	3	3	3	0	0	0
Neotoma lepida	11	12	22	2	3	9	2	1	0	0
Leporidae	0	3	4	0	0	0	0	0	0	0
Sylvilagus sp.	0	7	2	0	3	0	0	0	0	0
Lepus sp.	0	0	21	1	1	0	0	0	0	0
Lepus californicus	11	5	11	1	1	6	6	1	1	0
Arvicolinae	4	15	19	19	2	12	5	1	5	0
Microtus sp.	17	20	32	15	17	15	9	1	8	0
Dipodomys sp.	0	2	7	1	0	0	0	0	0	0
Dipodomys microps	2	4	5	2	3	3	1	0	0	0
Dipodomys microps cf.	0	0	0	3	0	0	0	0	0	0
Dipodomys ordii cf.	1	0	0	0	0	0	0	0	0	0
Mustela erminea	0	0	1	0	0	0	0	0	0	0
Microdipodops sp.	1	0	2	0	0	0	1	1	0	0
Perognathus longimembris	0	0	2	1	0	1	0	0	0	0
Perognathus parvus	0	0	0	0	0	0	0	0	0	0
Peromyscus sp.	0	0	0	1	0	0	0	0	0	0
Thomomys sp.	2	2	2	2	0	2	3	0	1	0
Thomomys townsendii	0	1	4	1	2	4	3	1	0	0
Thomomys bottae	0	0	2	0	0	0	0	0	0	0
Sciuridae	0	0	0	0	0	0	0	0	0	0
Urocitellus sp.	2	1	0	0	0	1	0	0	0	0
Urocitellus townsendii	0	0	2	1	1	0	0	0	0	0
Ondatra zibethicus	0	1	0	0	0	0	0	0	0	0
Unknown	0	0	2	0	1	0	0	0	0	0

Stratum	5/6/K	6/8a/K	6/8a/8/K		8/9/K	8/9		
m	98.60-98.55	98.55-98.50	98.50-98.45	98.45-98.40	98.40-98.35	98.35-98.30	98.30-98.25	98.25-98.20
Level	22*	23*	24*	25*	26*	27*	28*	29*
Neotoma sp.	0	0	1	3	4	2	1	0
Neotoma lepida	0	0	1	0	4	2	1	0
Neotoma cinerea	0	0	0	1	0	0	0	0
Sylvilagus sp.	0	0	0	0	1	0	0	0
Lepus sp.	0	0	0	0	2	0	0	1
Lepus californicus	0	0	0	1	0	0	0	0
Arvicolinae	2	1	3	6	6	3	0	0
Microtus sp.	0	0	1	2	4	0	1	1
Dipodomys sp.	0	0	0	0	0	0	1	0
Dipodomys microps	1	0	1	0	1	0	0	1
Mustela sp.	0	0	0	0	0	0	1	0
Unidentified Mouse	0	0	0	0	0	0	0	0
Microdipodops sp.	0	0	0	0	0	1	1	0
Perognathus sp.	0	0	0	0	0	1	0	0
Peromyscus sp.	0	1	0	0	0	0	0	0
Thomomys sp.	0	0	1	0	2	0	0	0
Unknown	0	0	0	0	1	0	0	0

*Undisturbed levels used for analyses

Identified Fauna from Unit N495 E500

Stratum	1						1/2	2	3/3b/4
m	99.65-99.55	99.55-99.45	99.45-99.35	99.35-99.25	99.25-99.15	99.15-99.05	99.05-98.95	98.95-98.85	98.85-98.75
Level	1	2	3	4	5	6	7	8	9
Neotoma sp.	0	1	0	0	5	0	8		1
Neotoma lepida	0	1	1	0	2	1	2	3	2
Leporidae	0	0	0	0	0	0	1	1	1
Sylvilagus sp.	0	0	0	0	0	1	0	0	0
Lepus sp.	3	2	1	0	4	1	1	2	1
Lepus californicus	0	0	0	2	3	0	5	0	0
Arvicolinae	104	44	43	33	89	52	85	15	3
Microtus sp.	83	61	68	52	80	27	54	6	6
Dipodomys sp.	0	0	0	0	0	0	1	0	0
Dipodomys microps	1	0	0	0	2	0	2	0	0
Dipodomys microps cf.	0	1	0	0	0	0	6	2	0
Dipodomys merriami	0	0	0	0	0	0	2	0	0
Dipodomys ordii cf.	0	0	0	1	0	0	0	0	0
Mustela sp.	0	0	0	0	0	0	0	0	0
Mustela frenata	0	1	0	0	0	0	0	0	0
Mustela erminea	1	0	0	0	0	0	0	0	0
Reithrodontomys megalotis	2	0	0	0	2	0	0	0	0
Microdipodops sp.	0	0	0	0	0	0	1	0	1
Perognathus sp.	1	0	0	0	0	1	4	0	0
Perognathus longimembris	0	0	0	0	0	0	1	0	0
Perognathus parvus	0	0	0	0	1	0	0	1	0
Peromyscus sp.	0	0	0	0	0	0	0	0	0
Thomomys sp.	0	0	0	0	0	0	1	1	0
Thomomys townsendii	1	0	0	0	5	0	1	0	2

Thomomys bottae	1	0	0	1	0	0	0	0	0
Urocitellus townsendii	0	0	0	0	0	0	0	0	1
Ammospermophilus leucurus cf.	0	0	0	0	0	0	0	1	0
Unknown	1	1	0	0	0	0	0	0	0

Stratum	4	4,5	5/6/K	6/7/K	7	8/9		9
M	98.75-98.65	98.65-98.55	98.55-98.45	98.45-98.35	98.35-98.25	98.25-98.15	98.15-98.05	98.05-97.95
Level	10	11	12*	13*	14*	15*	16*	17*
Neotoma sp.	6	3	1	0	0	0	0	0
Neotoma lepida	3	1	1	1	1	0	1	0
Leporidae	3	0	0	0	0	1	0	0
Sylvilagus sp.	1	0	1	0	0	0	0	0
Lepus sp.	6	0	4	0	0	3	0	0
Lepus californicus	3	0	1	0	0	1	0	0
Arvicolinae	3	5	1	2	0	3	0	0
Microtus sp.	4	2	3	2	3	5	0	1
Dipodomys sp.	1	0	1	1	0	0	0	0
Dipodomys microps cf.	0	1	0	0	0	0	0	1
Dipodomys merriami	0	0	0	0	1	0	0	0
Perognathus parvus	0	2	0	0	0	0	0	0
Thomomys sp.	0	0	0	1	0	0	0	0
Thomomys townsendii	0	1	2	0	0	1	0	0
Unknown	0	0	0	0	0	0	0	0

Identified Fauna from Unit N498 E497

Stratum	1								1/2	2	
m	100.38-100.05	100.05-99.95	99.95-99.85	99.85-99.75	99.75-99.65	99.65-99.55	99.55-99.45	99.45-99.35	99.35-99.25	99.25-99.15	99.15-99.05
Level	1	2	3	4*	5*	6*	7*	8*	9*	10*	11*
Neotoma sp.	0	0	0	0	0	0	0	0	0	0	0
Neotoma lepida	1	0	0	0	1	1	0	0	0	0	0
Leporidae	0	0	1	0	0	0	0	0	0	0	0
Sylvilagus sp.	0	0	0	0	0	0	0	0	0	0	0
Lepus sp.	0	0	0	0	0	0	0	0	0	0	0
Lepus californicus	0	0	0	2	0	0	0	0	0	0	0
Arvicolinae	105	34	44	47	170	126	118	76	33	30	25
Microtus sp.	115	28	65	84	258	221	167	135	38	19	18
Dipodomys sp.	2	0	0	0	0	0	0	0	0	0	0
Dipodomys microps	0	0	0	0	0	2	0	0	0	0	0
Dipodomys microps cf.	0	0	1	0	0	0	0	0	0	0	0
Dipodomys merriami	2	0	0	0	0	0	0	0	0	0	0
Dipodomys ordii cf.	0	0	0	0	0	0	0	0	0	0	0
Dipodomys ordii	0	0	0	0	0	0	0	0	0	0	0
Unidentified Mouse	0	0	0	0	0	0	0	0	0	0	0
Reithrodontomys megalotis	0	0	0	0	0	0	0	0	0	0	0
Perognathus sp.	1	0	0	0	0	0	0	0	0	0	2
Thomomys sp.	7	0	0	1	2	1	0	0	0	0	0
Thomomys townsendii	0	0	0	0	0	0	0	0	0	0	0
Thomomys bottae	2	0	0	1	1	1	0	0	0	1	0
Urotellus townsendii	2	0	0	0	0	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	0	1	0	0	0

Stratum	2/3		3	3/4	4	4/5	5		5/6		6/7	
m	99.05-98.95	98.95-98.85	98.85-98.75	98.75-98.65	98.65-98.55	98.55-98.45	98.45-98.35	98.35-98.25	98.25-98.15	98.15-98.05	98.05-97.95	97.95-97.85
Level	12*	13*	14*	15*	16*	17*	18*	19*	20*	21*	22*	23*
Neotoma sp.	0	0	1	1	1	0	1	0	1	0	2	0
Neotoma lepida	0	0	0	1	0	0	0	0	0	0	0	0
Leporidae	0	0	0	0	0	1	0	0	0	0	0	0
Sylvilagus sp.	0	0	3	0	1	0	0	0	0	0	0	0
Lepus sp.	0	0	0	1	0	0	0	0	0	0	0	0
Lepus californicus	0	0	0	0	2	1	0	0	1	0	0	0
Arvicolinae	10	39	51	67	45	31	3	0	1	2	3	5
Microtus sp.	15	45	36	84	76	30	9	3	4	0	1	6
Dipodomys sp.	0	0	0	0	0	0	0	0	0	1	0	0
Dipodomys microps	0	0	0	0	0	0	0	0	0	0	0	2
Dipodomys microps cf.	0	0	0	1	1	0	0	0	0	0	0	0
Dipodomys merriami	0	0	0	0	0	0	0	0	0	0	0	0
Dipodomys ordii cf.	0	0	0	0	0	0	0	0	0	1	0	0
Dipodomys ordii	0	0	0	0	0	0	0	0	0	1	0	0
Unidentified Mouse	0	0	0	0	1	0	0	0	0	0	0	0
Reithrodontomys megalotis	0	0	0	0	0	0	0	0	0	0	1	0
Perognathus sp.	0	2	2	0	0	1	0	0	0	0	0	0
Thomomys sp.	0	0	1	0	0	0	0	0	0	0	2	2
Thomomys townsendii	0	0	0	0	0	0	0	0	0	0	1	1
Thomomys bottae	0	1	0	0	0	0	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	1	0	0	0	0	2

*Undisturbed levels used for analyses