AEOLIAN GEOMORPHOLOGY AND GEOARCHAEOLOGY OF THE GOSHUTE VALLEY, NEVADA, USA

A Thesis

by

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ABSTRACT

This thesis presents new data on aeolian geomorphology, geochronology, and site formation in the Goshute Valley, Nevada. Two dune fields were the focus of this study: the Hardy Creek Dune Field in the north and White Horse Dune Field in the south. This study provides an example of the significance of geomorphological, chronological, and geoarchaeological studies of aeolian settings in the eastern Great Basin.

Granulometric analysis determined the characteristics of the dunes from each field while aerial imagery and Ground Penetrating Radar (GPR) determined morphology. Optically Stimulated Luminescence (OSL) dating determined the age of representative dunes from each field. Results indicate that the lunettes in the Hardy Creek Dune Field and the weathered linear dunes in the White Horse Dune Field range in age from the middle to late Holocene.

An archaeological survey in each dune field showed that people traversed the Goshute Valley throughout the Holocene. The survey also showed that people were most likely hunting seasonally in the dunes, since a considerable number of the sites were found in the dunes instead of the playa. Projectile points dating from the early to late Holocene also indicate that hunting was the primary activity within the dunes.

This research shows the importance of the geochronological and geoarchaeological results from the Hardy Creek and White Horse dune fields, demonstrating the Holocene paleoclimate and human interaction with aeolian environments.

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1.1 Introduction

There is a paucity of geomorphological and geoarchaeological studies in northeastern Nevada, including the Goshute Valley (Figure 1) and the surrounding area. There has, however, been extensive ecological and climatic studies from the surrounding area. No aeolian studies have been conducted in the Goshute Valley, and archaeological surveys and excavations have been limited. The current project, however, identifies dune sediment characteristics, stratigraphy, and geochronology for two dune fields in the Goshute Valley to understand dune formation, aeolian processes, and paleoclimate in the region. In addition, we further assess paleoecology of the study area using sediment samples from a nearby archaeological rockshelter site as a proxy. Lastly, we identify archaeological site formation processes in each dune field. Our reasons for pursuing these topics are (1), dune formation has not been extensively studied in this region (Jewell and Nicoll 2011) and (2) there have been few geoarchaeological studies of this type in this basin (Hockett 1995).

This research will contribute to our knowledge of how paleoclimate, archaeology, and aeolian processes affect landform and archaeological site formation. The research goals are twofold: to study aeolian geomorphology in the Goshute Basin and to document the surficial archaeological record of sites in aeolian these settings. Specific objectives include the following:

1. Determine the aeolian geomorphology and sediments of the Goshute Valley.
2. Investigate aeolian chronology in the Goshute Valley using optically stimulated luminescence (OSL) dating.
3. Reconstruct Holocene climate and environment in the Goshute region using palynological data from Bonneville Estates Rockshelter, a nearby archaeological site, in addition to petrographic and granulometric analysis.
4. Document archaeological sites in the Goshute Valley and develop a model for geoarchaeology in aeolian settings by understanding how artifacts are distributed, both horizontally and vertically in a dune-field setting.

Figure 1. Red marker indicates the location of the Goshute Valley, Nevada, USA. Brown area denotes the area defined as the Great Basin. Map adapted from Mensing et al. 2013 and GoogleMaps.

The Great Basin, part of the Basin and Range Province, is defined as the extensive region encompassing 200,000 km^2 of the arid western United States that consists of endoreic, basins. This hydrographical definition of the Great Basin was first coined by John C. Fremont, circa 1845 (Grayson 2011).

In reference to paleoclimate, the Great Basin is regionally distinct. For example, the eastern Great Basin was not affected by prolonged drought during the Late Holocene, whereas the western Great Basin was affected by drought (references). Starting at the transition from the Terminal Pleistocene to the Early Holocene, Beck and Jones (1997) indicate that the Great Basin was characteristized by drastic hydrological, biological, and climatic change, but even so, humans persisted in much of the Great Basin through time. For this reason, McGuire (2005) claims that the Great Basin is an excellent case of human-environment interaction and humans adapting to extreme environmental fluctuations. As a result, a study of stone tool variability could inform on landscape use as humans responded to changing landscapes during the Holocene.

1.2. Literature Review and Background

1.2.1 Geomorphology and Paleoclimate Literature Review

The current study site is located in the Basin and Range Province of the western United States. The Basin Province and Range includes four arid zones: Sonoran, Chihuahuan, Great Basin, and Mojave (Tchakerian and Lancaster 2002). More specifically, it includes two dune fields located in the Goshute Valley in the Great Basin within a transition zone between arid and semi-arid climate.

Dunes are not as extensive in the northern Great Basin as they are in the Mojave Desert (Jewell and Nicoll 2011). For example, the Winnemucca dunes in Nevada are characteristic of discontinuous barchan, traverse, and parabolic morphologies, and the Great Salt Lake dune field consists of discontinuous dunes (Jewell and Nicoll 2011). Yet they do exist and their presence and nature can inform on aeolian processes and paleoenvironments in this region of the western United States, especially when compared with dunes in areas such as the Mojave.

Over the past 33 years, aeolian sediments from the Mojave Desert have been the focus of geomorphic studies (e.g. Tchakerian and Lancaster 2002). During the late Quaternary, the southern Great Basin was subjected to humid and arid oscillations driven by glacial/interglacial periods (Tchakerian and Lancaster 2002). The Last Glacial Maximum (LGM), 20,000 cal BP, witnessed the presence of many large lakes at their greatest capacity. While lake stands are associated with atmospheric changes, aeolian deposition was variable depending on sediment supply, storage, and transport (Tchakerian and Lancaster 2002).

Lake level fluctuations were a persistent phenomenon in the Mojave region. The dunes in the Mojave Desert are vulnerable to climatic shifts (Clarke and Rendell 1998). Sand supply is a factor of short-term pluvial systems and transport. Intermittent periods of lower lake activity provided a source of sand before lakes totally desiccated; therefore, aeolian activity is not inhibited by pluvial lake activity (Clarke and Rendell 1998).

Major dune building events in the central and northern Great Basin occurred during the early to middle Holocene from about 8,000 to 5,000 cal BP (Tchakerian 2009; Jewell and Nicoll 2011). This may have been initiated by an increase in wind strength, caused by a sharp atmospheric gradient between the Sierra Nevada and the Mojave Desert, which provided an ideal climatic regime for aeolian processes to build dunes and sand ramps (Tchakerian and Lancaster 2002). This proves that there was a continental arid cycle. Ernst Antevs (1955) called this period the “Altithermal”. However, instead of a simple 3,000 year drought, it was a period of climatic oscillations between arid and non-arid conditions which were not uniform across the Great Basin (Grayson 2011).

As a result of increased temperature and reduced effective moisture, Pleistocene lakes receded differentially across the Great Basin, leaving behind playa sediments which would become a source for dunes. Increased aeolian activity is associated with these climatic changes; however, drying does not necessarily equate to dune development (Tchakerian 2009). There are several major factors which are concomitant with xeric conditions, such as sediment supply, availability, mobility, and storage (Lancaster 2008). Sediment supply is the most important variable for dune development. In the valleys of the Great Basin, fine-grained sediment supply sources include desiccated lakes, arroyos, alluvial fans, ephemeral streams, and beach deposits (Tchakerian 2009). Desert aeolian systems are highly vulnerable to fluctuations in climate (Tchakerian 1991). For example, after the Pleistocene-Holocene transition, the Polar Jet took a northerly trajectory which caused climate to become warmer and wetter due to summer/winter monsoons, and led to periodic aeolian activity (Tchakerian 2009). Furthermore, dune building is associated with stable conditions, but can become vulnerable to hyper-arid conditions as the climate becomes hot, dry, and windy. Dunes systems are also impacted by changes in climatic stability as vegetation accumulates to anchor dunes.

Surface wind is another factor of dune building and is greatly impacted by the physical geography of the Great Basin (Jewell and Nicoll 2011). Generally, the eastern Great Basin paleowind direction was oriented in a north-northeastern direction while the west Great Basin was oriented in an east-northeast direction (Jewell and Nicoll 2011).

Climate Throughout the Holocene

There are two ideas that concern how the climatic sequences throughout the Holocene should be divided. Ernst Antevs's Neothermal Sequence started with the Anathermal, which was characterized by a warm and moist climate around 9,000-7,000 cal BP (Grayson 2011). This period was followed by the Altithermal, which was characterized by hot and dry climates around 7,000-4,500 cal BP (Grayson 2011). Lastly, the Medithermal is characteristic of cooler and moister climates starting at 4,500 cal BP to the present (Grayson 2011). Generally, these terms do not find their way into North American scientific writing because Antevs was partially incorrect. Instead, Grayson (2011) divides the Holocene epoch into early (10,000-7,500 cal BP), middle (7,500-4,500 cal BP), and late (4,500 cal BP-present). The period Antevs deemed the Altithermal produces the most inconsistencies in Holocene climate across the Great Basin.

One of the major archaeological questions in the Great Basin centers on human-environment interaction with an emphasis on human response to extreme climatic fluctuations. Human presence in the Great Basin during the Middle Holocene is particularly debated. Due to drought conditions of this period, some have argued that the region was abandoned, however, there have been several archaeological sites recorded that date to the Middle Holocene (Madsen and Schmitt 2005). If there was no hiatus during the middle Holocene, then apparently the climatic conditions were conducive for human occupation. This brings to mind the next question: how were people able to adapt to their changing climate? To answer whether people were in the Goshute Valley throughout the Holocene and how they were living, it is important to first reconstruct local climatic conditions.

The Early Holocene (10,000-7,500 cal BP)

Between 12,500-11,600 cal BP, the Great Basin was relatively cool and mesic, and Lake Bonneville extended into a vast region of basins (Goebel et al. 2011). During the Younger Dryas (12,900 - 11,600 cal BP), Lake Bonneville consisted of present day Great Salt Lake, Sevier Lake, Lake Gilbert, and the Old River Bed which connected to Lake Gunnison (Goebel et al. 2011). Archaeological records show that Bonneville Rockshelter, a well-known site in Utah, was utilized by humans around 12,900-10,500 cal BP which indicates that even though the climate was harsh, a hiatus did not occur during the Younger Dryas in the Great Basin (Goebel et al. 2011). Other sites such as Sunshine Locality, Danger Cave, Smith Creek Cave, and Buhl (Figure 2) indicate human occupation during the Younger Dryas (Goebel et al. 2011). There is some discrepancy, however, in the dates from the Lahontan region; and, it is difficult to construct a temporally comprehensive record since sites dating after the Younger Dryas are more ubiquitous than earlier sites (Goebel et al. 2011).

Pollen data recovered from a Blue Lakes (just east of the Goshute Mountains) core suggests that vegetation was dominated by sagebrush and pine suggest warm and dry conditions during the Pleistocene (Louderback and Rhode 2009). Evidence from other marginal Lake Bonneville sites, however, suggests marsh habitats indicating cool and wet conditions (Louderback and Rhode 2009). Prior to 13, 000 cal BP, climate in the Bonneville Basin would have been cooler. Limber pines were growing in the foothills of the Goshute Mountains and associated with a sagebrush-conifer vegetation (Louderback and Rhode 2009). Thirteen thousand years ago, the eastern Great Basin landscape became characterized by shadscale (Louderback and Rhode 2009). The Gilbert shoreline environment was primarily marsh as demonstrated by peat in the cores; and, the pollen from the cores consisted of algae, cattail, and sedges (Louderback and Rhode 2009). Packrat midden records from near Bonneville Estates Rockshelter suggest that 13,000 cal BP, the area was dominated by steppe vegetation, such as sagebrush and snowberry (Rhode and Madson 1995; Rhode 2001). Limber pine continued to grow in the region until 11,000 cal BP, but shortly after increased summer temperatures forced its demise, and in its place grew scrub vegetation (Madson and Rhode 1995). *Pinus* and *Artemisia* are most abundant from 14,000-11,000 cal BP, indicating cold temperatures, further supporting that climate was cooler prior to the Holocene (Madson and Rhode 1995).

The Northern Hemisphere during the Younger Dryas would have been affected by extraterrestrial climatic forcing such as greater tilt, as well as the July perihelion; summers, therefore, would have been warmer and winters, colder (Oviatt et al. 2003). In fact, the vegetation record further suggests this by indicating a cold and moist climate (Thompson et al. 1992). The southern Great Basin was also experiencing wet conditions during the Younger Dryas, as demonstrated by black mats and rock varnish in the southern portion of the Great Basin (Huckleberry et al 2001; Waters and Haynes 2001).

The Holocene ended the cold climate episode and thawed an environment, depleting widespread marshlands from about 11,000-9,500 cal BP (Louderback and Rhode 2009). By 8,000 cal BP, Blue Lakes was completely desiccated as iodinebush and grass replaced sedges, and the marsh margins of western Lake Bonneville were replaced by playas (Louderback and Rhode 2009).

The Middle Holocene (7,500-4,500 cal BP)

The Holocene was a period of recurrent lake level oscillations controlled by the positioning of the polar jet stream (Benson and Thompson 1987). The middle Holocene was warmer and more arid than the early and late Holocene, but there is no evidence of abandonment (Kelly 1997). Lake Bonneville dropped in lake level from 7000 BP until it resurged around 2000 BP (Kelly 1997). The northwestern Great Basin was much drier than the northeastern Great Basin at this time and the central Great Basin was even drier than the northwestern region, as indicated by the lack of lakes and marshes (Kelly 1997). Population reflects climatic change in the archaeological record in that only the periphery of the Central Great Basin eluded to human occupation, as evidenced by rockshelters and caves (Kelly 1997). People did not seem return to the central Great Basin until around 5000-4500 BP as a result of an increase in moisture (Kelly 1997).

It is hard to imagine that the Great Basin was warmer and drier during the Middle Holocene than today; but, pollen evidence from the Blue Lake cores correspond with low accumulation rates and drought-tolerant shrubs, indicating a warm dry climate (Louderback and Rhode 2009). Louderback and Rhode (2009), acknowledge the initial migration of pinon pine into the Goshute Mountains around 8,000 cal BP. ChenoAm and sagebrush pollen also appears in the record along with the pinyon pine (Louderback and Rhode 2009).

The very start of the Middle Holocene at Blue Lakes was warm and dry, which harbored xerophilic shrubs and very little pine and sagebrush, but by 6,500 cal BP, the vegetation shifted back towards sagebrush (Louderback and Rhode 2009). In addition, pollen deposition increased, thereby indicating a cool and wet climate. Pine pollen accumulation rates also increased during the Middle Holocene. Madsen and Rhode (1990) found pinyon pine macrofossils in the packrat midden record near Bonneville Estates Rockshelter, dating to 7,200 cal BP, near Danger Cave, dating to 7,600 cal BP, and some middens from the Goshute Mountain Range, dating to 6,800 cal BP. Faunal records from the Great Basin indicate that before 10,200 cal BP, the yellow-bellied marmot, bushy-tailed woodrat, Ord's kangaroo rat, and pygmy bunny were all thriving in a relatively cold climate, until shortly after when their populations began to decline, along with waterfowl (Grayson 2011; Schmidt and Lupo 2012). By 9,000 cal BP, small mammals disappeared from the record completely (Grayson 1998). Around 9.500 cal BP to 8,500 cal BP, marshlands, like the Old River Bed Delta, appear to have dried up (Oviatt et al. 2003). By 8,000 cal BP, playa-margin shrubs and grasslands took over the diminishing marshes and accompanying sedge vegetation (Louderback and Rhode 2009).

Between 8,000-7,000 cal BP, the climate became considerably warmer throughout the Great Basin as evidenced by the desiccation of Blue Lakes around 8,000 cal BP (Louderback and Rhode 2009). Middle Holocene climates were thought to have been a time when climate was at its hottest and driest, although some sites in the northwest might suggest less severe climate. Hogup Cave sagebrush/saltbrush pollen ratios suggest greater effective moisture in Eastern Great Basin around 6,000 cal BP (Harper and Alder, 1970). This is supported by pollen data from the Ruby Marshes and Snowbird Bog which suggest cooler temperatures. Around 6,500, pollen data from Blue Lakes suggests cooler temperatures (Louderback and Rhode 2009). Although the climate between 8,800 cal BP and 6,800 cal BP at Snowbird Bog was warm and dry the climate after 6,000 cal BP became cooler and wetter (Madsen and Currey 1979). This is also corroborated with pollen data from the Great Salt Lake cores suggesting a transition from warm and dry weather between 7,800 cal BP to 5,700 cal BP to cooler, wetter weather after 5,700 cal BP.

The Late Holocene (4,500 cal BP-present)

Late Holocene climate oscillated between cool to warm periods. Climate change was not uniform across the eastern Great Basin. For example, at Crescent Springs, northwestern Utah, cool, wet periods occurred around 3,900, 2,800, and 1,400 cal BP, while warm, dry periods occured around 3,400, 2,600, and 1,800 cal BP (Louderback and Rhode 2009). The Blue Lake pollen cores recorded Late Holocene climatic oscillations of cool periods between 4,400 cal BP to 3,400 cal BP and 2,700 cal BP to 1,500 cal BP, and warm periods of 3,400 cal BP to 2,700 cal BP and after 1,500 cal BP (Louderback and Rhode 2009).

The early late Holocene was cooler and wetter in the eastern Great Basin. Around 4,600 cal BP, the Ruby Marshes in eastern Nevada increased ponding and sagebrush grew, indicating a cooler climate (Louderback and Rhode 2009). At Crescent Springs, cheno-ams decreased as conifer forests and sagebrush increased around 4,400 cal BP, suggesting cooler and wetter conditions (Louderback and Rhode 2009). Louderback and Rhode (2009) concur that during the Late Holocene, the eastern Great Basin was not subjected to the droughts experienced by the western Great Basin, since drought occurred before 3,500 cal BP, 2,500-1,800 cal BP, and around 1,200 cal BP in eastern Great Basin.

After learning about the global warming trend about 1,200 cal BP, Stine (1994) analyzed drowned tree stumps from Mono Lake and found through dating tree rings and ultimately lake levels that there was a warming trend. Shortly after this interval, the Little Ice Age occurred as evidenced by the increase in of juniper trees at Ash Meadows, Nevada, the deepening of Ruby Marshes, and the expansion of Sevier Lake (Grayson 2011). Starting at about 3,000-2,000 cal BP, *Pinus* began to make a comeback in the pollen record supporting other evidence a cooling trend during this time interval, when conditions in the Great Basin were cooler than during the Middle Holocene. Most of the pollen records containing *Pinus* were found at higher elevations (Grayson 2011).

Reconstructions of central Great Basin paleoclimate from the late Holocene reveal that there was a drought between 2,800 and 1,850 cal BP, referred to as the Late Holocene Dry Period (Mensing et al. 2013). Their evidence from Stonehouse Meadow, Spring Valley, Nevada, came from pollen, mollusks, and diatoms in spring sediments. The drought was most likely associated with subtropical high systems and increased radiation, combined with Milankovitch cycles. In contrast, depleted lakes and marshes in the Mojave Desert indicated drier climates earlier which did not recover as quickly as the late Holocene advanced (Grayson 2011). It seems as though the Medieval Climatic Anomaly (1,150-700 cal BP) was well represented in the Great Basin as evidence from drowned trees and other vegetation in Walker, Pyramid, and Mono lakes showed illustrate a warm interval during the same time.

From much of the existing work on paleoecology in the Great Basin, there are still smaller sub-regions that need to be filled in between the comprehensive larger sites in order to create a better mosaic of contingent climatic and paleoecological data. Most of this work is going to come in the form of additional pollen analyses from sediment cores and from geologic data.

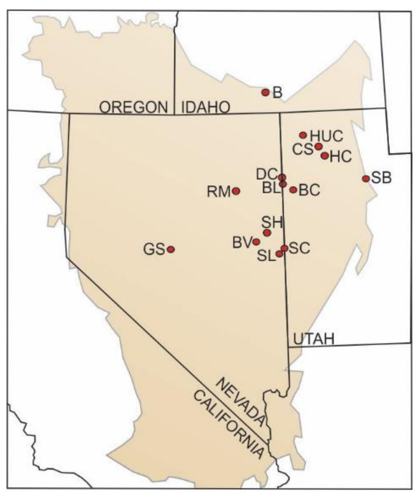


Figure 2. Brown area denotes the extent of the Great Basin. Red markers indicate sites in the Great Basin. B = Buhl Site, BC = Buzz Cut Dune, BL = Blue Lakes, BV = Butte Valley, CS = Crescent Springs, DC = Danger Cave, GS = Gatecliff Shelter, HC= Hidden Cave, HUC = Hogup Cave, RM = Ruby Marshes, SB = Snowbird Bog, SC = Smith Creek Cave, SH = Stonehouse Meadow, SL = Sunshine Locality. Map adapted from Mensing et al. 2013.

1.2.2 Eastern Great Basin Archaeology Literature Review

Projectile point series vary across the Great Basin, which was first proven by the points discovered at Hogup Cave; what may be referred to as an Elko projectile point could have different attributes and definitions differing between western and eastern Great Basin typologies (Thomas 1981). Monitor Valley, located in central Nevada, is a well know archaeological region known for its projectile point type series found in stratified and surface contexts (Thomas 1981). Monitor Valley archaeological sites, such as Gatecliff Shelter, exhibit example of common projectile series such as Cottonwod Leaf-Shaped/Triangilar, Large side-notched, Humboldt, Rosegate, Elko, Desert side-notched, and Gatecliff. Cottonwood Leaf-shaped projectile points are rare in central Great Basin (Thomas 1981). Rose Spring and Eastgate projectile points are combined into the same series, known as Rosegate, because they have similar morphologies (Thomas 1981). Almost 500 Elko projectile points were discovered in the Monitor Valley and have been classified into further morphologies as eared, side-notched, corner notched, and contracting stem. Greta Basin Stemmed points are common in the Great Basin beginning around the terminal Pleistocene. These points will be further discussed in chapter three.

Butte Valley is an archaeological site in eastern Nevada where Beck and Jones (1990), found Late Pleistocene/early Holocene projectile points. These points included points with shouldered, tapering stems, Parman Type 1, Silver Lake, and Concaved Base Stemmed. They also found Archaic projectile points such as Pinto, Humboldt, Elko, Northern Side-notched, Gatecliff, and Rosegate. From the 11,000+ lithic artifacts collected, they determined that basalt biface reduction was fabricated from the production projectile points and that local material was used to replace exhausted tools. Beck and Jones (1990) concluded that the existing model which hypothesizes that the Western Stemmed Point Tradition is found in pluvial environmental settings, may have an addendum which includes terrestrial and fluvial environments. It is important to continue the survey of northeastern valleys in the Great Basin to develop a regional lithic assemblage record so as to understand the human-environment interaction to variability; and, one way to approach it is to incorporate paleoenvironmental records and lithochronology (Beck and Jones 1990). Located southeast of Butte Valley, is the Sunshine Locality archaeological site (Jones et al. 1996). They found a fluted projectile point which they believe dates between 11,200 to 10,900 cal BP. Based on stratigraphy and AMS dates, Jones and Beck (1996) believe that after Lake Hubbs dried, the Sunshine Locality was hospitable to human occupation throughout the Holocene. Evidence includes the discovery of Elko, Humboldt, and Gatecliff projectile points.

Archaeological Sites in a Dune Contextual Setting

Archaeological sites in dune formations are rarely informative because they are either not well preserved or they are rarely found in well-stratified, datable contexts. There are, however, some exceptions to this. At the Ake site in the plains of San Augustin, New Mexico, artifacts span a range of 11,000 years of human occupation with Folsom, Archaic, Mogollon, and Spanish components (Beckett 1980). A hearth was found in association with a Folsom point and bison tooth enamel, but unfortunately the radiocarbon date on charcoal from this hearth showed that deflation and re-deposition had occurred because the age averaged 3,400 cal BP (Beckett 1980). Unlike the Ake site, the Claypool site in

Colorado was preserved by an argillic soil horizon for about 8,000 years until the Dust Bowl; however, the integrity of these artifacts were also compromised after subsequent aeolian processes led to erosion and the site was blown out (Albanese 1977). At the Buried Dune site in the Picacho Basin, Arizona, a Pinto occupation was found preserved beneath a calcic horizon overlain by a paleosol (Waters 1992). The artifacts and a hearth feature were preserved and the date on charcoal from the feature yielded and age of 4,300 cal BP (Waters 1992). The site was overlain by more sediment and later stabilized with a vegetated cover (Waters 1992). The Casper site in Wyoming was a very unique and fortunate discovery. Below 6.5 m of sand in the deflation hollow of a parabolic dune, 74 bison were found with diagnostic Hell Gap artifacts (Albanese 1974). The 10,000-year-old bison kill and butcher site was preserved by a 6.5-m buffer of aeolian sediment, and more importantly, by consolidated pond sediment and calcareous silty sand (Albanese 1974). It was deduced that at the time of deposition, Hell Gap hunters rounded the bison into the parabolic dune (Waters 1992). The dune feature was used as a bison trap (Waters 1992). Dunes can provide interesting archaeological contexts when they are well enough preserved to provide buried, datable materials, such as charcoal and bone for radiocarbon dating. However, dunes are typically not ideal for preservation due to the nature of aeolian morphology. Both active and inactive dunes are subject to exposing site material leaving it in an unpreserved context which cannot be reliably dated.

In 2001, approximately 55 km southeast of the Goshute Valley, an archaeological site called Buzz-Cut Dune was surveyed and excavated. The results from this endeavor are significant to understanding dune sites in northeastern Great Basin and Buzz-Cut Dune is a substantial model for setting the fundamental questions. Dune building occurred around 8,500 cal BP, but occupation of Bizz-Cut Dune was determined to begin around 5,000 cal BP as evidenced from charcoal in the dune dating 4,340 ± 40 cal BP (Madsen and Schmitt 2005). The dunes and surrounding area was seasonally occupied between 5,000 cal BP and 2,700 cal BP (Madsen and Schmitt 2005). Macrofossil analyses indicate the procurement of pickleweed seeds which are mature from September through November, but can mature as early as August or as late as December (Madsen and Schmitt 2005). Since the primary seed in eastern Great Basin culture is the Pinyon Pine, Madsen and Schmitt (2005) hypothesize that Buzz-Cut Dune was occupied mostly during pickleweed season when pinyon pine was not as reliable. Based on faunal remains, they also hypothesize that mostly jack rabbits were hunted around the dunes.

1.2.3 Previous Archaeological Studies in the Goshute Valley

Not many archaeological investigations have occurred in the Goshute Valley (references). Just a few BLM-directed archaeological surveys following seismic lines, fences, and railroads prior to construction, have yielded artifacts mostly ranging in age from the Late Archaic to the historical period. Only two major archaeological investigations were conducted in the Goshute Valley since the mid-1990s. Below is a summary of results from this work which inspired me to pursue archaeological research in the Goshute Valley.

Oranjeboom Cave was first discovered in 1993 by a BLM archaeologist and later excavated as a joint project by the Desert Research Institute (DRI) and BLM in 1999. Oranjeboom Cave is situated 2,000 m (6,500 ft) above sea level on the western slope of the Goshute Mountains and overlooks the playa by 300 m (1,000 ft) to the southwest (Buck et al. 2002).

In 1999, Oranjeboom Cave was further excavated with the collaboration of the University of Nevada, Las Vegas. Stratum 1 consisted of compacted woodrat dung pellets and bighorn sheep fecal matter. Stratum 2a was a silt layer with a white ash and charcoal-rich feature interpreted to be an unlined hearth feature. Stratum 2b consisted of silt and a grey-ash concentration with minimal charcoal that dissipated away from the hearth feature of stratum 2a, demonstrated hearth cleaning. A juniper bark mat also found in stratum 2b was contemporaneous with the stratum 2b hearth feature. Both strata 2a and 2b represented the cultural component of the site. Four radiocarbon dates were obtained on materials deposited within strata 2a and 2b: 1,100 ± 40 (Beta-144436) ^{14}C BP from soot/charcoal on pottery; 1,220 ± 60 (Beta-144731) ^{14}C BP from juniper-bark matting; 1,440 ± 60 (Beta-144732) ^{14}C BP from a hearth feature; and 1,660 ± 50 (Beta-121678) ^{14}C BP (Buck et al. 2002). They disregard the two dates on juniper from the feature as potentially being obtained on old wood. Likewise they discount the date on pottery soot and keep the age on juniper-bark matting as being most reliable because this directly dates an artifact. Strata 3 and 4 are composed of thin silt bands with slight red fire-staining at the top of stratum 3. Stratum 5 is the limestone bedrock of the Goshute Mountain.

The lithic assemblage from strata 2a and 2bconsist of 1,054 debitage pieces, 58 tools, and 2 cores for a total of 1,114 lithic artifacts. The most common raw material type is CCS (cryptocrystalline silicate), followed by rare frequencies of basalt, obsidian, quartzite, and limestone. Of the debitage, about 88% resulted from resharpening bifaces and unifaces and possibly trimming cores. The tool assemblage contains 47 bifaces, six unifaces, and five groundstone fragments. Four bifaces were Eastgate projectile points, while the others were undiagnostic. In addition, 24 ceramic artifacts were discovered and represent one Great Salt Lake Gray wide-mouthed jar manufactured using a coiling method. Based on its construction and pigmentation, this vessel was likely used for storing dry goods. Both the pottery sherds and projectile points are diagnostic of the Fremont Culture, dating to about 1,550-600 cal BP.In addition to the juniper bark matting, other organic artifacts found in the cultural component include one bone bead, one conical wooden object, and fragments of arrow cane. Macrobotanical remains include goosefoot and juniper carbonized seeds, branches of juniper, a pine-nut shell fragment, fruit, and wood charcoal identified as juniper, pine, sagebrush, conifer, and species from the rose family. Faunal remains include bison, elk, pronghorn antelope, deer, and sheep. Artifacts, features, and ecofacts indicate Oranjeboom Cave was a short-term hunting camp used by a small group of Fremont foragers between 1,100-970 BP. Also in 1999, the Goshute Valley floor was surveyed for archaeological sites. In 1999 and 2000Ted Goebel, Kelly Graf, and crew found 21 sites in the Goshute Lake – Upper Nelson Creek and Lower Nelson Creek areas of the valley. Ten isolated sites yielded four Elko corner-notched points, one Windust point, one Great Basin stemmed point fragment, one biface, one Pinto point, one Elko eared point, and one stemmed point and Windust point.

Seven sites were associated with either sand dunes or sand sheets. Beach (*CRNV – 11 – 10054*) is indirectly associated with sand dunes. It is situated in an erosional beach feature where sand dunes overlie the pluvial lake feature. Paleoindian artifacts, such as one Haskett stemmed point base, one Parman stemmed point, and biface fragments, and a Late Archaic Desert side-notched point were found. There were no artifacts reported in association with the dunes. This situation is similar to the dune fields in Hardy Creek Quadrangle and Independence Mountains SE Quadrangle where there are dunes overlying beach features. Phalan Creek-2 (*CRNV – 11 – 10071*) had artifacts eroding out of a thin sand sheet which overlaid a bedrock knob feature. Four Gatecliff points were found among other artifacts. Nelson Creek Dunes-1 (*CRNV – 11 – 13181*) is a 4 m high blowout dune. Artifacts included two Cottonwood triangular points, a leaf-shaped bifacial knife, a bifacial drill, and biface point fragments. Charcoal was also found eroding from the blowout. Nelson Creek Dunes-2 (*CRNV – 11 – 13182*), a 10 m tall dune produced similar results. Two Desert side-notched points, one triangular point, and pieces of fire cracked rock were fund. Mizpah Well-4 (*CRNV – 11 – 13185*) is located on a dune ridge which looks out at Nelson Creek wash and overlies a beach feature. Fire cracked rock, debitage and one obsidian Desert side-notched point was found. Coronado Well-1 (*CRNV – 11 – 13186*) is a dune where artifacts were found on the south-facing slope. Once again, the dune overlies a beach feature. One basalt stemmed point was found among hundreds of debitage pieces. At Gulf Well-1 (*CRNV – 11 – 13188*), three basalt side scrapers, and a basalt triangular biface was found along with debitage which is associated with the production of side scrapers and bifaces. Gulf Well-2 (*CRNV – 11 – 13189*) is the site of another sand dune where basalt and crypto-crystalline silicates (CCS) debitage was found on the crest and two side scrapers were found on the edge. Three northern side-notched points were found on the edge of the other side of the dune.

1.3 Study Area and Materials

1.3.1 The Goshute Valley and Surrounding Area

The Goshute Valley

In Figure 3, the black rectangle represents the extent of the study area which centers on the Goshute Valley. It is located in northeastern Nevada in Elko County near the Nevada-Utah border. It is approximately 22 km west from the Great Salt Lake Desert and about 72 km east from the Ruby Marshes. It is characterized as a semiarid biome, although Currey (1991) used “hemiarid” because of the half humid/half arid climate regime in neighboring Bonneville Basin. The Goshute Valley is approximately 63 km north-south by 15 km east-west. There are two dune fields located in the Goshute Valley which are the focus of this study. Hardy Creek is located in the northern extent of the valley and White Horse is located in the southern extent of the valley.

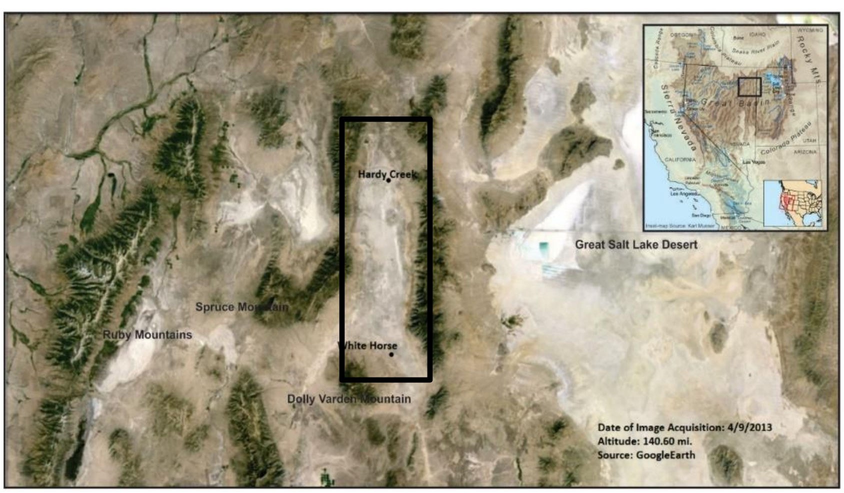


Figure 3. Map of the Hardy Creek and White Horse study sites in the Goshute Valley, northeastern Nevada, USA.

The playa in the Goshute Valley is a remnant of Pleistocene Lake Waring sediments. In Figure 4, lake stands are visible as beach ridges in front of the Goshute Mountains. It was suggested by Currey et al. (1984), that the lake had a maximum extent of 103 km (64 mi) north-south by 27 km (17 mi) east-west at its high stand and the highest shoreline they surveyed was 1,768 m (5,801 ft) above sea level, which is 34 m (110 ft) below the lowest point in the Lake Waring basin rim. The lowest point they surveyed is 1,700 m (5,579 ft) above sea level. Other studies by Mifflin and Wheat (1979) suggest that while at Lake Waring's high stand, the lake would have covered 541 mi^2 of the 3,244 mi^2 which encompasses the basin. Two dates from gastropod shells were obtained from lagoonal silts and beach sands at 12,690 ± 140 cal BP and 12,100 ± 150 cal BP, respectively (Currey et al. 1984). These dates are associated with the last deep-lake cycle in the Goshute Basin and are synchronous to the Lake Bonneville post-Provo regression (Currey et al. 1984).

Figure 5 shows the extensive distal fan deposits of the mostly limestone Goshute Mountains. The fans are vegetated with juniper/pine mixed stands, cheat grass, and bunch grass.

Figure 4. Beach ridges along the Goshute Mountains in the Goshute Valley, Nevada.

Figure 5. Alluvial fan deposits in the Goshute Mountains, Goshute Valley, Nevada.

Bonneville Estates Rockshelter, Nevada

Bonneville Estates Rockshelter is an archaeological site located in the Lake Bonneville pluvial lake basin east of the Goshute Mountains in Elko County, Nevada, on the state line between Nevada and Utah. The rockshelter is mostly formed out of Lower Pennsylvania-Lower Permian limestone with sparse dolomite, siltstone, and sandstone. The rockshelter is found in the juniper/sagebrush climatic zone approximately 1,219-1,524 m (4,000-5,000 ft) in elevation. The stratigraphy of the shelter is indurated cultural (human occupation) and sterile (silt bands suggesting aeolian activity) layers. There are aeolian and roof spall stratigraphic boundaries with cultural units localized in deposited intermittently with unconformities caused by human and packrat disturbance. Bonneville Estates Rockshelter is a near-ideal situation of pollen preservation. It is a circular rockshelter measuring approximately 24 m (wide) x 16 m (deep), where the elevation slants out to the mouth and to the left from the interior. It is near ideal because of the pooling that occurs on the left interior side of the shelter. No sediment samples were taken from that area. An arroyo is located near the shelter which is the cause of monsoonal water flow.

Figure 6. Red arrow denotes the location of Bonneville Estates Rockshelter, Goshute Mountains, NV.

Bonneville was excavated from 2000 to 2009 by Ted Goebel of the University of Nevada Reno, Ken Adams, Kelly Graf, and David Rhode of the Desert Research Institute, Bryan Hockett of Elko Bureau of Land Management, and students from the field schools (Goebel 2007; Graf 2007; Hockett 2007). Their research goal was to understand human adaptation to their environment as a response to climate change between 10,000 and 5,000 years ago. Their results yielded the interpretation that during the hot, dry middle Holocene, humans did not abandon the shelter. This was evidenced by several stratigraphic occupations dating 7,000-5,000 B.P. Interestingly, evidence from Danger Cave also supports the interpretation that during the middle Holocene, a hiatus did not occur, as it did in other localities in the Great Basin (Rhode. D, and D. Madsen 1998).

1.3.2 Geologic History

The Goshute Basin exhibits common characteristics with other basins in the Great Basin, such as faulting and warping, aeolian deflation, interdune systems, and groundwater dissolution (Laity 2008). To understand sediment source, or province, it is important to know how the basin formed.

The oldest rocks in the Great Basin are 2.5 billion year old schists and granites. These pre-Paleozoic rocks are identified by their strontium isotope ratios (Fiero 2009). The Great Basin underwent millions of years of tectonism. Two billion years ago, the southern half of Nevada would have been underwater until 1.75 billion years ago when subduction began, advancing an island arc towards what is now Nevada. Over the millions of years, three orogenic processes occurred: the Antler Orogeny around 350 million years ago (mya), the Sonoma Orogeny around 250 mya, and later, the Cordilleran Orogeny, 195-80 mya.

According to Fiero (1986), the following sequence of geological events has occurred in the study area. About 17 mya (Miocene), the Great Basin as seen today began to take shape. First, there was the extension and thinning of the crust which doubled its original extent. Thereafter, uplifting and more extension caused the crust to break along a north-northeast orientation shaping the uplifted mountains (horst) and the dropped valleys (graben). As a result, large blocks of crust were either tilted because of stretching or subsided owing to cracking. There is a normal fault that drops down to the west along the Goshute Mountains as well as the northern portion of the Pequop Mountains. There are also signs of warping through Wells, Nevada, and Wendover, Utah. This discontinuity in the ages of Paleozoic sedimentary and Paleozoic thrust belts has been called the Wells Fault and occurred during the Mesozoic. There is still some debate over the fault's existence since the only evidence is a disconformity of ages in the rock record, but it might have occurred as a result of a flaw in the crust or a bend in the continental margin.

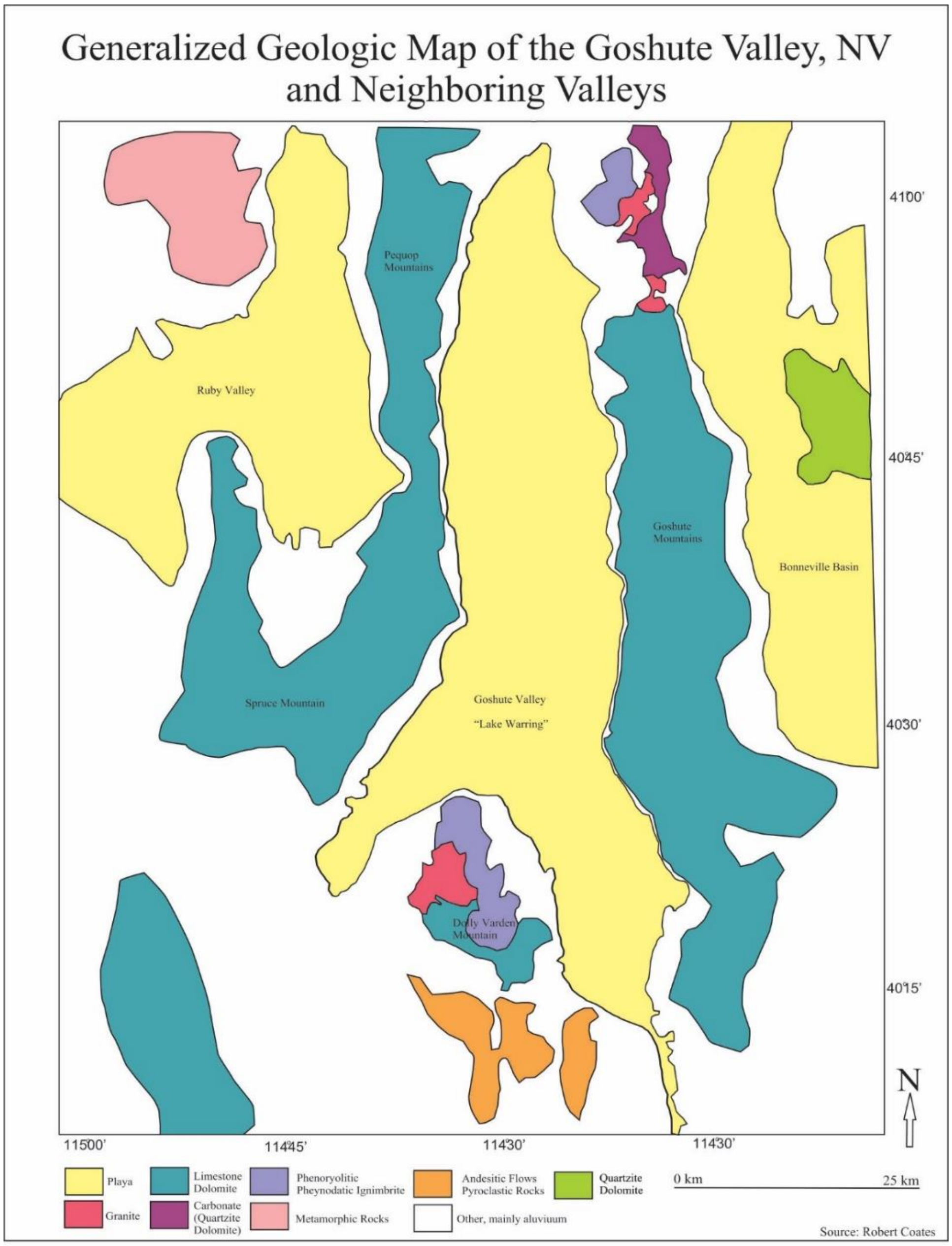


Figure 7. General geologic map of the Goshute Valley, Nevada.

1.3.3 Climate

The average annual precipitation for Wendover, Utah, located about 30 km from the study site, is about 17 cm (Madsen 2000). The wettest months are May and August through October. The average annual temperature for Wendover, is about 11.15°C. The warmest months are June through August with temperatures ranging between 2°C and 27°C (Madsen 2000).

Weather in Northeastern Nevada is subject to general west to east winds because of the trajectory of the jet stream, orographic effects, and its inner-continental locality (Madsen 2000). To a lesser extent, it is also affected by the high albedo of the sparsely vegetated playas and windward sides of mountains. The highest mountains near the Goshute Valley include Independence and Ruby Mountains, and part of the Humboldt Range.

Elevation is the most variable factor regarding temperature; higher elevations provide relief from summer heat, and low elevations (such as the playa) are subjected to the most extreme heat. The Goshute Valley has a dichotomous climate regime with a hot dry valley with limited precipitation, and cool wet mountains with higher precipitation. Most precipitation in the Great Basin is generated from northern Pacific storms and storms from the Gulf of Mexico and Gulf of California (Madsen 2000).

1.3.4 Playa Characteristics and Vegetation

The term playa is not regionally synonymous. Ordinarily, playa is defined as an "arid or semi-arid lacustrine basin," although sometimes it is referred to as a pan, implying a "depression with a saline surface" for smaller basins (Laity 2008). Playa environments reflect an exclusive relic of complicated history which has impacted associated geomorphic systems, where the most central aspect is that small fluctuations are recorded for a specialized region which is as transient as its lake is ephemeral. There are two different categories of playa systems (Laity 2008). A wet system contains a water table that is closer to the surface than a dry system. In a wet system, a film of evaporates coat the surface due to a short capillary rise to the surface where it evaporates. A dry system also has capillary forces enacting on the water table; however, the salts (halite and gypsum) never rise to the surface for evaporation because the water table is too low. The dry ground in a wet system is deceiving, since below ground, is moist and sticky due to cohesive properties of fine silts and clays (Laity 2008). Sometimes the water table depth can be beyond the capability of capillary forces to exert enough energy to move the water. In this case there would be less salt accretion and more fine silt and clay accumulation (Laity 2008). In periods of drought, for both wet and dry playa environments, cracks inevitably appear, some of which can create meter wide polygons (Laity 2008).

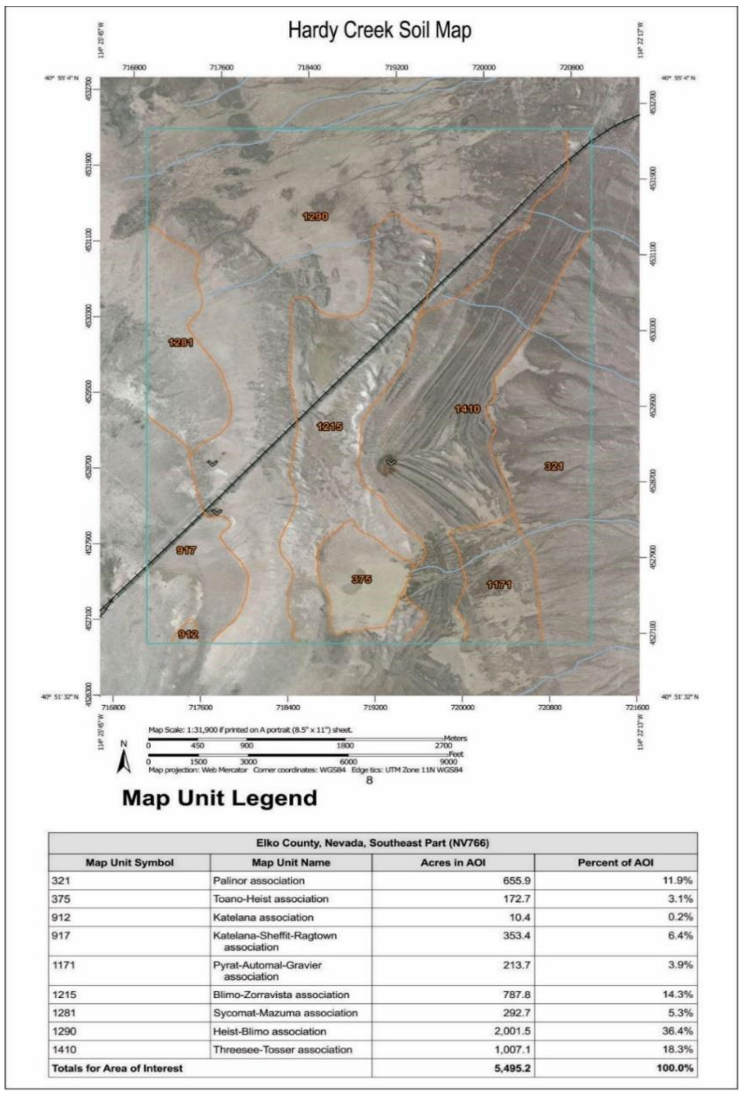
Sand tolerant plant species have adapted to drought, saline soils, sand blasting and burial, transient moisture conditions, low nutrient supply, and growing long roots which anchor into the sand and adjust when exposed (Laity 2008). Vegetation cover reduces wind velocity, which reduces sediment transport and increases wind velocity needed to mobilize sand grains, trap sand, and increase organic content causing the dune to become more cohesive and stable (Laity 2008). The size of dunes anchored by vegetation is controlled by the relative size and tolerance of vegetation (Laity 2008). Usually, vegetated dunes are heavily reliant on precipitation; however, if the water table is close enough to the surface, such as the nebkhas, vegetated dunes, in the Mojave, then they can reap from the benefits of a “wet aeolian system” (Laity 2008).

The Goshute Valley is situated within the Great Basin vegetation zone. Both of its dune fields are moderately vegetated with about 45-60% coverage. Vegetation commonly sighted from both survey areas include low sagebrush (*Artemisia rigida*), shadscale (*Atriplex confertifolia*), greasewood (*Sarcobatus vermiculatus*), and rubber rabbitbrush (*Chrysothamnus nauseosa*). Other vegetation observed included cheatgrass (*Bromus tectorum*), Indian rice grass (*Achnatherum hymenoides*), and winterfat (*Krascheninnikovia lanata*). Within the dune fields, the common vegetation is greasewood and rubber rabbit brush, while surrounding the dunes in the playa is greasewood and big sage. Vegetation is sparser outside of the dunes on the playa in comparison to the denser vegetated dune field.

1.3.5 Soils

The USDA’s online interactive Web Soil Survey was used to isolate the study areas to obtain a soil map, according to taxonomic soil classes. Associations are comprised of two or more geographically similar associated soils which are presented as one unit on the map (USDA Web Soil Survey).

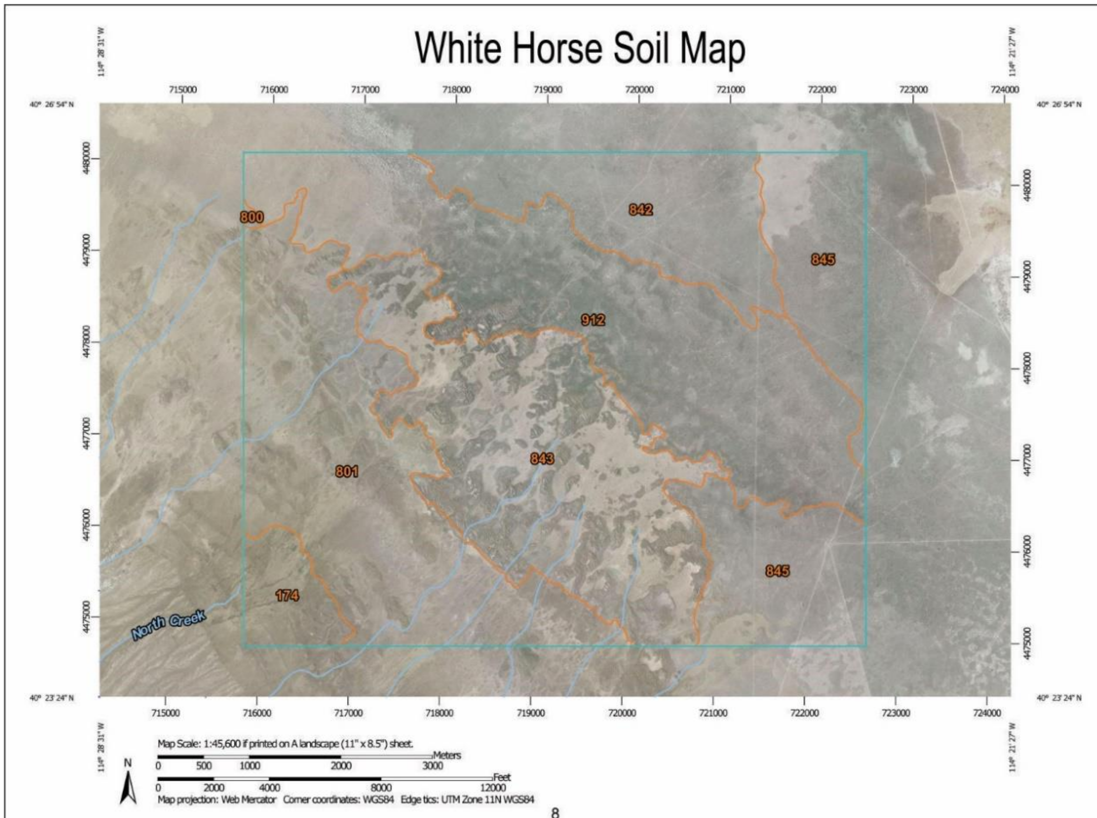
The Hardy Creek dune field is part of the Bilmo-Zorravista association which has four soil horizons: H1 sandy loam, H2 gravelly sandy loam, and H3-4 sandy loam (top to bottom of profile). The geologic setting of the Bilmo-Zorravista association is typical of remnant barrier beaches as Lake Warring dried. Since the major landform is a barrier beach, the parent material is composed of carbonate alluvium. The dune field is surrounded by gravelly loam derived from barrier beaches and spits from the Goshute Mountains to the east, and silt loam derived from alluvial fans from the Goshute Mountains to the east. Situated to the west are silt loams from the Pequop Mountains as part of remnant barrier beaches.



Elko County, Nevada, Southeast Part (NV766)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
321	Palinor association	655.9	11.9%
375	Toano-Heist association	172.7	3.1%
912	Katelana association	10.4	0.2%
917	Katelana-Sheffit-Ragtown association	353.4	6.4%
1171	Pyrat-Automal-Gravier association	213.7	3.9%
1215	Blimo-Zorravista association	787.8	14.3%
1281	Sycomat-Mazuma association	292.7	5.3%
1290	Heist-Blimo association	2,001.5	36.4%
1410	Threesee-Tosser association	1,007.1	18.3%
Totals for Area of Interest		**5,495.2**	**100.0%**

Figure 8. Web Soil Survey Analysis for the Hardy Creek Dune Field, Goshute Valley, NV.

The White Horse Dune field is a part of the Katelana-Kawich associations. The Katelana association has four horizons: H1-3 (0-80 cm below surface of the playa) silt loam, and H4 silty clay loam (top to bottom of profile). The geologic setting of the Katelana association is lake plain, or pluvial sediment. Therefore the parent material is lacustrine sediments (from Lake Waring) overlain by limestone and dolomite alluvium from the Goshute Mountains. The Kawich association has two horizons. Both horizons are characterized as fine sand measuring from 0 cm to 152 cm. The study area is best described as a sodic dune field because it contains with 10% calcium carbonate, 5% gypsum, and is slightly to moderately saline (4.0-8.0 mmhos/cm). The pH is about 8.8 suggesting alkaline soils, which is common for desert sediments. The dune field is surrounded by silt loam sediment and fine sandy loam sediment derived from distal fan deposits from the Dolly Varden Mountains to the south west, and very gravelly sandy loam derived from barrier beaches and spits from the Goshute Mountains to the north and north east.



Map Unit Legend

Elko County, Nevada, Southeast Part (NV766)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
174	Wintermute-Linoyer-Okan association	280.7	3.1%
800	Mazuma-Toano association	9.8	0.1%
801	Mazuma-Zerk-Okan association	2,086.1	22.9%
842	Katelana-Timpie association	937.8	10.3%
843	Katelana-Kawich association	2,073.8	22.8%
845	Katelana-Ragtown-Timpie association	1,341.2	14.7%
912	Katelana association	2,382.2	26.1%
Totals for Area of Interest		**9,111.5**	**100.0%**

Figure 9. Web Soil Survey Analysis for the White Horse Dune Field, Goshute Valley, NV.

1.4 Methods

The following will discuss field and lab methods for this project. Field methods include general mapping and geomorphologic observation, remote sensing via GPR, subsurface sampling, and archaeological survey. Lab methods involve OSL dating, remote sensing via satellite imagery, granulometric analysis, petrographic analysis, and palynological analysis.

1.4.1 Field Methods

Permit Application

Because we were undertaking a project which included surveying for and recording archaeological sites, a cultural resources permit was obtained prior to field work. The permit granted us permission to conduct research on BLM land which included taking subsurface samples at the designated dune fields. Field research was conducted between June 15th and 29th of 2015.

Geomorphological Data Collection

The extent of the Goshute Valley was determined by examining geologic maps and driving along the boundary following fault lines. This method is standard among geologists to define basin boundaries. We then constructed several cross-sections using geological maps. The different cross-section localities were determined once we completed the reconnaissance survey.

We used a Garmin handheld GPS to record the locations of dunes and other geomorphological features such as playas, alluvial fans, sand sheets, arroyos, and beach ridges. The dune fields of interest are potential indicators of paleowind direction and can determine certain basin characteristics such as micro-climates.

Sediment Collection

We concentrated our study in two dune fields. Surveys were completed in the Hardy Creek Quadrangle (11 T 4531000mN, 718000mE; 4531000mN, 721000mE; 4529000mN, 721000mE; 4529000mN, 718000mE) and the White Horse Mountains NW Quadrangle (11 T 4477000mN, 719000 m E; 4477000mN, 721000mE; 4475000mN, 721000mE; 4475mN, 719000mE).

Sand samples were collected from the Hardy Creek and White Horse dune fields. Only two samples were collected from the Hardy Creek field for three reasons. First, a few of the dunes were disturbed by a road cut. Second, the dunes appeared uniform in morphology, grain size, and vegetation cover. Finally, the extent of the dune field was relatively small. More samples were taken from White Horse because of the relatively large aerial extent of the field and because there were apparent deviations in dune morphology. Collectively, however, each selected dune is representative of the field and the two fields are distinct. Samples were taken from the crests of the dunes.

Core samples were also taken from each dune field using a vibracore, motor, and PVC pipes for sediment collection. The cores were essential to preserving the stratigraphy of the dune so the granulometric analysis could correlate to dune chronology via OSL dating. In addition, paleoenvironmental data was collected from the cores and later analyzed using thin sections in conjunction with pollen analysis and granulometric analysis, which supported the reconstruction of Holocene climate in the Goshute Valley and surrounding area. The vibracore uses vibration frequencies to reduce friction of the outer and inner core wall as the core penetrates the sediment. The porous air space in the dune allows for grain displacement, although, consolidated sediment is more difficult to core. Since the dune was more compact towards the playa, the rest of the core had to be hammered into the dune, which cased greater friction, thus greater sediment disturbance. One dune was selected from each field. The dune selected from the Hardy Creek dune field is also referred to as Dune 168 and the dune selected from the Hardy Creek dune field is also referred to as Dune 128. GPR was used to determine where to take core samples (as discussed below). Geomorphological and sediment data collection was crucial for determining aeolian geomorphology in the Goshute Valley.

Remote Sensing: GPR Methods

Before the core samples were taken from the dunes, we examined Dunes 168 and 128 using ground penetrating radar (GPR) to non-invasively study dune stratigraphy and draw tomographic, or sub-surface, profiles. We used a 500 MHz GPR because of its finer resolution. Sand dunes are good features to analyze with GPR because they have low conductivity and magnetic permeability (Bristow 2007). Bristow et al. (2005, 2007a, 2007b) determined the rate of dune migration by using optically stimulated luminescence (OSL) dating in conjunction with GPR. We modeled our research design based on their methods for interpreting dune stratigraphy and site formation processes. GPR pulses radar energy through the ground, much like seismic pulses, and reflects signals back up to create a tomographic reading. When the radar pulse contacts an object in the profile, the signal returns and is viewed as a parabola on the screen monitor. Through obtaining tomographic profiles of each dune sampled, we can assess the presence of different stratigraphic facies. We expected two outcomes from the GPR survey: either no internal structures (i.e. massive recent sand sheet formation), or internal structures (i.e. dune stratigraphy and presence of successive earlier dunes (cross-bedding) with potential buried surfaces). Since we found subsurface stratigraphy with the GPR, we took three core samples (10 cm diameter) across the apex of the dune to facilitate a more detailed understanding of the dune stratigraphy. In addition to the dunes we cored, we also took sub-surface samples of other dunes from each dune field to process in the lab and conduct a granulometric analysis to assess aeolian sedimentary characteristics. Subsurface sampling in dunes with archaeological sites was avoided. Three cores from one dune in each field were taken according to where the GPR image showed stratigraphy.

We created profiles and stratigraphic drawings by interpreting the raw GPR images. The tomographic profile generated by the GPR was simplified (removing noise and minor reflections following bounding surface reflections) and redrawn using the program CorelDraw (Bristow et al. 2005). This was prepared by tomographically flipping the raw image and rectifying it by hand with the dune height and distance specifications. Then, the depth of the cores and core samples were correlated to the rendered GPR image. We analyzed the image and determined the ages using the OSL results from the samples taken from each layer. In the images, we looked for dipping reflections, indicating dune migration, and truncation, which indicate erosional unconformities (Bristow et al. 2005). Both erosional and depositional surfaces were further abstracted from the other strata and arranged temporally based on its corresponding OSL ages from the core and the dune face to create a sequence stratigraphic profile. The OSL ages from the cores were measured by their distance along the length of the dune (Bristow et al. 2005).

Archaeological Survey

An archaeological survey was conducted before sediment collection and before GPR survey because the integrity of potential archaeological sites needed to be protected from disturbances caused by the aforementioned data collection methods. Archaeological sites were avoided when using GPR and collecting sediment samples and cores.

Survey transects were in conducted in 30-m intervals. This is a standard survey method established by Nevada BLM. When archaeological sites were encountered, 5-m-interval transects were conducted across the site to establish artifact density and the areal extent of the site. Surficial archaeological sites were mapped, and artifacts were recorded and mapped in the field to assess typology of tools and debitage, cultural affiliation, and density of artifacts. No artifacts were brought back to the lab for post-field analysis, as per permit agreement. The archaeological survey and following analysis were crucial for developing a model for geoarchaeology in aeolian settings by understanding how artifacts are distributed, both horizontally and vertically in a dune-field setting.

1.4.2 Lab Methods

Remote Sensing: Satellite Imagery

The rest of the mapping was completed post-field using aerial photography to get an overhead view and analysis of the geomorphic features, especially the two previously mentioned dune fields.

Field data, or *in-situ* data, was used as a comparative standard for checking Landsat 8 TM images representing the spectral reflectance of land type and cover. Landsat 8 was the latest satellite launched in the Landsat series and was used because it runs on a push broom sensor which collects one line of data at a time and measures the pixels instantaneously (Jensen 2007). The image found was taken during the time that the field work was being conducted. After searching on USGS EarthExplorer, imagery was selected from TM images from Landsat 8. The time of the images corresponds to the time when this project was in the field (June 13, 2015). The image has 504 ground control points. The image was taken on NADIR at a central coordinate of N 40°19’58”, W115°02’31.20”. The sun angle was 65.93° and the sun azimuth angle was 129.65°. Cloud cover was low and the sensor seemed well calibrated since there were no questionable lines.

Band ratio 6/7 was used to represent quartz and carbonate materials. This ratio is infrared to mid-infrared wavelengths which are common in geologic studies since rocks and minerals absorb and emit infrared light (Jensen 2007). Thermal data illuminates particular minerals and rocks that emit variable wavelengths within the infrared and thermal bands, and can distinguish outcrops, faults, and hardness. Band ratio 7/5 was used to represent mafic minerals. This ratio is of the thermal to near-infrared wavelengths, also commonly used for geophysics and geothermal mapping.

OSL Methods

Optically stimulated luminescence (OSL) dating is a method in which quartz or feldspars are excited by blue frequencies and near ultra violet light is measured in return from radioactive elements such as U, K, and Th. Older samples emit more light because the radiation dose has not been totally absorbed by radiation from the sun; therefore it calculates the age of the sediment when it was last exposed to solar radiation.

Uncut cores were submitted to Dr. Steve Forman at the Baylor University Geochronological Lab for OSL dating. OSL is a useful method used by many archaeologists and geomorphologists to date sediment, and is usually consistent with radiocarbon control (Forman et al. 2005). Single aliquot regenerative (SAR) dating procedures were used by the Baylor Geochronological Lab (Murray and Wintle 2000). SAR dating averages approximately 20-40 individual equivalent doses from aliquots (about 2,000-4,000 “light-tight” quartz grains between 150-500 µm) to calculate the mean equivalent dose. The quartz fraction is derived by heavy density separation using Na-polytungstate followed by a 40 minute HF immersion, to “etch” the outer 10 µm of quartz grains (Forman et al. 2005; Mejdahl and Christiansen 1994). These are then subjected to alpha radiation (Forman et al. 2005; Mejdahl and Christiansen 1994). A petrographic evaluation of the degree of quartz purity was conducted by point counting representative aliquots. Samples which were less than 1% of minerals other than quartz were winnowed out using hydrogen fluoride (HF) and checked under the petrographic scope once more. An automated Risø TL/OSL reader was used for single aliquot measurements (Forman et al. 2005). Blue light was emitted at 90% power to excite the sample using 30 light-emitting diodes (15mW/cm^2). A photomultiplier tube with three detection filters (3 mm thickness that transmit between 290-370 nm) was used to measure photon emissions (near ultra-violet range). A calibrated $^{90}Sr/^{90}Y$ beta source combined with the Risø reader and software conducted experimental sequences. Emissions were integrated for the first 0.8/500 s of stimulation. Dose recovery was tested to ensure errors did not exceed 1σ owing to lab environment subtleties. Using OSL dating, the investigation of aeolian chronology in the Goshute Valley was accomplished.

Sediment Analysis Methods

Sediment samples from the dunes were collected for granulometric analysis. The samples were dried in an oven for an hour at 60°C and screened with a #10 sieve. They were then prepared for particle size analysis, carbon assessment, and Chitticks, which measures the percentage of calcite and dolomite. The following methods are established methods which are used in the Texas A&M Soil Characterization Lab.

Particle size distribution was used to determine the grain size from very coarse to fine clay (Kilmer and Alexander 1949). After the samples were sieved, 5 ml of Calgon solution (sodium hexametaphosphate) were used as a dispersing agent and added to 10 g of sediment in a bottle. Distilled water was added to the bottles. The bottles were then agitated in a reciprocating shaker overnight. Before transferring to water bath, the bottles were cooled and temperature was measured as the tolerance level of 1°C of the temperature of the water bath. The bottles were weighed and distilled water was added to where each bottle measured 400 ml of liquid solution by volume. Stir bars were added. Bottles were placed into the water bath and the temperature was taken. The sedimentation rate was looked up for every 20 µm and 2 µm particles. Bottles were then stirred for two minutes and transferred back to bath and the timer was set to the sedimentation period. One minute before the sedimentation period ended, 5 ml was pipetted into the suspended solution using a 5 ml pipet and was then transferred into a crucible. These last couple of steps were repeated for the 2 µm pipetting. For testing the fine clays, the same pipetting method was used after allowing the solution to settle, except this time they were pipetted into centrifuge tubes. One degree was added to the temperature when looking up the rates. The samples were centrifuged at 2000 rpms according to the 20 µm and 2 µm. After they spun down, they were pipetted at 2 cm below the surface and pipetted into crucibles. All crucibles were weighed. The sands were washed for five minutes and left to dry overnight in the sediment oven at 60°C. Sand was then placed into a nest of sieves and mechanically shook for five minutes. Individual sieves were then weighed. Calculations were inputted into the computer program for calculations and final results.

Total carbon was used to obtain the percentage of total inorganic to organic carbon (Nelson 1982). A combustion furnace was preheated to 950°C and the system was “swept” with oxygen 100 cm^3/min. The weight of the absorption bulb was weighed. The inlets were connected to the flow tube and the stopcock was immediately opened. Then, the control was run using calcium carbonate, and the bulb was weighed. Each sample was then processed in the same manner. After every five samples, the control was run. The recordings were input into a computer program which ran the calculations.

Chitticks was used to obtain the calcite, dolomite, and calcium carbonate equivalent (Dremanis 1962). About 3 grams of fine-grinded sediment was used since the sediment was classified as a 1 on the effervescent scale. Starting pressure was recorded. A stir bar was dropped into a flask and four drops of amyl alcohol was added. Then the buret tip was filled with $HCL\text{-}FECl_2$. The 3-way stopcock was opened and the liquid levels were adjusted in the measuring buret to “set” the pressure with the leveling bulb on the Chitticks apparatus. The system was then closed and the leveling bulb was lowered to check the pressure in the measuring bulb. While adding HCL-$FECl_2$ to the flask by opening the buret tip and turning on the stirrer, the leveling bulb was being lowered and held 1 to 2 cm below the measuring bulb as it dropped. After 30 seconds, the volume of CO_2, temperature, and pressure was recorded. This process repeated about six more times for the next 30 minutes without recording the CO_2, temperature, and pressure. On the last repetition the CO_2, pressure, and temperature were recorded. Chitticks was repeated two to three times for each sample. The recordings were input into a computer program which ran the calculations.

Grain size analysis was conducted to calculate the statistics for grainsize distribution. Common methods include calculating mean grain size, sorting (standard deviation), skewness and kurtosis (Tchakerian 1991). Dune sands are characteristically fine grained and well sorted, so they should be either symmetrical or left skewed. Grain shape was also measured. Grains were analyzed under a binocular microscope. We qualitatively measured roundness using a grain size/shape chart. Also, we recorded any marks caused by abrasion during transport, which would indicate roughly how far the sediment traveled from its original source.

Petrology Methods

Petrology is the study of rock composition, structure, texture, and origin (Blatt et al. 2006). Minerals are defined as any inorganic solid crystalline structures formed by geologic processes involving high temperatures over extensive time; and, rocks are composed of these minerals (Perkins and Henke 2002). Therefore, the specific composition of minerals in a rock can identify provenance. Likewise, the study of these mineral grains, weathered from rocks, can also identify provenance.

One core section was taken from the White Horse Dune Field 15m core (85-114 cm) and another from the Hardy Creek 15m core (75-105cm) and sent to National Petrographic Service in Houston, Texas. The core sections were filled with a blue epoxy to hold the grains together in a matrix. The matrix was stained pink with Alizarin Red S and Potassium Ferricyanide for carbonates, since dolomite and carbonate can look similar if twining in dolomite is not visible. The matrix was then cut to 0.03 mm thickness, and mounted onto separate 2x3 in slides. The slides were viewed using a petrographic microscope and counted by transects in a 50,000 by 30,000 μm area centered on the thin section.

Palynology Methods

Twelve samples were weighed at 10 g and distributed into separate beakers. One *Lycopodium* tablet was added to calculate pollen concentration values. About 25 ml of HCL (15%) was added to each sample and swirled to dissolve the Lycopodium tablet and carbonates. After the effervescing ceased, the swirl and decant method was used to screen out large pieces of charcoal, sand, and organic material using a 250 μ screen for each sample one at a time. This was accomplished by adding 100 ml of water, swirling (without creating a vortex), holding for 12 seconds and decanting into a beaker marked “X”. This step was then repeated two more times (a total of 3x). The beaker marked “X” was then swirled, held for 12 seconds, and decanted back into the labeled beaker. This step was repeated two more times (a total of 3x). After completing the swirl and decant method for all 12 samples, the samples were then left to sit undisturbed for 3 hours. After 3 hours, the samples were decanted and a squirt of HF (48%) was added down the side of the beaker and swirled. Then, 60 ml of HF was added and was left to sit undisturbed overnight (no shorter than 8 hours). In the morning, water was filled to the top of the beakers and left to sit undisturbed for 3 hours. After 3 hours, the samples were decanted and about 100 ml of HCL was added and left to sit undisturbed for 3 hours.

After 3 hours, samples were transferred from the beakers to centrifuge tubes to prepare for acetolysis, which would break down cellulose. Glacial acetic acid was added to 2/3 of the tube and centrifuge. This would transition the sample into acetolysis since it would react with water. An 8:1 ratio of acetic anhydride to sulfuric acid was used ($C_4H_6O_3$ to H_2SO_4). After acetolysis, the samples were washed in glacial acetic acid and later water several times to bring the samples out of acetolysis. The samples were then stained in water, centrifuged and decanted.

The samples were examined under the microscope to see what further processing they would need. They still contained many silicates and charcoal; therefore, they were sonicated to get rid of charcoal and ran through heavy density separation to get rid of silicates. Sonification involves covering a small beaker with an apparatus holding a screen. The sediment is washed through a 10µ screen using alcohol (95%) and a hand held sonicator set at output level 2.5 for 3 minutes. The apparatus was removed from the beaker and screen contents were washed into another beaker. This step was repeated for all 12 samples one at a time. The beakers containing the screen material were then washed into centrifuge tubes. The material that passed through the screen was discarded. Heavy density separation involves pouring zinc-bromide half way up the centrifuge tubes and flushing any pollen on the sides of the tubes with a little bit of alcohol. The sample was agitated for 30 seconds using a wooden stir stick on the side of the tube using an up/down motion with the vortex mixer set on low. Two milliliters of water was added. The samples were centrifuged at 500 RPMs for 5 minutes, then spun at 3500 RPMs for 5 minutes. Samples were pipetted off for the band of pollen which was above the zinc-bromide.

The samples were examined under the microscope to see what further processing they would need. The samples could still use some more cleaning, so they were bleached. The samples were divided to preserve the processed samples in case bleach destroyed the pollen grains. Two drops of bleach were added to the samples and agitated vigorously with a wooden stir stick for 30 seconds. Then, they were centrifuged for 2 minutes, decanted, and immediately washed with water several times. At this point, there is not much more that can be done to the samples, as bleach is the last resort. I did screen the samples once more using a 200 μ screen, but this really should have been done after acetolysis. The discard screened material was carefully checked under a microscope to ensure no pollen was left behind on the screen, such as *Abies*. The samples were then re-stained and washed into drums using alcohol. Several drops of glycerin were added. A toothpick was added to each sample and left overnight.

Slides were mounted for each sample. Transects were made along the slides until about 200 grains had been counted. The data was then processed in excel and CorelDraw, and then analyzed for interpretation.

2 AEOLIAN GEOMORPHOLOGY, CHRONOLOGY, AND PALEOECOLOGY OF THE GOSHUTE VALLEY

2.1 Results

The significance of this study stems from the novelty of combining granulometric, GPR, and OSL data from the Goshute Valley with palynological data from nearby Bonneville Estates Rockshelter in the western Bonneville Basin, and contributes to regional Quaternary climatic data. There are no previous aeolian studies in the Goshute Valley; therefore the results from this study exemplify their uniqueness in the Goshute Valley. The stratigraphy and dates from this study contribute to the knowledge of dune-building sequences, and therefore, lend to the understanding of past climate and human occupation (as discussed later in Chapter 3).

2.1.1 Aeolian Geomorphology

Based on field and laboratory analysis, two aeolian depositional, or episodic, units were identified: the dune field in the Hardy Creek, and the dune field in the White Horse. The perimeter of the Hardy Creek dune field (Figure 12) is 6.45 km, measuring 2.90 km long by 0.94 km wide, and the area is 1.50 km^2. The dune field is located 17 km from the top of the Pequop Mountains and 9 km from the top of the Goshute Mountains. The dune field is located at 2,706 m (8,878 ft) above sea level. It is located approximately 3 km from the toes of the Goshute alluvial fans and 9.5 km from the toes of the Pequop Mountain alluvial fans. Figure 10 shows the windward side of Dune 168 from the Hardy Creek dune field, which was selected for core sampling.

Figure 10. Dune 168, Hardy Creek Dune Field, Goshute Valley, NV.

The perimeter of the White Horse dune field (Fig. 10) is 20 km, measuring 8.5 long by 3 wide, and the area is 15.10 km^2. The dune field is located 14 km from the top of the Dolly Varden Mountains and 12.5 km from the top of the Goshute Mountains. The dune field is located 1,711 m (5,614 ft) above sea level. It is located approximately 2 km from the toes of the Dolly Varden alluvial fans and 5.5 km from the toes of the Goshute Mountain alluvial fans. Figure 11 shows the crest axis of Dune 128 from the White Horse dune field, which was selected for core sampling. The Hardy Creek dune cores were sampled at 6, 15, and 24 m starting from the leeward side and White Horse dune cores were sampled at 10, 15, and 22 m starting from the leeward side.

Figure 11. Dune 128, White Horse Dune Field, Goshute Valley, NV.

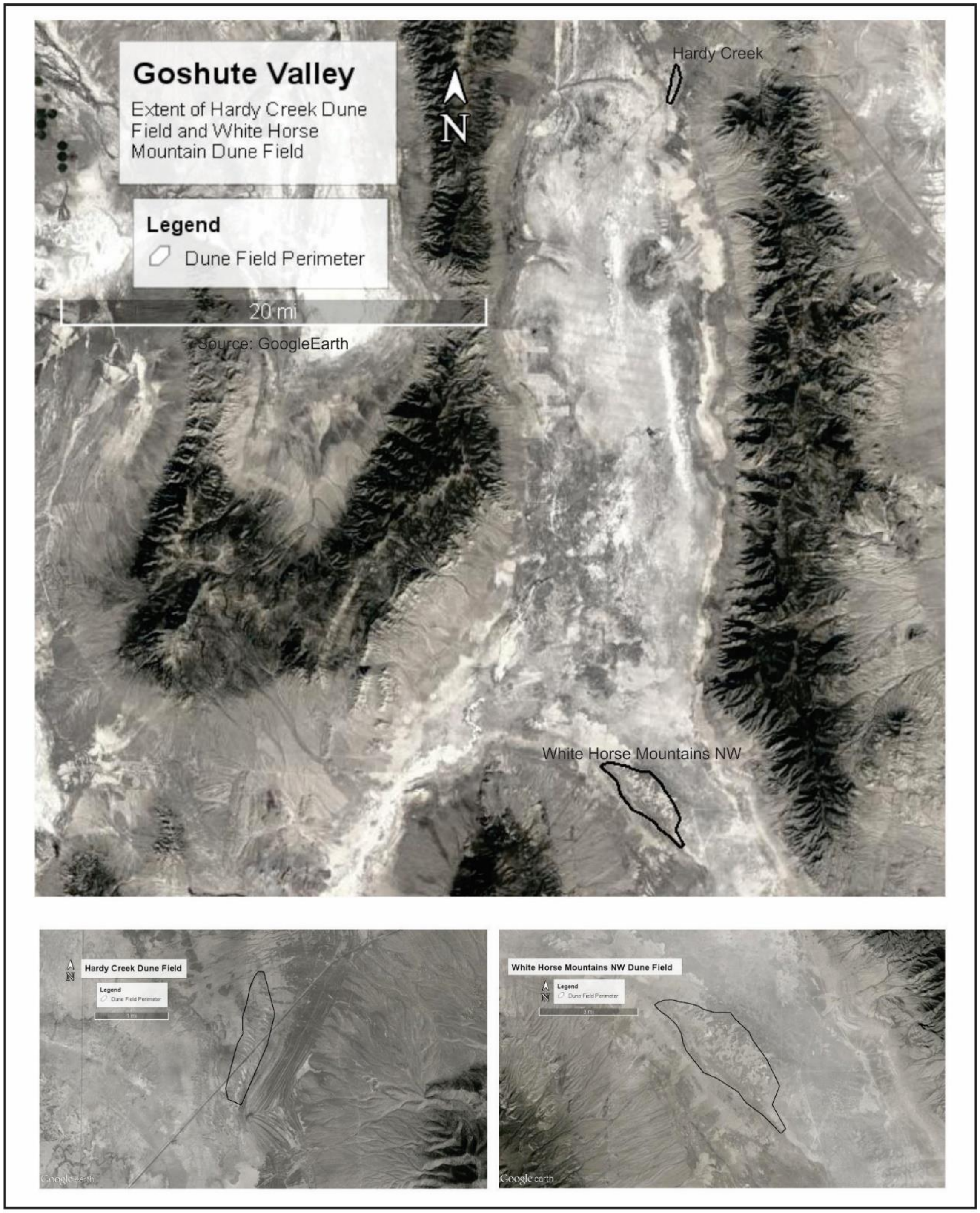


Figure 12. Perimeter of the Hardy Creek Dune Field (bottom left) and White Horse Dune Field (bottom right), Goshute Valley, NV.

2.1.2 Granulometric Analysis and Texture Class

Determining grain size analysis is significant for understanding the composition and morphology of the dunes. Common statistics significant for granulometric, or particle size analysis, include, mean grain size, sorting, skewness, and kurtosis. Mean grain size is an average of the grain size distribution. Sorting, which is really standard deviation, is the measure of homogeneity across the distribution. Skewness measures the symmetry of a distribution, and kurtosis measures uniformity, or outliers.

Dune	Mean Grain Size	Standard Deviation	Skewness	Kurtosis
Hardy Creek	2.16	0.86	0.16	0.88
White Horse	1.67	1.07	0.19	1.24

Table 1. Average grain size, sorting (standard deviation), skewness and kurtosis for Dune 128 (White Hosrse Dune Field) and 168 (Hardy Creek Dune Field).

Table 1 and Figure 13 summarize particle size distribution statistics of the Hardy Creek and White Horse Dune Fields. The sediments from the Hardy Creek dune field have a mean grain size of 2.16, a standard deviation of 0.86, a skewness of 0.16, and a kurtosis of 0.88. This represents a unimodal, moderately sorted medium sand, fine skewed, and platykurtic (less kurtosis than normal distribution) dune field. The sediments from the White Horse dune field have a mean grain size of 1.67, a standard deviation of 1.07, a skewness of 0.19, and a kurtosis of 1.24. This represents a unimodal, poorly sorted medium sand, fine skewed, and leptokurtic (greater kurtosis than normal distribution and centers on mean grain size) dune field. With respect to grain size, both White Horse and

Hardy Creek dunes are positively skewed, indicating that sediment grades coarse to fine, and unimodal, with predominantly medium sand.

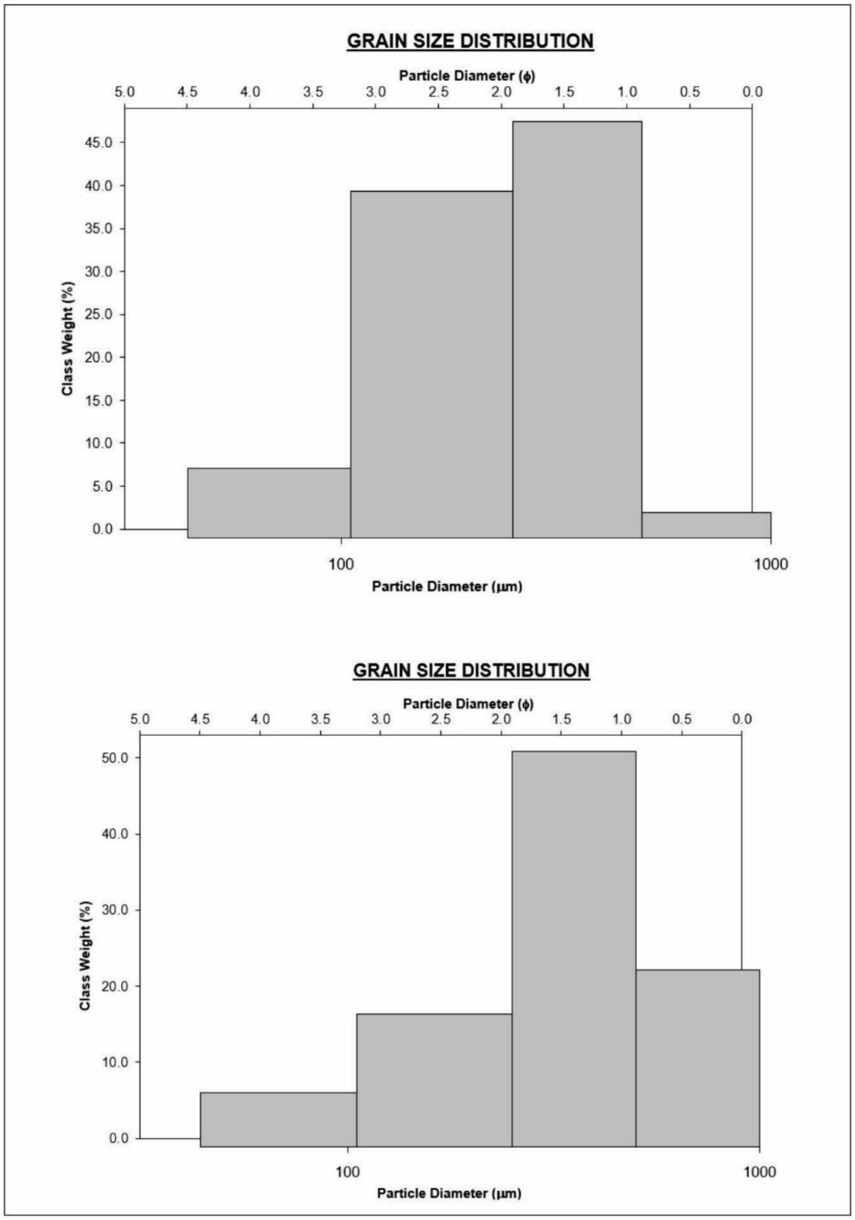


Figure 13. Grain size distribution for Dune 128 (White Horse Dune Field) and Dune 168 (Hardy Creek Dune Field).

Figure 14 shows grain size histograms of sediment samples from each core from the Hardy Creek Dune Field. Histograms labeled a through c are sampled from the slip face of the dune. Histograms d through f are sampled from at the crest of the dune, and histogram g and h are sampled from the windward side of the dune. In both dunes, the presence of very coarse sediment grains are under-represented, but this is expected since this is an arid aeolian feature, and not a beach setting. Dunes typically contain finer sediment towards the bottom of the feature and coarser sediments towards the crest of the dune. However, the grain size from these dunes are surprisingly larger than expected for Lunette dunes. The dunes from Hardy Creek Dune Field are mostly unimodal centering on medium to fine grain sediment. The Hardy Creek Dunes are characteristic of a fining downward sequence where the oldest strata, from the windward side to the slip face, range from mostly very fine to fine sand. The windward side of the dune is comprised of more fine grain sediment than the slip face indicating sediment starvation and erosion, which is characteristic of dunes with large blowouts.

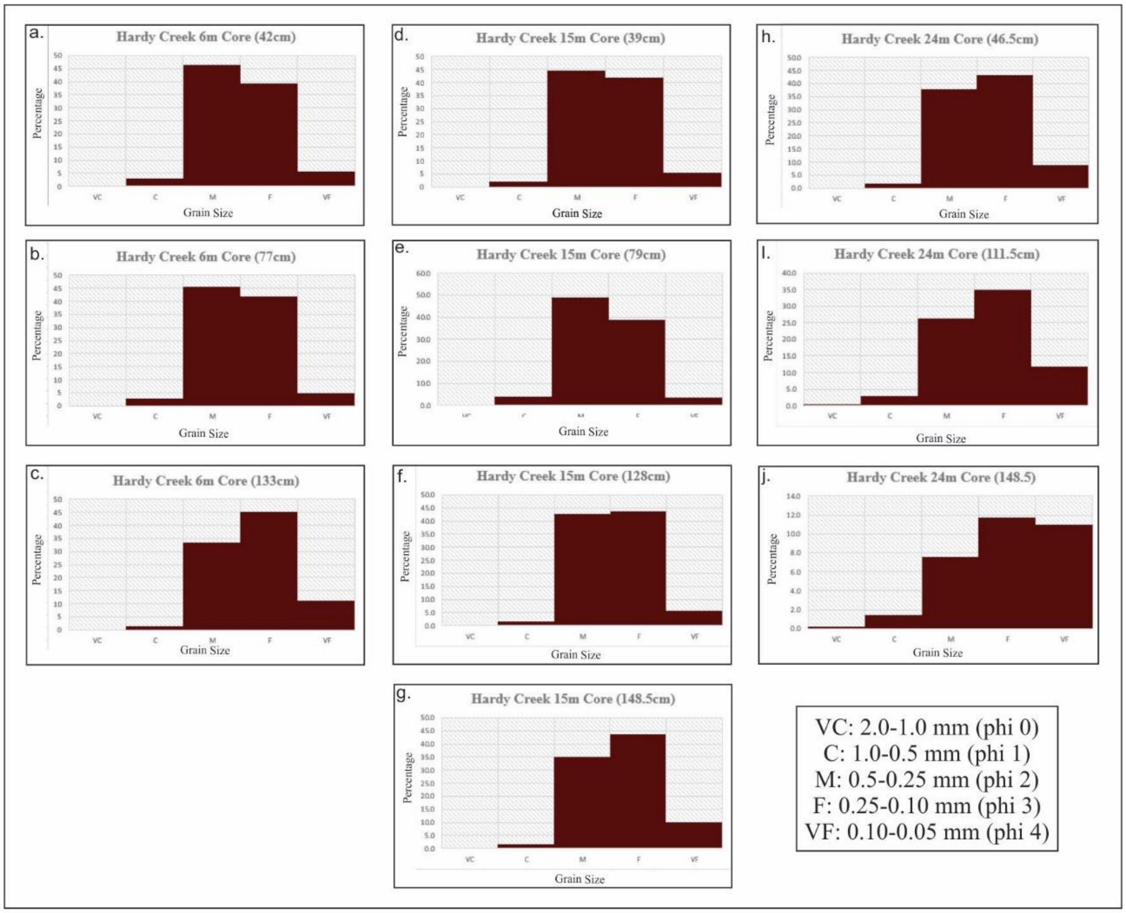


Figure 14. Grain Size distribution histograms for Dune 168 (Hardy Creek Dune Field).

Figure 15 demonstrates the sediment profile from Dune 168. This particular profile is from the middle core (15 m). From 15 to 65 cm, the sediment can be characterized as massive medium sand. Starting from about 65 cm to the bottom of the core, the grain size is silt, which corroborates the data from the particle size analysis previously mentioned. Just below 75 cm, there is a color change in the sediment from dark tan to light tan. At 90 cm, there is a large clast, or cobble size feature which is uncharacteristic since the surrounding sediment is silt. Generally, as previously discussed, the fining downward sequence in the cores is characteristic of dunes, however, the grain size is larger than expected. The silt is most likely deposits from the playa.

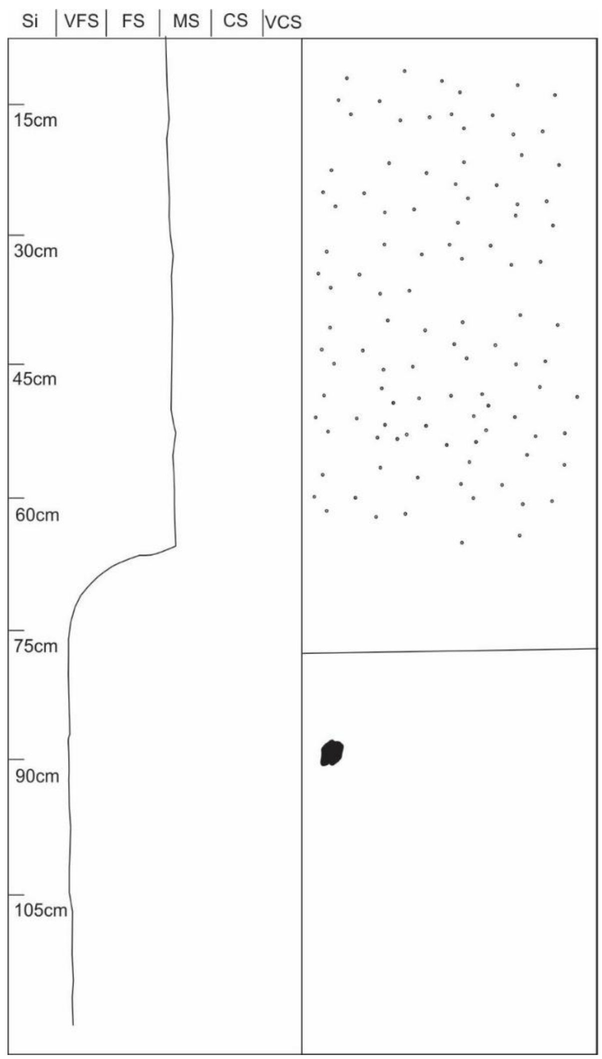


Figure 15. Profile of Core 15 from Hardy Creek Dune.

Figure 16 shows grain size using histograms of sediment samples from each core from the White Horse dune. Histograms labeled a through c are sampled from the slip face of the dune, histograms d through g are sampled from the crest of the dune, and histogram h through j are sampled from the windward side of the dune. The White Horse dune is less well sorted than the Hardy Creek dune which has moderate to poor sorting. The dunes are unimodal centering on medium to fine grains. The White Horse Dunes are characteristic of a fining downward sequence where the oldest strata, from the windward side to the slip face, range from mostly very fine to fine sand. The windward side of the dune is comprised of more fine grain sediment than the slip face. Once again, this is because of large blowout features on the windward side of the dune caused by erosion and sediment starvation. The dunes from White Horse Field are also surprisingly coarser grained than expected perhaps indicating a nearby source, or more weathering resistant sediment grains. However, the White Horse dunes cannot characterized as sand sheets because they are not comprised of bimodal sand centered with one coarse grain mode (Tsoar 2011).

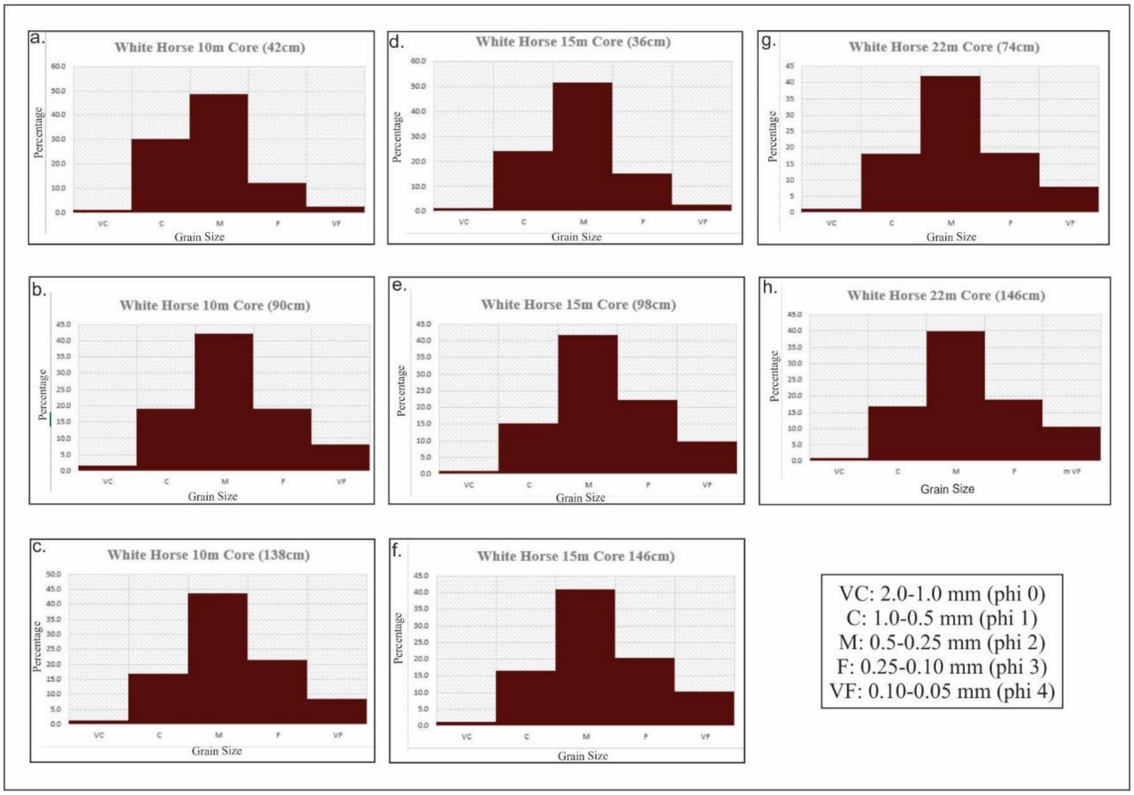


Figure 16. Grain size distribution histograms for Dune 128 (White Horse Dune Field).

Figure 17 demonstrates the sediment profile from Dune 128. This particular profile is from the middle core (15 m). From 15 to 60 cm, the sediment is interbedded coarse grains in medium grained sand. From about 60 cm to the bottom of the core, the grain size is medium, which corroborates the data from the particle size analysis previously mentioned. Between 56 and 70 cm, there are three modern organic bands. At 60 cm, there is a large clast, or cobble size feature which is uncharacteristic compared to the mean grain size. At 70 cm, a small pressure flake was found. Generally, as previously discussed, the fining downward sequence in the cores is characteristic of dunes, however, the grain size is larger than expected.

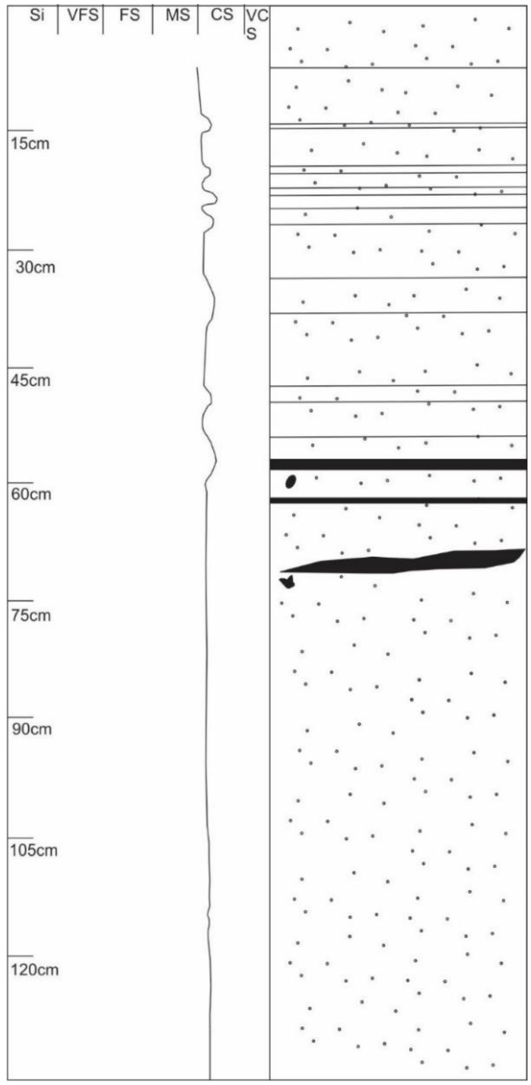


Figure 17. Profile of Core 15 from White Horse Dune.

Table 2 shows the particle size distribution and chemical composition for the Hardy Creek and White Horse Dune Fields. Hardy Creek Dune Field had on average a composition of .08% very coarse grains, 11% coarse grains, 37% medium grains, 38% fine grains, and 8% very fine grains. White Horse Dune Field had on average a composition of 1.2% very coarse grains, 20% coarse grains, 44% medium grains, 18% fine grains, and 8% very fine grains.

			PARTICLE SIZE DISTRIBUTION (mm)														
			----SAND----						----SILT----		----CLAY----						
			VC (2.0-1.0)	C (1.0-0.5)	M (0.5-0.25)	F (0.25-0.10)	VF (0.10-0.05)	TOTAL (2.0-0.05)	FINE (0.02-0.002)	TOTAL (0.05-0.002)	FINE (<0.0002)	TOTAL (<0.002)	TEXTURE CLASS	CAL-CITE	DOLO-MITE	CACO3 EQ	ORGN C
SAMPLE		cm from bottom of core	----%----											----%----			
E5099	Hardy Creek, 6m	19	0	1.3	33.4	45.3	11.1	91.1	2.2	4	1.7	4.9	S	11.2	0.8	12.1	0.21
E5103	Hardy Creek, 6m	75	0	2.8	45.7	41.7	4.7	94.9	1.2	2	2.2	3.1	S	9.5	0.7	10.3	0.25
E5100	Hardy Creek, 6m	110	0	3	46.4	39.4	5.7	94.5	0.7	1.6	2.3	3.9	S	9.8	0.5	10.3	0.17
E5222	Hardy Cr, 15m	79	0.1	3.9	48.7	38.9	3.6	95.2	0.9	1.3	1.5	3.5	S	10.3	0.6	11.0	0.21
E5101	Hardy Creek, 15m	113	0	2.2	44.7	41.7	5.4	94	0.9	1.7	2.1	4.3	S	9.5	0.9	10.5	0.12
E5223	Hardy Cr, 15m	128	0.0	1.6	42.7	43.6	5.7	93.6	1.0	2.3	1.6	4.1	S	10.5	1.1	11.7	0.27
E5224	Hardy Cr, 15m	148.5	0.0	1.7	35.0	43.8	10.2	90.7	2.0	4.2	2.0	5.1	S	11.3	0.7	12.1	0.28
E5023	Hardy Creek, 24m	3.5	0.2	1.4	7.6	11.7	11.0	31.9	30.7	52.4	1.9	15.7	SiL	42.9	0.9	44.3	0.69
E5024	Hardy Creek, 24m	40.5	0.5	3.0	26.4	34.9	11.8	76.6	7.9	13.0	2.2	10.4	FSL	19.7	1.3	21.2	0.43
E5025	Hardy Creek, 24m	105.5	0.0	1.8	37.9	43.1	8.8	91.6	2.3	3.9	1.9	4.5	S	11.4	1.1	12.6	0.21
E5026	White Horse, 10m	14.0	1.4	17.0	43.6	21.4	8.6	92.0	1.9	3.2	1.4	4.8	S	7.5	1.4	9.0	0.08
E5027	White Horse, 10m	62.0	1.6	19.1	42.3	19.0	8.3	90.3	2.9	4.1	1.4	5.6	S	7.7	1.0	8.8	0.18
E5028	White Horse, 10m	110.0	1.2	30.2	48.7	12.4	2.7	95.2	1.0	1.1	0.9	3.7	CoS	5.9	1.1	7.1	0.15
E5029	White Horse, 15m	6.0	1.2	16.5	41.0	20.3	10.2	89.2	2.9	5.5	1.0	5.3	S	8.7	0.9	9.7	0.24
E5030	White Horse, 15m	54.0	0.9	15.2	41.8	22.2	9.8	89.9	2.4	4.5	1.2	5.6	S	8.1	1.2	9.4	0.19
E5031	White Horse, 15m	116.0	1.2	24.3	51.6	15.2	2.8	95.1	1.3	1.8	1.2	3.1	S	6.6	0.9	7.6	0.14
E5102	White Horse, 22m	78	1.2	18.2	42	18.3	8.1	87.8	4.2	4.7	2.6	7.5	LS	9.7	1.1	11	0.25
E5225	White Horse, 22m	146	1.0	16.9	40.0	18.9	10.5	87.3	4.4	6.1	1.7	6.6	LS	8.8	1.6	10.5	0.22
E5032	Dune 01		0.2	12.8	48.9	22.3	6.0	90.2	2.2	3.8	1.9	6.0	S	8.3	1.3	9.7	0.25
E5033	Dune 10		0.2	12.0	51.5	23.5	6.4	93.6	1.6	2.5	1.7	3.9	S	8.2	2.0	10.4	0.16
E5034	Dune 25		0.0	12.8	48.7	18.1	9.5	89.1	3.4	5.8	1.3	5.1	S	2.3	0.9	3.3	0.50
E5035	Dune 39		0.0	7.3	51.3	29.9	5.6	94.1	1.4	1.6	1.6	4.3	S	5.8	1.7	7.6	0.11
E5036	Dune 40		0.2	5.9	42.4	37.8	7.0	93.3	1.4	1.7	1.5	5.0	S	6.2	0.1	6.3	0.23
E5037	Dune 77		0.2	12.2	51.8	23.8	5.3	93.3	1.6	1.8	1.6	4.9	S	7.1	1.5	8.7	0.14
E5038	Dune 127		3.1	29.9	42.8	12.7	4.7	93.2	2.3	2.5	1.1	4.3	CoS	7.8	1.0	8.9	0.18
E5039	Dune 167		0.0	3.5	47.6	39.9	4.1	95.1	0.8	1.5	1.2	3.4	S	9.6	0.7	10.4	0.21
E5040	Dune 169		0.1	3.3	44.5	42.2	5.5	95.6	0.9	1.6	1.2	2.8	S	9.5	0.8	10.4	0.59

Table 2. Particle size distribution and other characteristics for Hardy Creek Dune field, White Horse Dune field, and selested dunes. Dunes 1-127 are located in the White Horse Dune field and dunes 167-169 are from the Hardy Creek Dune field. Texture class key: FSL = fine sandy loam; S = sand; CoS = coarse sand; SiL = silty loam; LS = loamy sand.

Table 3 shows the carbonate cmposition for each sample from the Hardy Creek and White Horse dune field cores in asending depth starting from the bottom of each core. Hardy Creek dune contains more calcite (crystalline calcium carbonate $CaCO_3$) at 15%, while the White Horse Dune has 8% calcite. However, White Horse Dune has a higher percentage of dolomite at 1.2%, in comparision to the Hardy Creek Dune which has 0.9%. The calcium carbonate equivalency is a measure of carbonate content in a liming matrix (calcareous soil) and is calculated as though all the carbonate is in the form of $CaCO_3$

(Schaetzl and Anderson 2005). The Hardy Creek Dune has a total of 16% $CaCO_3$ equivalency, while the White Horse Dune has 9% $CaCO_3$ equivalency. Lastly, the Hardy Creek Dune has a higher percentage of organic carbon at 0.3%, while the White Horse Dune has 0.2% organic carbon.

Holliday's (1997) study of old (25,000-8,000 ^{14}C yr B.P) lunettes in the northwest Texas and eastern New Mexico plains yielded calcareous sandy loam/loamy sand dunes, which consisted of 15-40% $CaCO_3$. Other dunes from his study yielded sand/loamy sand/ dunes that were low in carbonates (0-15% $CaCO_3$). The Hardy Creek Dune sediment samples were recorded between 10.5% and 21.2 % $CaCO_3$, and the White House Dune sediment samples were between 7.6% and 10.5 % $CaCO_3$. Whereas Holliday's (1997) lunettes have an A through Btk horizon, the soil classification in the soils from the dune fields in the Goshute Valley are mostly Entisols, meaning that they are comprised mostly of massive units of immature soils that have not weathered persistently past the unconsolidated parent material; and, they may only have an A horizon at most (Schaetzl and Anderson 2005).

The Hardy Creek Dune Field contained only 0.25% total organic material, and the rest was inorganic. White Horse contained 0.21% organic material and the rest was inorganic. Organic content increased as core depth increased, which means that any organic material from the roots of the shrubby plants are percolating down but not past the clays and silts. The restrictive layer is the playa sediment, in this case very compacted marl which overlays bedrock.

			TEXTURE	CAL-	DOLO-	CACO3	ORGN
		cm from	CLASS	CITE	MITE	EQ	C
SAMPLE		bottom of core		------------------------%----------------------			
E5099	Hardy Creek, 6m	19	S	11.2	0.8	12.1	0.21
E5103	Hardy Creek, 6m	75	S	9.5	0.7	10.3	0.25
E5100	Hardy Creek, 6m	110	S	9.8	0.5	10.3	0.17
E5222	Hardy Cr, 15m	79	S	10.3	0.6	11.0	0.21
E5101	Hardy Creek, 15m	113	S	9.5	0.9	10.5	0.12
E5223	Hardy Cr, 15m	128	S	10.5	1.1	11.7	0.27
E5224	Hardy Cr, 15m	148.5	S	11.3	0.7	12.1	0.28
E5023	Hardy Creek, 24m	3.5	SiL	42.9	0.9	44.3	0.69
E5024	Hardy Creek, 24m	40.5	FSL	19.7	1.3	21.2	0.43
E5025	Hardy Creek, 24m	105.5	S	11.4	1.1	12.6	0.21
E5026	White Horse, 10m	14.0	S	7.5	1.4	9.0	0.08
E5027	White Horse, 10m	62.0	S	7.7	1.0	8.8	0.18
E5028	White Horse, 10m	110.0	CoS	5.9	1.1	7.1	0.15
E5029	White Horse, 15m	6.0	S	8.7	0.9	9.7	0.24
E5030	White Horse, 15m	54.0	S	8.1	1.2	9.4	0.19
E5031	White Horse, 15m	116.0	S	6.6	0.9	7.6	0.14
E5102	White Horse, 22m	78	LS	9.7	1.1	11	0.25
E5225	White Horse, 22m	146	LS	8.8	1.6	10.5	0.22

Table 3. Calcite, Dolomite, Calcium Carbonate Equivalent (the amount of limestone which is effective in neutralizing acid), and Organic percentages for Dune 128 (White Hose Dune Field) and Dune 168 (Hardy Creek Dune Field). Texture Class Key: FSL = fine sandy loam; S = sand; CoS = coarse sand; SiL = silty loam; LS = loamy sand.

Both Hardy Creek and White Horse dune fields are positively skewed, indicating that sediment grades course to fine, and unimodal, with predominantly medium sand, yet the histograms indicate two unique dune fields. This can be further emphasized by the mineral content from the samples. The White Horse dune contained considerably less calcium carbonate. The results from stratigraphy and OSL dating will discuss how the results previously mentioned support the distinctness of the two dune fields in age, morphology, and sediment, which will later determine source provenance, wind direction, and paleoenvironment.

2.1.3 Luminescence Dating

Three cores were taken from each dune on the windward, crest, and lee where the GPR image indicated strong structures (Figure 18). The GPR images are taken across the dunes' crest. Since the sediments in leeward core were expected to have been deposited closer to modern time, only the windward and crest cores were dated. Overall, the ages of the dunes are young and are relatively similar in age to one another. As previously mentioned, the texture classes of both dunes are sand. However, on a finer resolution within the cores, the texture varies.

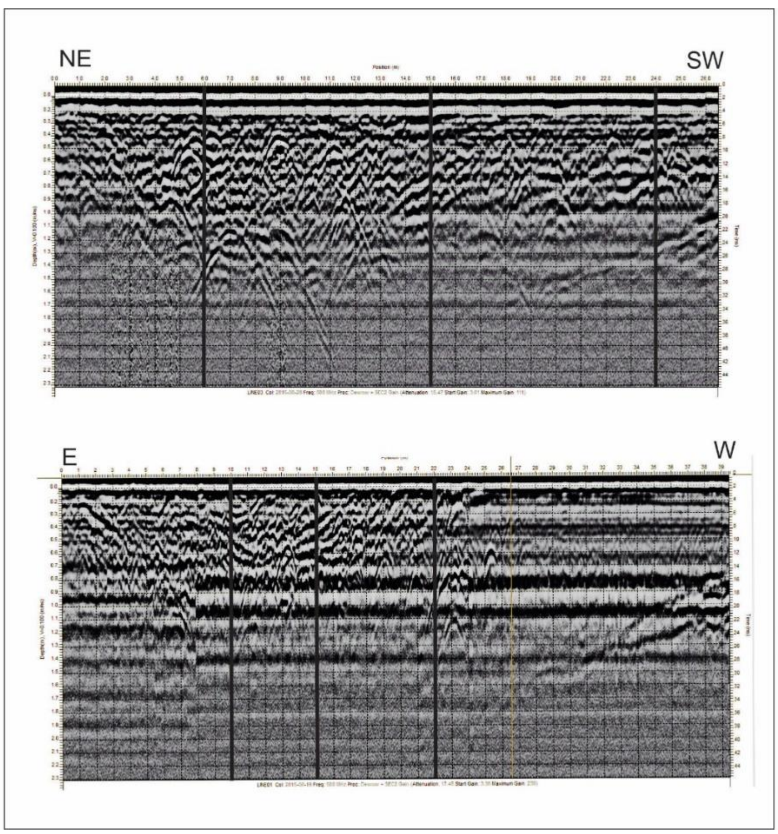


Figure 18. GPR images of Dune 128 (White Horse Dune Field), shown on top, and Dune 168 (Hardy Creek Dune Field), shown on bottom.

The dashed lines in Figures 19 and 20 represent stratigraphic uncertainty when the GPR image was interpreted. Also, in Figure 20, the void in the stratigraphy between the cores taken at 6m and 15 m is left ambiguous because of noise interference in the GPR image.

Primary features of both dunes focus on grading on a fining downwards sequence and minor cross-bedding. No secondary features are found in either dune. The prevailing wind direction, as preserved in internal bedding structures, is southwest to northeast for both dunes which is indicated by the angles of the foresets (slipface deposits) and topsets (deposits from dune accretion).

Figure 19 shows the positions of the cores and associated OSL ages within the internal structure of the Hardy Creek Dune. It shows several bounding surfaces of dune accretion, most of which the topsets are terminated. The wedge-like foresets, or slipface deposits are also truncated. The oldest date from the Hardy Creek Dune yielded 5,160 ± 620. This date was sampled from the bottom of the windward core (24m) at 98 cm actual dune depth. The second unit yielded a date of 1,290 ± 140 BP and was sampled from the crest core (15m) at a depth of 121.5 cm. The third unit above this date yielded 1,680 ± 105 BP and was sampled from the windward core. It is overlain by a unit which dates 1,135 ± 145 BP. As expected the uppermost stratum is overlain by modern units less than 80 years. There appears to be a reversal towards the bottom of the core taken at the crest, however, part of the stratigraphic context was lost dune to noise in the GPR image. Another interpretation is that the two dates are actually within the same strata due to the overlap in OSL ages.

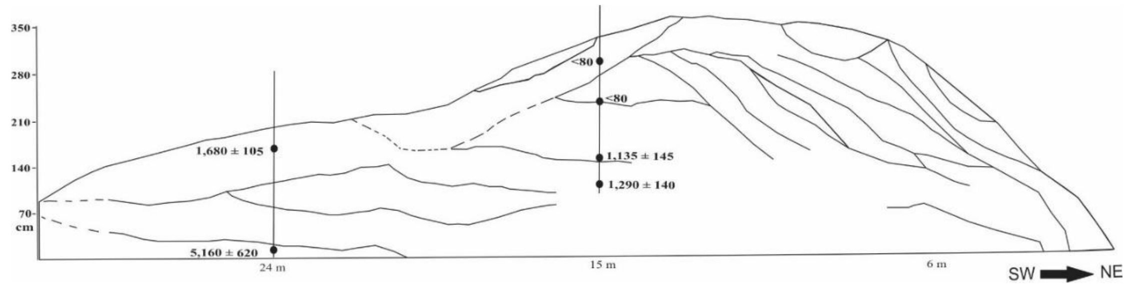


Figure 19. Hardy Creek internal dune structure with correlated OSL ages.

Figure 20 shows the positions of the cores and correlated OSL ages within the internal structure of the White Horse dune. It shows several bounding surfaces of dune accretion, where the two younger strata are truncated. The oldest sample from White Horse dune yielded 1,570 ± 190 BP. This date was sampled from the bottom of the windward core at 120 cm actual dune depth. Above this unit, measured at 45 cm actual dune depth, is a younger deposit dated to 710 ± 80 BP. Overlying this unit, sampled at 102 and 69 cm actual dune depth, are two younger units dating 755 ± 85 BP and 510 ± 40 BP, respectively. In the figure, the dates appear inverted; however, this can be accounted for by the overlap in standard error. As expected the uppermost strata are overlain by modern units of less than 80 years. Like the Hardy Creek dune, there also appears to be a reversal towards the bottom of the core taken at the crest. Yet, another interpretation is that the two dates overlap in age since the range in error is high.

Dune/Core/depth	Lab Number	Aliquots[a]	Grain Size (μm)	Minimum Equivalent dose (Gray)[b]	Finite mix/central Equivalent dose (Gray)[b]	Over-dispersion (%)[c]	U (ppm)[d]	Th (ppm)[d]	K (ppm)[d]	Dose rate (mGray/yr)[f]	Minimum OSL age (yr)[g]	Finite mix or central model OSL age (yr)[g]
168/15/43	BG4044	5/33	250-355	<0.4	<0.4	NC	2.22±0.01	5.72±0.01	2.34±0.01	3.10±0.15	<80 years	<80 years
168/15/79	BG4045	2/13	355-500	<0.4	<0.4	NC	1.97±0.01	5.04±0.01	2.22±0.01	2.90±0.14	<80 years	<80 years
168/15/128	BG4046	27/35	355-500	3.19±0.33	3.15±0.32	51±7	2.30±0.01	6.86±0.01	2.24±0.01	2.76±0.13	1155±145	1135±145
168/15/148.5	BG4047	24/27	150-250	3.87±0.25	4.27±0.39	51±8	2.46±0.01	6.78±0.01	2.18±0.01	3.29±0.16	1170±100	1290±140
168/25/59	BG4051	35/36	150-250	NC	5.76±0.18	8±1	2.41±0.01	6.75±0.01	2.33±0.01	3.42±0.11	NC	1680±105
168/25/125	BG4050	25/30	355-500	11.70±0.65	11.37±1.25	32±6	2.89±0.01	4.95±0.01	1.02±0.01	2.20±0.12	5310±385	5160±620
128/15/69	BG4054	4/25	150-250	<0.4	<0.4	NC	3.31±0.01	18.85±0.01	3.34±0.01	5.44±0.27	<80 years	<80 years
128/15/93	BG4053	27/35	150-250	NC	3.98±0.40	31±4	3.30±0.01	17.15±0.01	3.27±0.01	5.24±0.26	NC	755±85
128/15/136	BG4052	37/50	355-500	2.46±0.09	2.48±0.15	43±5	3.16±0.01	17.60±0.01	3.10±0.01	4.83±0.24	505±30	505±31
128/22/72	BG4049	38/50	355-500	3075±0.23	3.40±0.32	56±7	3.25±0.01	17.95±0.01	3.00±0.01	4.79±0.24	780±65	710±80
128/22/146	BG4048	24/37	355-500	7.70±0.45	7.50±0.81	27±5	3.46±0.01	17.60±0.01	2.94±0.01	4.76±0.24	1610±125	1570±190

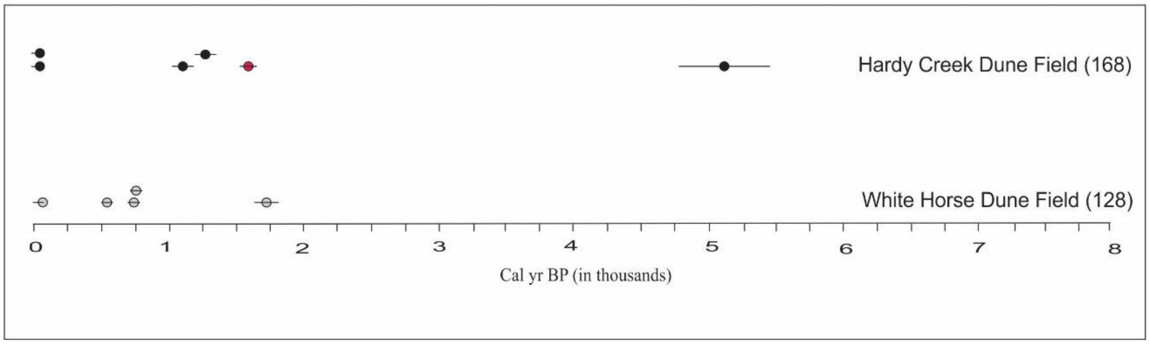


Table 4. OSL ages of core samples from Hardy Creek and White Horse Dune fields.

The dunes at the White Horse Dune field are vegetated linear dunes. These vegetated dunes are characteristic of low, rounded profiles which sometimes join to create a y-junction and have formed from bimodal winds (Tsoar 2001).

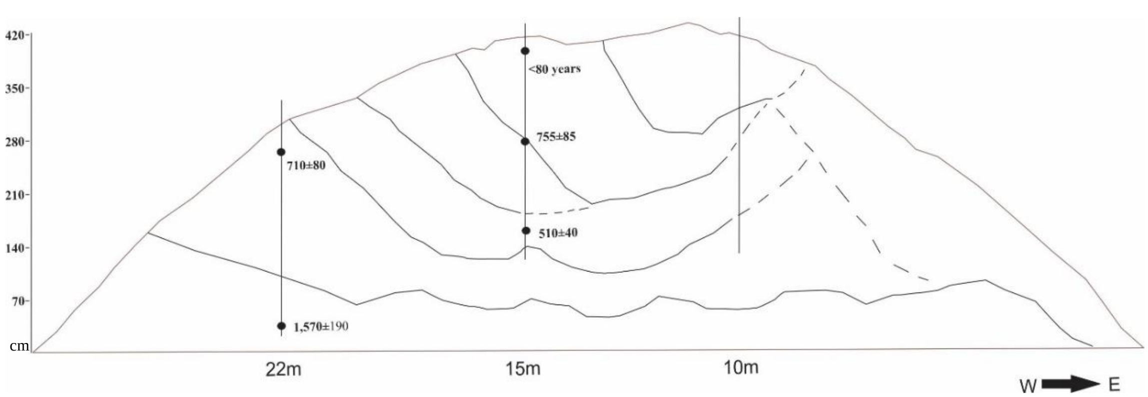


Figure 20. White Horse internal dune structure with correlated OSL ages.

The dunes in the Hardy Creek Dune field, however, are older than expected at 5,160 ± 620 cal BP, which dates the Hardy Creek Dune Field to the middle Holocene. The late Holocene sand had not been completely recycled, which left behind relic dunes of the middle Holocene. The Hardy Creek were most likely lunettes as a result of the desiccation of Lake Waring. Figure 21 shows the northwest-southeast orientation of the dunes in the Hardy Creek Dune field and their position in the valley. Lunettes typically form downwind of a lake and their sediment is derived from the playa floor (Laity 2008). There is strong evidence that the dunes in the Hardy Creek Dune field are lunettes since they are well vegetated, contain higher amounts of fine silts and sands, and are located downwind of where Lake Waring would have been, if filled.

Figure 21. Aerial imagery of dune field structure in the Hardy Creek Dune Field, Goshute Valley, NV.

This research shows that the relatively small dune fields in the Goshute Valley are Holocene in age, as expected. The White Horse Dune field is late Holocene in age around 1,570 ± 190 cal BP, and reflects a completely new cycle of weathering and deposition. Prior to the late Holocene, the dunes in the White Horse Dune field were most likely part of a linear dune system. Figure 22 shows an aerial view of the dune field. Note the linear-like dune structures which are oriented northwest-southeast. As arid conditions prevailed during the Late Holocene Dry Period (2,800-1,850 cal BP), the linear dunes were re-worked. As conditions stabilized, many of the linear dunes became subject to blowouts.

Figure 22. Aerial imagery of dune field structure in the White Horse Dune Field, Goshute Valley, NV.

Concluding Remarks

Both dune systems, in present form, are stabilized dune systems, but are eroding. The cause of erosion is primarily sediment starvation. Seasonal wind patterns are the main cause for grain transport. Grain entrapment and dune stability is enforced by shrub vegetation on the dunes. The particle size distribution and mineral content with associated OSL ages and depth in dune/core depth. As mentioned previously, the percentages of fine silts and clays, calcite, dolomite, organic content, and the calcium carbonate equivalency increases as dune depth and age increases. The dunes in the Hardy Creek Dune field are suggested to be lunettes because of the high content of fine sediments (average fine clays: 6%; average fine silts: 8.6%) and calcite, averaging at 14.6% (Table 2). The White Horse dunes are most likely blown out linear dunes which can be characterized by their grain size and morphology. These dunes can be sourced to the Dolly Varden Mountains based on the low percentage of carbonate.

2.1.4 Thin Section Analysis

Thin section analysis is important for understanding provenance of the dunes. Thin sections were made to further analyze the mineral composition of grains from a section of a core from each dune. This analysis is significant for identifying the provenance of the sediment forming the dunes from each field. By examining the slides, it is possible to construct the geologic history of the sediment source, as well as the movement of the grains from source to sink. In regards to the dune sediments, the minerology is significant to evidencing provenance through understanding the resistance of materials to weathering.

Figure 23 shows a map of the Goshute Valley with selected cross-sections. As previously mentioned, the Hardy Creek dune field is located approximately 3 km from the base of the Goshute Mountain distal fan deposits and 9.5 km from the base of the Pequop Mountain distal fan deposits. The White Horse dune field is located approximately 2 km from the base of the Dolly Varden Mountain distal fan deposits and 5.5 km from the base of the Goshute Mountain distal fan deposits.

Most grains were sub-angular and exhibited frosting, or abrasion from other grains. The importance of grain shape and abrasion are important for determining provenance. The predominant grain shape at Hardy Creek and White Horse Dune Fields is sub-angular to angular. Frosting is an indicator of long distance travel. The presence of frosting of grains from White Horse Dune Field corroborates with the evidence of long distance travel deduced from other indicators such as grain shape. Hardy Creek Dune Field, however, had less frosting, suggesting the source material was closer to the dunes.

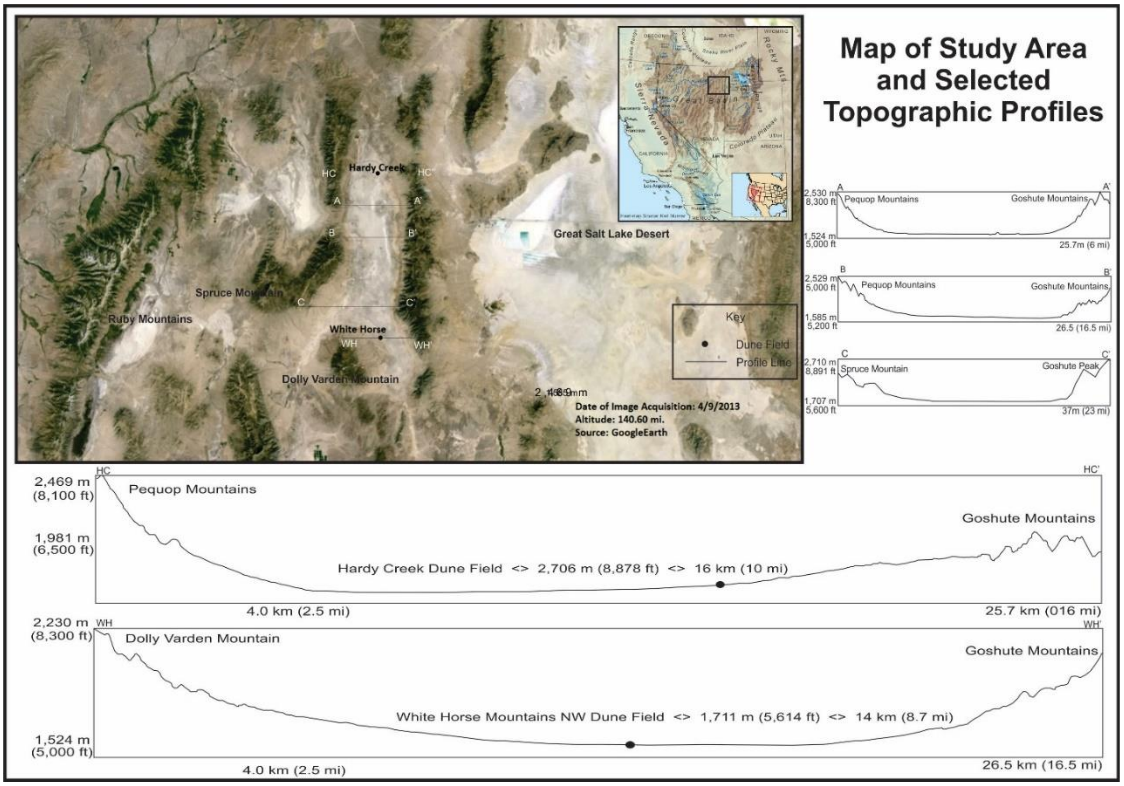


Figure 23. Cross-sections of the Goshute Valley.

Table 5 shows the results from the Hardy Creek thin section counts: 27% carbonate, 20% quartz, 16% feldspar, and 37% heavy mineral. The White Horse thin section counts yielded 14% carbonate grain, 15% quartz grain, 8% feldspar, and 61% heavy mineral. Figure 24A and 24C represent Hardy Creek and White Horse, respectively. In Figure 24A, there are noticeably fewer heavy minerals than in Figure 24C. Also, the grain sizes in Figure 24A are larger than those in Figure 24C. The importance of the carbonate, quartz, feldspars, and heavy minerals is that they weather at different rates. Granite weathers into its mineral constituents which are comprised of quartz, mica, Fe-Mg minerals, and feldspars. The feldspars, micas, and Fe-Mg minerals weather further into clays and hematite and goethite, while the quartz remains as a residual mineral (Dincauze 2000). With common rocks such as granite, it is difficult to assess where the source of the sediment is located, unless there are conspicuous minerals from unusual sources. Limestone is primarily composed of calcite, and as it weathers Ca^{+2} and CO_3^{-2} is leached into the soil. Heavy minerals from igneous rocks are usually left as residual minerals, as are most silicates.

MINERALOGY RAW COUNT							
	Carbonate	**Quartz**	**Plagioclase**	**Microline**	**Orthoclase**	**Other**	**TOTAL**
Hardy Creek Dune Field	1,517	1,134	433	202	292	2,072	5,650
White Horse Dune Field	697	752	232	15	231	2,964	4,891
MINERALOGY PERCENTAGE							
	Carbonate	**Quartz**	**Plagioclase**	**Microline**	**Orthoclase**	**Other**	**TOTAL**
Hardy Creek Dune Field	26.85%	20.07%	7.66%	3.58%	5.17%	36.67%	100.00%
White Horse Dune Field	14.25%	15.38%	4.74%	0.31%	4.72%	60.60%	100.00%

Table 5. Raw count and percentage of carbonate, quartz, feldspar, and heavy mineral grains from Dune 128 (White Horse Dune Field) and Dune 168 (Hardy Creek Dune Field).

Table 6 shows that over half of the total volcanic (devitrified) glass from Hardy Creek was whole, at 62.5%, while 37.5% partial glass shards were counted. Figure 24D is a picture of a whole volcanic glass shard from the Hardy Creek thin section. Over half of the total volcanic glass shards from White Horse were partial, at 76%, while 24% whole volcanic glass shards were counted. The significance of counting the volcanic glass is because of its fragility. Devitrified glass forms through crystallization as magma cools and the circular shape of the shards occurs as the glass crystalizes around air bubbles. With the presence of whole volcanic glass shards, it is most likely that those grains did not travel far. With the lack of whole volcanic glass shards, it stands to reason that those grains traveled further from the source.

VOLCANIC GLASS RAW COUNT			
	Whole Volcanic Glass	**Partial Volcanic Glass**	**TOTAL**
Hardy Creek Dune Field	45	27	72
White Horse Dune Field	9	28	37
VOLCANIC GLASS PERCENTAGE			
	Whole Volcanic Glass	**Partial Volcanic Glass**	**TOTAL**
Hardy Creek Dune Field	62.50%	37.50%	100.00%
White Horse Dune Field	24.32%	75.68%	100.00%

Table 6. Raw count and percentage of volcanic glass shards from Dune 128 (White Horse Dune Field) and Dune 168 (Hardy Creek Dune Field).

In addition to the aforementioned minerals, specific minerals like zircon, which is a very resistant igneous mineral, pyroxene, a silicate, and shell fragments were also found in the Hardy Creek thin section. The abundance of whole volcanic glass shards in the Hardy Creek thin section indicates that the source was near. A plethora of carbonates suggest that the source is the Permian limestone/dolomite Goshute Mountains. Since feldspars weather quickly, the high percentage of potassium (Figure 42E), microline (Figure 42G), and plagioclase (Figure 42F) feldspars also suggest a nearby source. Furthermore, the Hardy Creek dunes are no more than 3 km from the Goshute Mountains, which is close proximity to an available source of sediment. Along the Goshute Mountains evidence of Pluvial Lake Waring are visible in the form of old beach ridges. A remnant spit, composed of a volcanic outcrop, is left today by the wave action of Lake Waring, located less than 1 km from the Hardy Creek dune field. It is very likely that some of the beach ridge material washed down onto the playa and became entrained into the Hardy Creek dune field, especially since the bases of the dunes are gravel-littered.

Also found in the White Horse thin section was biotite, a common mineral in mica. The partial volcanic glass shards from the White Horse thin section indicates that the source was further from the field. The relatively low carbonate count suggests that the source is not the Goshute Mountains. Instead, the abundance of heavy minerals, and relative lack of feldspars suggest that the source is the volcanic outcrops of the Dolly Varden Mountain, which is comprised of granite and phenoryolitic and pheynodatic ignimbrites. Furthermore, the volcanic outcrops are located roughly 2 km away from the White Horse dunes.

Concluding Remarks

The heavy minerals and partial volcanic glass shards from the White Horse dune field suggest a nearby source from the volcanic rocks from the Dolly Varden, and wind direction from the south which was variably dependent on season. The abundance of carbonates and whole volcanic glass shards from the Hardy Creek dune field suggest a nearby source from the limestone Goshute Mountain. Based on the directionality of the dunes, the Holocene wind direction was not much different than present day. Wind is generally from the southwest, which means that some of the carbonate grains could have come from Pequop Mountains. This data is corroborated with spectral reflectance data from satellite imagery, as discussed below.

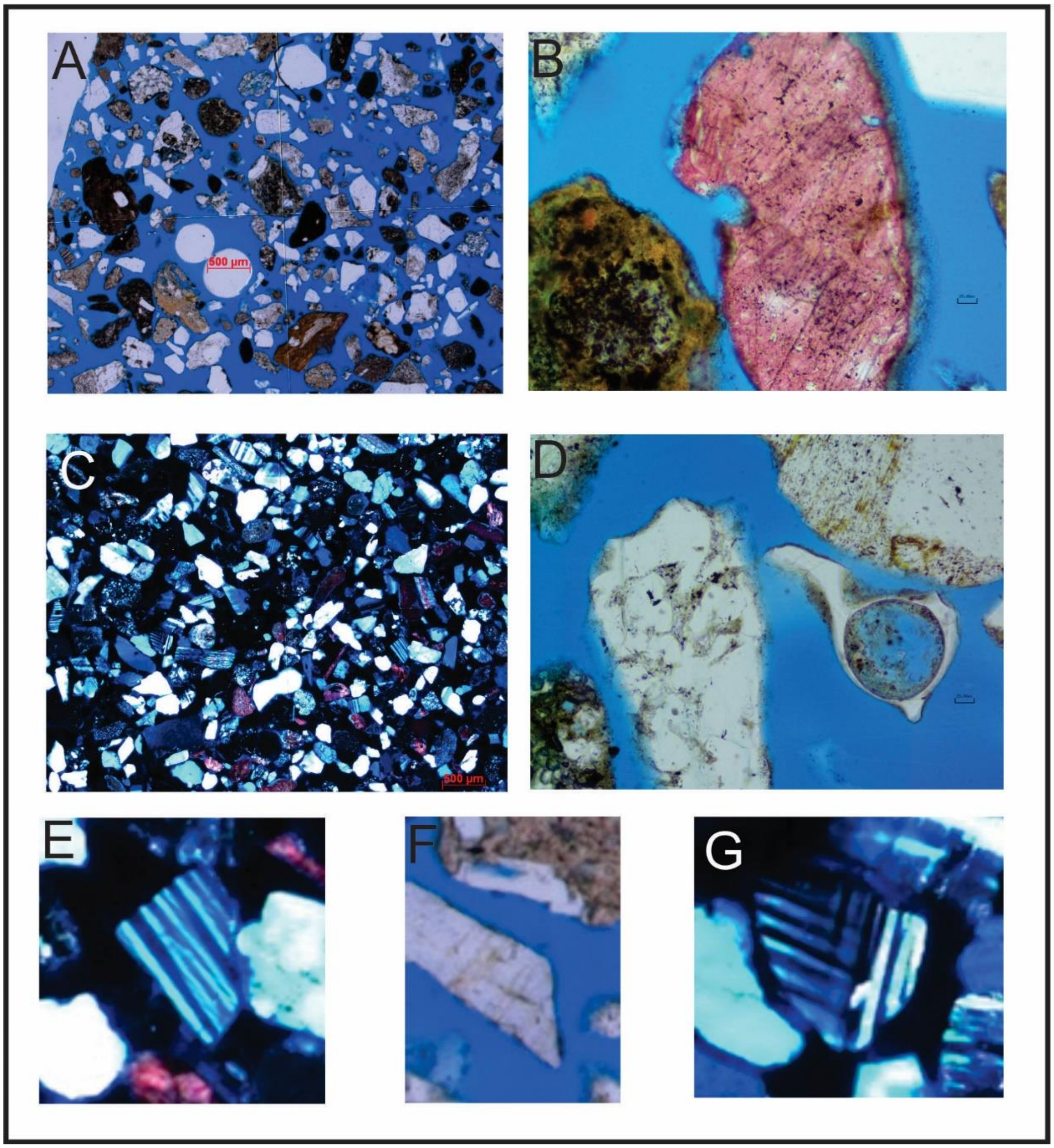


Figure 24. Thin section images: a) Hardy Creek thin section view; b) carbonate grain; c) White Horse thin section view, d) whole volcanic glass shard; e) potassium feldspar; f) plagioclase feldspar, g) microline feldspar.

2.1.5 Remote Sensing of Hardy Creek and White Horse Study Areas

The spectral analysis via aerial remote sensing is a broad method of determining provenance. Thin section analysis proved to be a more specific method of determining provenance, as was discussed in the previous section. F Most spectral reflectance studies are focused on pre-Holocene dunes. The dunes in those studies are well stabilized and have formed crusts, which affect spectral reflectance (Jacobberger 1989). Other studies focus on active dunes where there is no vegetation to interfere with mineralogical spectral reflectance (Pease et al. 1999). The dunes in this study are post-Pleistocene, less than 8,000 years BP, and located in a semi-arid environment. The purpose of this inquiry is to use multi-faceted data to better understand the inactive dune systems in the Goshute Valley, a semi-arid setting. Semi-arid environments leave much area of exploration for remotely sensed spectral data, especially since fringe environments can provide important resources (Connors et al. 1987; Pinker and Karnieli 1995). Spectral reflectance can be useful for understanding where the source of sediment is derived. This study focused on the spectral reflectance of minerology in the dune fields in the Goshute Valley to better understand sediment provenance.

The minerology in a dune can be identified by using satellite data coupled with field samples (Pease et al. 1999). If minerology can be identified, then “pathways,” as Pease et al. (1999) would term the directionality of source material, can also be identified; thus providing much insight to source provenance. Typically, this is a viable method for large dune fields and sand seas, however, the application can also prove sufficient for a smaller dune field or sand sheet. Since the dunes in the Goshute Valley are vegetated, the dune blowouts are the focus of this study.

Brightness values for blowout pixels are considerably higher than they are for the rest of the dunes which are vegetated. The blowouts contain both carbonate and quartz grains. The band ratios used are near and middle infrared and are particularly useful for geologic studies because rocks reflect back this short wavelength based on geothermal activity, but in this case it represents heat retention. Shortwave infrared (SWIR) light (1,100-3,000 nanometers) is useful for analyzing the different rock reflectance, such as between volcanic material, sandstone, and limestone. It is also an indicator for soil moisture and responds to the 1,400, 1,900, and 2,400 nanometer range. This is important because even though vegetation covers the sediment, the plants shrubs can reflect soil tilth (soil health) through their own reflectance.

The albedo of un-vegetated sand is high, meaning that it shows up on the image very brightly. Blowouts have higher sand coverage, therefore they also have a higher reflectance. Okin and Painter (2014) show in their study that the spectral reflectance in a plume is very high as it increased from 360 to 430 nm. In both Hardy Creek and White Horse dune fields, there is a distinct difference in spectral reflectance between the crests of the dunes and the blowouts. The crests have vegetation cover and the blowouts do not. Likewise, it is easier to distinguish minerology because of the blowouts.

Color differences from the satellite images reflect different minerology compositions and structures and can be used to track the distribution of sand grains to their origin (Pease et al. 1999). For example, there is a spectral difference between quartz, carbonate, and mafic mineralogy. Pease et al. (1999) used a 6/4 and ratio to identify mafic materials. They also used a 5/7 band ratio for discerning between quartz and carbonate since their spectral reflectance appears similar. It should be noted that they used Landsat7 TM data. Feldspars, in particular plagioclase feldspar minerals, reflect low wavelengths (Adams and Goulaud 1978). Generally, each rock and mineral (basalt, rhyolite, andesite, $CACO_3$, dolomite, and quartz) respond highly to low wavelengths. Dolomite and limestone are distinguishable in the wavelengths of 2.3 and 2.5 microns (Gaffey 1986). Any iron absorption in dolomite will reflect higher energy, shorter wavelengths (Gaffey 1986).

The most common rocks in the Pequop Mountains include Devonian, Silurian, and Ordovician dolomite with chert and limestone inclusions, limestone, and Triassic marine sedimentary rocks. The most common rocks in The Goshute Mountains are limestone, Upper to Middle Devonian limestone and dolomite, and Middle to Lower Ordovician limestones. The most common rocks in the Dolly Varden Mountains are granite, chert, and limestone. Therefore, it was expected that the quartz minerals should be darker than the carbonate rocks.

The top and bottom left images in Figure 25 show the TM images of the Hardy Creek and White Horse dune fields filtered using band ratio 7/5. Notice the dark colored dunes and light colored playa and alluvial features. This is mainly because of the amount of quartz in the alluvial fans and the fine grain size of the playa in comparison to the vegetated, inactive dunes. The top and bottom right images in Figure 25 represent the TM images of the Hardy Creek and White Horse dune fields filtered using band ratio 6/7. For the purposes of this study band ratio 6/7 was better, since it showed more discrimination between the sandsheet/blowouts and playa sediment.

This is complicated by vegetation cover, but most likely it is the result of using two short wave bands instead of using a thermal band on land cover which is poorly sorted in grain size. Concentrations of larger grains are being recognized as heavier minerals. In short, the remote sensing portion of this study concurs with what the petrographic portion has concluded with regards to sediment provenance. The sediment from White Horse dunes is derived from the Dolly Varden Mountain, and the sediment from Hardy Creek is derived from the playa, Pequop Mountains, and the Goshute Mountains.

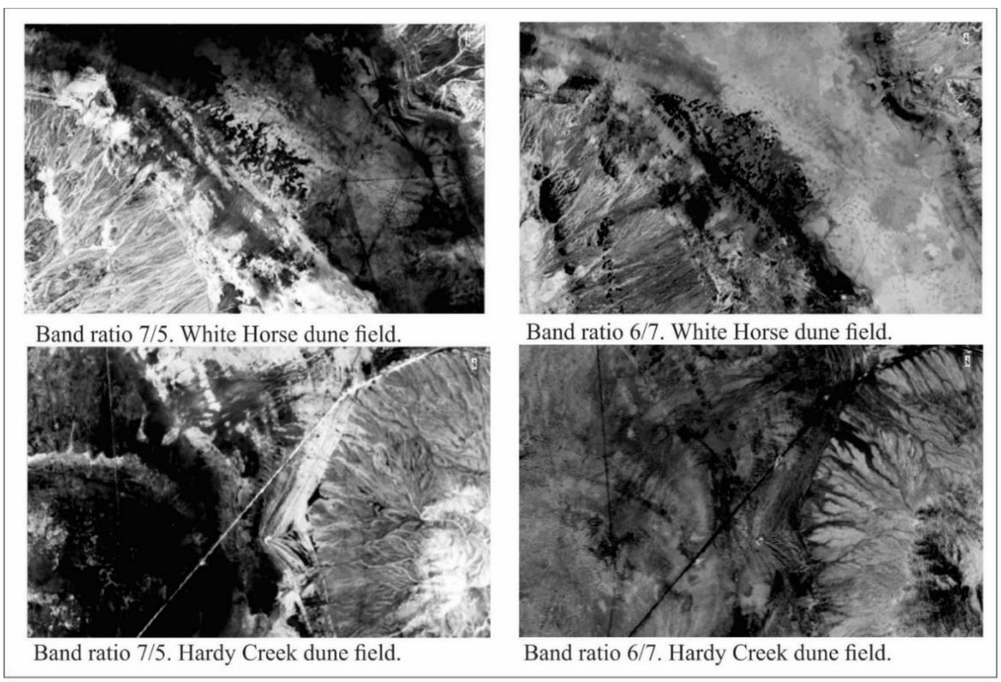


Figure 25. Band ratio comparison between 7/5 and 6/7 on Hardy Creek and White Horse satellite imagery.

2.1.6 Palynology

Pros and Cons of Studying Pollen from Caves and Rockshelters

Several studies have shown that rockshelters and caves provide valuable insight into past climates because of their ideal preservation of pollen (Hall 1981). Pollen preservation in rockshelters depends on the shape and size of the entrance, the shape of the room, and the climate within. Round rockshelters with large mouths and a dry climate are more adept for preserving pollen (Burney and Burney 1993; Cole 1989; Hall 1981; Navarro et al. 2011). Rockshelters with these characteristics are good for analyzing activity within the rockshelter and potentially the local climate.

However, rockshelters do not provide ideal regional pollen records because of poor airflow and contamination from montane water flow, animals, and people (Dimbleby 1985; Reitz and Shackley 2012, Chapt 9). Both transportation and deposition by animals and humans could skew pollen concentration results as patterns of pollen localization occur (Hall 1981). Problems that arise in rockshelters/caves occur when flooding events or heavy rainfall percolates into the cave via sills in the roof and groundwater flow. This can result in seasonal pollen destruction and long-term pooling. Although rockshelters are capable of pollen preservation within the rockshelter and can provide a fine scale resolution of activities within the rockshelter, pollen analysis of rockshelter sediments are not valuable for a regional environmental reconstruction. In contrast, bogs and marshes are precise and accurate sources for pollen analysis as they openly trap pollen from the region. This is why the results from this study will be compared to Blue Lakes and Ruby Marshes pollen data.

Pollen samples from the Hardy Creek and White Horse cores were processed, however, they proved to be unfeasible for two reasons. First, the pollen grains were heavily degraded from aeolian activity. Sediment type can lead to advanced deterioration. In this case, sand grains have abraded the delicate pollen walls and it was difficult to determine the genus of some grains. Second, the pollen did not preserve well in the PVC pipes before they were finally extracted and processed. Access to well preserved pollen from a nearby archaeological site known for its abundance of paleoclimate proxies, however, was available. Twelve sediment samples were analyzed from Bonneville Estates Rockshelter in an attempt to ascertain additional Holocene paleoenvironmental data from a nearby context.

Palynological Results of Holoocene-Aged Samples from BER

Stratum 2, 3a, 3b, 7a, 7b, 8, 9, 10, 11, 12, 13, and 14a were sampled from the profile. Throughout all the sampled profiles, there were no significant differences in the represented taxa. Figure 26 shows that the most common taxa counted was Amaranthaceae *Chenopodium* and *Sarcobatus* (greasewood), *Asteraceae* Artemisia (sagebrush), Pinaceae (pine), Cupressaceae *Juniperus* (juniper), and Poaceae (grass). Species were not identified because of the lack of my palynological experience and difficulty of identifying degraded grains. Taxa which were not evenly distributed throughout the strata included Ephedraceae *Ephedra* (Mormon tea), Onagraceae *Eremothera* boothii (formally *Oenthera*; Booth's evening primrose), Betulaceae *Betula* (birch), Asteraceae (daisy, aster, sunflower, and high/low spine composite family), and Apiaceae (celery, carrot, and parsley family). It is important to keep in mind that Pinaceae is highly overrepresented because of its bladders, or air sacks, which allow the pollen grain to travel up to many kilometers in the wind; whereas, juniper, may be under represented in deposition because it has thin pollen walls which commonly break. Another overrepresented taxa is *Chenopodium* since it is more recognizable than other taxa as it degrades. *Artemisia, Ephedra, and Juniperus*, on the other hand, are underrepresented taxa. With this being stated, it is important to note that these counts and percentages are not corrected for pollen representation.

The only distinction between taxa can be determined by the percentages of taxa throughout time. Pollen Concentration values are derived by adding a known number of exotic marker grains to a sample of fossil pollen (Faegri and Iversen 1989). In this study, the number of marker pollen grains was 15,584 Lycopodium spores. The following formula is used for determining the pollen concentration value of a sample: Total fossil pollen = (Fossil pollen counted x Total number markers) / Markers counted. Concentration values indicate desert to semi-desert environment. Although the concentration values oscillate between high and low, the general trend is slightly decreasing, which favors an idea presented by Hall (1981) suggesting that sediment reworking and recycling attributed to biogenic processes, is the cause of low concentration values in the upper strata.

Pollen concentration values of 1000 are considered to have more indeterminate grains through deterioration, however, pollen concentration values of 100,000 yield lower levels of indeterminate pollen grains (Bryant et al. 1994). The pollen concentration throughout the profile remained relatively constant (Table 7). After 5,000 cal BP, the pollen concentration value decreases and the number of degraded grains increases and this can most likely be attributed to drier conditions blowing the pollen grains into the cave.

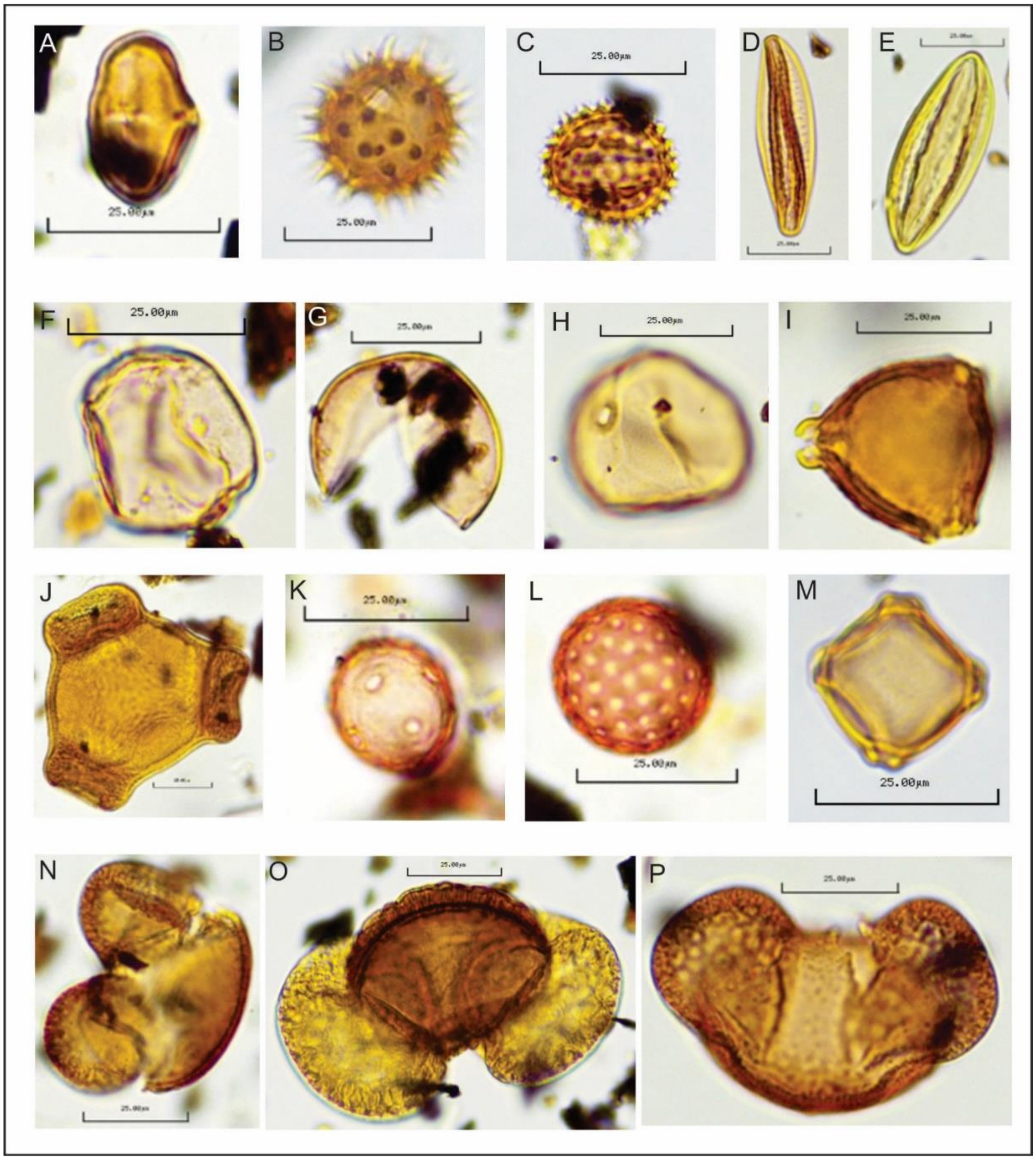


Figure 26 Microscopic images of common pollen types found in this study: A) Apiaceae, B-C) Composites, D-E) Ephedraceae, F-G) Cupressaceae, H) Poaceae, I) Betulaceae, J) Onagraceae, K-L) Amaranthaceae, M) Betulaceae, and N-P) Pinaceae.

The number of degraded grains, although not useful for determining pollen type ratios, however, are useful for interpreting the depositional environment. The integrity of a pollen grain can be compromised by abrasion in the wind (much like frosted sand grains), emersion in water, etc. (Faegri and Iversen 1989). About 20% of all the pollen counts were represented by degraded grains. The older strata, such as strata 14a, 13, 12, 11, and 10, surprisingly had fewer degraded grains than the younger strata (strata 9, 8, 7b, 7a, 3b, 3a, and 2). Strata 14a through 10, dating approximately 7,500 cal BP to 4,530 cal BP, are culturally sterile (no artifacts to imply human occupation) and are characterized by windblown silt. Finding smaller percentages of degraded grains in these strata was unexpected, since pollen grains that have been subjected to aeolian activity are typically more degraded. Stratum 14a through 10 have fewer degraded grains which may imply less dry, windy conditions, while stratum 9 through 2 higher degraded grain percentages may suggest dry and windy conditions. Perhaps the low distinction between degraded grains can be attributed to other factors in the rockshelter pertaining to water flow.

Vegetation is divided into four categories: 1) trees (Pinaceae and Cupressaceae); 2) shrubs (Asteraceae and Ephedraceae); 3) forbs (Composites, Chenopodium); and, 4) grasses. Throughout all 12 strata, the dominant vegetation type are shrubs, most likely attributed to their hardy nature. From strata 14a to strata 7b, trees are the second most dominate vegetation type, while the least dominate type are grasses. However, there is a slight change in vegetation type after strata 7b about 2,250 cal BP, where the second most vegetation type is grasses and the least dominate vegetation type are trees. Grasses increase during the Middle Holocene Dry Period (6,500-3,500 cal BP) and decreases afterward as climate cools. Poaceae also increases at stratum 10, as climate becomes drier. Cupressaceae (most likely Rocky Mountain and Utah Juniper) is under represented for the first four strata which ranges throughout the Middle Holocene Dry Period. Beginning from stratum 8, the Cupressaceae percentages increase suggesting milder climate until stratum 10 where it declines.

	Stratum																							
	2		3a		3b		7a		7b		8		9		10		11		12		13		14a	
Lycopodium	6		4		11		4		9		6		15		8		4		3		3		6	
		%		%		%		%		%		%		%		%		%		%		%		%
Degraded	21	7.00	27	11.59	27	10.09	24	9.84	23	9.04	17	6.97	16	7.02	14	4.70	18	6.82	12	5.29	10	5.50	12	5.19
Unidentified	2	0.67	2	0.86	5	1.87	8	3.28	6	2.36	12	4.92	12	5.26	5	1.68	0	0.00	2	0.72	0	0.00	1	0.43
Amaranthaceae Chenopodium	106	35.33	85	36.48	100	37.38	94	38.52	102	40.08	98	40.16	101	44.30	97	32.55	82	31.06	67	24.19	118	41.26	93	40.26
Asteraceae Artemesia	80	26.67	46	19.74	24	8.97	31	12.70	39	15.32	47	19.26	32	14.04	103	34.56	64	24.24	55	19.86	68	23.78	58	25.11
Pinaceae	37	12.33	18	7.73	38.5	14.39	28	11.48	40.5	15.91	23	9.43	26	11.40	27	9.06	35	13.26	42	15.16	45.5	15.91	29.5	12.77
Cupressaceae	2	0.67	8	3.43	7	2.62	9	3.69	8	3.14	19	7.79	26	11.40	9	3.02	10	3.79	6	2.17	10	5.50	6	2.60
Poaceae	43	14.33	33	14.16	54	20.19	39	15.98	26	10.22	16	6.56	7	3.07	25	8.39	33	12.50	27	9.75	22	7.69	19	8.26
Asteraceae Composite	8	2.67	10	4.29	8	2.99	7	2.87	7	2.75	10	4.10	8	3.51	14	4.70	16	6.06	15	5.42	6	2.10	10	4.33
Ephedraceae	1	0.33	3	1.29	4	1.50	2	0.82	2	0.79	1	0.41	0	0.00	2	0.67	5	1.89	1	0.36	5	1.75	2	0.87
Apiaceae	0	0.00	0	0.00	0	0.00	2	0.82	1	0.39	1	0.41	0	0.00	1	0.34	0	0.00	0	0.00	0	0.00	0	0.00
Betulaceae Betula	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0	0	0.00	1	0.34	0	0.00	0	0.00	0	0.00	0	0.00
Oenthera boothii	0	0.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0	0	0.00	0	0.00	1	0.39	0	0.00	1	0.35	0	0.00
TOTAL	300	100.00	233	100.00	267.5	100.00	244	100.00	254.5	100.00	244	100.00	228	100.00	298	100.00	264	100.00	227	100.00	285.5	100.00	230.5	100.00
Pollen Concentration	92,920		108,251.00		45,193		113,362.00		52,551		75574		28247		69225		122,654		140,618		177,167		71,584	
	Stratum																							
	2		3a		3b		7a		7b		8		9		10		11		12		13		14a	
		%		%		%		%		%		%		%		%		%		%		%		%
Trees	39.00	13.00	26.00	11.16	45.50	17.01	37.00	15.16	48.50	19.06	42.00	17.21	52.00	22.81	37.00	12.42	45.00	17.05	48.00	17.33	55.50	21.41	35.50	15.37
Shrubs	187.00	62.33	134.00	57.51	128.00	47.85	127.00	52.05	143.00	56.19	146.00	59.84	133.00	58.33	202.00	67.79	151.00	57.19	123.00	44.41	191.00	66.79	153.00	66.24
Grasses/flowers	51.00	17.00	44.00	18.45	62.00	23.18	48.00	19.67	34.00	13.36	27.00	11.07	15.00	6.58	40.00	13.43	50.00	18.95	42.00	15.17	29.00	10.14	29.00	12.59

Table 7. Pollen Concentration, raw count, and percentage of represented taxa.

There appears to be compounded data suggesting perhaps it was not as dry as previously thought right at 5,000 BP (Figure 27). The *Artemisia* / *Chenopodium* (A/C) ratio was computed by the following equation: (A-C)/(A+C) (Mensing 2001). Positive values reflect higher *Artemisia* percentages indicating a wetter climate and negative values reflect higher *Chenopodium* percentages indicating a drier climate. The Altithermal is represented by *Chenopodium* bolstering the surmounting evidence of a warmer period, but then *Chenopodium* stagnates until stratum 10 about 5,000 BP where *Artemisia* dominates to represent a wetter climate. These data do not fit with the convention of a drought starting at 5,000 BP. Several records show that temperature increased, or total effective moisture decreased.

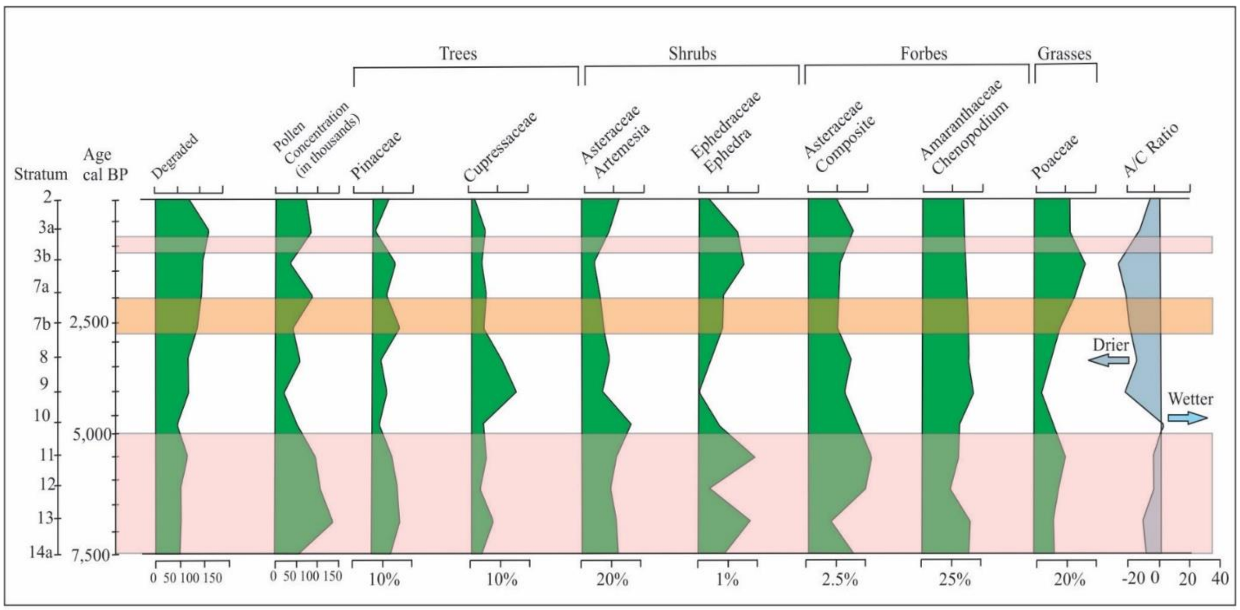


Figure 27. Pollen percentage diagram of selected taxa.

What BER Pollen Can and Cannot Tell Us About Regional Paleoclimate

The Bonneville Estates pollen assemblage from strata 14a to 2 are well preserved. However, variant pollen concentration values are most likely because of chemical weathering within the rockshelter as the sediment underwent oxidation and sediment reworking from inhabitants. Because of habitation and geomorphologic activity within the rockshelter, the palynological data is skewed and may misrepresent regional climate throughout the Holocene.

In short, the A/C ratio suggests that during the Middle Holocene, climate was warm and dry. Stratum 13 and 14a are represented a greater presence of *Chenopodium* and *Artemesia,* averaging 41% and 24%, respectively. Stratum 11 and 12 has on average 28% *Chenopodium* and 22% *Artemesia*. This indicates that climatic conditions between 7,100 and 7,500 cal BP were warmer. Poaceae counts, however do not shadow the same result simultaneously, instead they yield the opposite until 7,500 cal BP where they indicate a slightly warmer climate than previous conditions. In general, the decrease in shrubs and increase in trees indicate that the western Bonneville Basin was slightly cooler by 5,000 cal BP than it was around 8,000 cal BP. Stratum 14a has a low pollen concentration value at 71,584 in comparison with the last 4 stratum, and strata 13 has a high pollen concentration value of 177,167. This indicates a stable rockshelter environment with less sediment reworking. Shortly after 5,000 cal BP, conditions were less warm and dry.

This intermission of relatively cooler and wetter climate transitioned back to warmer and drier weather around 4,500 cal BP. Between 4,500 cal BP and 750 cal BP, the climate became increasingly drier and warmer, which was then followed by less warm and dry climate from 750 cal BP to modern day. During this time, the Medieval Climatic Anomaly (1,150-700 cal BP) occurred, followed by the Little Ice Age (500 cal BP to 200 cal BP). The Medieval Climatic Anomaly is considered to be one of the warmest and driest times throughout the Holocene (Mensing 2001). *Artemisia* declined at the beginning of this warm episode while *Chenopodium* remained stable and grasses increased, indicating warmer climate. Currey (1990) indicated that during the Little Ice Age, Lake Bonneville deepened and freshened. Vegetation analysis in the Bonneville region indicates a trend towards increased effective moisture during the Little Ice Age (Rhode 2000). In this study, *Artemisia* increased and grasses decreased, also indicating a cooler and wetter winters. The Ruby Marshes recorded its highest water levels indicating the coolest and wettest episode since the late Pleistocene/early Holocene transition (Thompson 1992).

2.2 Discussion

Dune building is the result of sediment supply, storage, mobility, and climatic variables (Tchakerian and Lancaster 2002). As a lake desiccates, its sediment becomes subject to aeolian processes which enable more dune building owing to the readily abundant sediment; but, only if enough time has elapsed and the climate is conducive for storage and deflation (Tchakerian and Lancaster 2002). For example, dunes in the Mojave Desert were minimalized during the Altithermal because sediment supply was inadequate (Tchakerian and Lancaster 2002). Dunes are a geomorphic phenomenon that are more responsive to oscillating atmospheric patterns than they are to large scale climatic factors which affect lake levels. Throughout the climatically oscillating late Pleistocene and early Holocene in the Mojave Desert, as Tchakerian and Lancaster (2002) point out, lake building, wet, humid climate increased vegetation cover decreased sediment transport, while lake desiccating, arid periods facilitated sediment movement (Fig. 27). They also point out that during wet periods, sediment is available from fluvial and lacustrine sources while the sources for sediment in arid periods are fans, basin bottoms, and fluvial deposits. The right amount of stability with the right amount of wind enables dune growth and mobility. Figure 28 shows that while the much older dunes in the Mojave Desert were building, so were the dunes in the Goshute Valley.

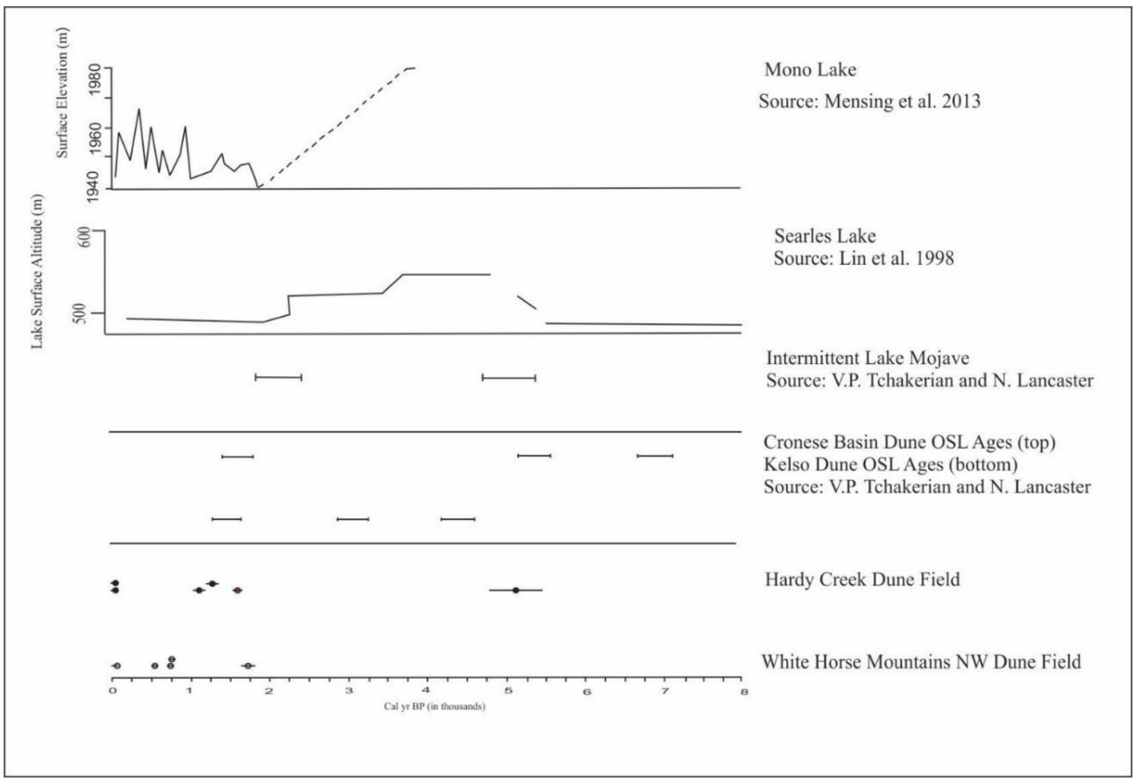


Figure 28. Stacked chart of paleoenvironmental indicators in the Mojave Desert. Figure adapted from Mensing et al. 2013.

Lyle et al. (2012), correlated wet/dry periods in along the southern California coast and southern desert interior, and ascertained that the strongest wet intervals advanced in a northwesterly pattern towards the Oregon coast from the southwest from the LGM to modern time. The significance of their study showed that the high stands of the innermost desert west do not correlate with the climatic change that occurred simultaneously on the western seaboard. Instead, they showed that there was a succession of strong wet intervals which started as far south as New Mexico and occurred before 17,000 cal BP and probably before the strongest lake building intervals in the Great Basin. The strongest wet period post 14,000 cal BP occurred west of Lake Lahontan on the California coastline (Lyle et al. 2012). The outcome of their research suggests that instead of westerly winter monsoonal influences, it is plausible that tropical easterlies from the tropical Pacific and Gulf of Mexico attributed to the increase of precipitation to feed into pluvial lakes. Their re-analysis of CLIMAP (Climate: Long range Investigation, Mapping, and Prediction) models indicate that instead of the southern shift of north Pacific storms via the polar jet stream split, tropical low pressure systems were a major contributor of summer precipitation (Lyle et al. 2012). Interglacial wet periods in the Great Basin not observed along the west coast are attributed to increased summer monsoon precipitation from the Gulf of Mexico and a high pressure system blocking precipitation from the Pacific (Lyle et al. 2012). Lake Lahontan’s maximum lake level occurs around 15,000 cal BP and is correlated to strong low pressure systems from Oregon (Lyle et al. 2012).

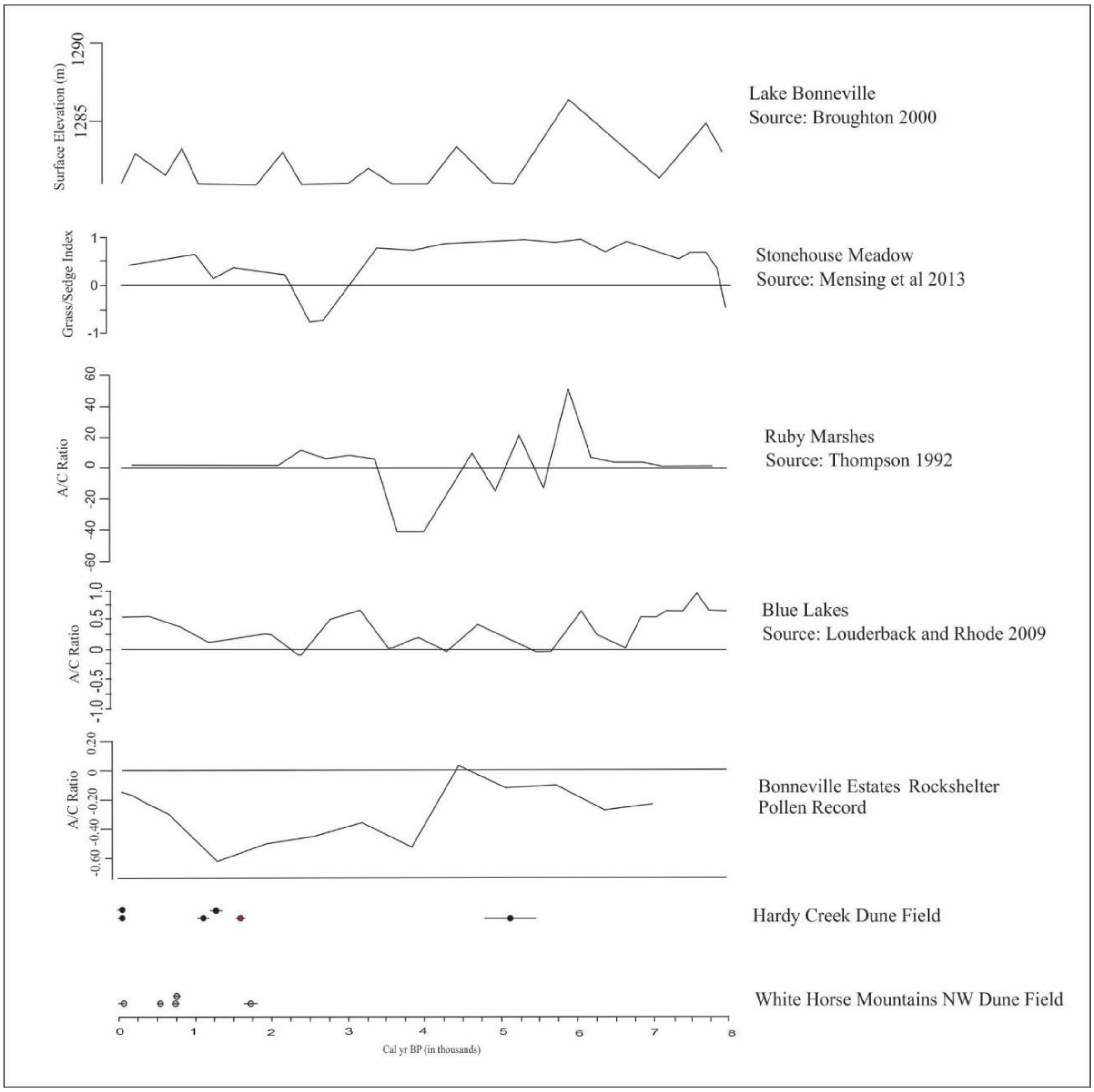


Figure 29. Stacked chart of paeloenvironmental factors in the Great Basin. Figure adapted from Mensing et al. 2013.

Grayson (2011) has noted two climatic events associated with drought: the earlier drought, the mid Holocene dry period, occurred between 7500 and 5000 cal BP and the later drought, better known as the Medieval Climatic Anomaly, occurred between 1,200 and 750 cal BP. Drought has been substantiated by the Lake Tahoe tree stumps (Lindstrom

1990), the reduction of the Ruby Marshes (Thompson, 1992), and lowered lake levels at both Bonneville and Lahontan (Benson et al. 2002; Oviatt 1992).

Reconstructions of central Great Basin paleoclimate from the late Holocene reveal that there was a drought between 2800 and 1850 cal BP (Mensing et al. 2013). Their evidence arose from Stonehouse Meadow, Spring Valley, Nevada from spring sediment. According to Milspaugh et al. (2000), the drought is associated with subtropical high pressure systems and increased solar radiation, combined with Milankovitch cycles.

Relatively speaking, Late Holocene climatic conditions were stable. Out of the 11 OSL dates from this study, four coincide with warm/dry periods and seven with cooler conditions. Figure 29 shows that overall the dunes appear to be accumulating during both cool/wet and warm/dry cycles indicating that the fundamental driving factor of dune formation in the Goshute Valley is sediment supply. Climate is a supplementing factor.

Arid conditions prior to 8,000 cal BP may have caused the playa to deflate and build the sandy loam/loamy sand dunes. The drought which occurred between 8,000 cal BP and 5,000 cal BP caused further deflation and the deposition of carbonate-rich sands. Around 5,000 cal BP, the oldest dune-building sequence, as recorded from this study, occurred in the Hardy Creek dunes. It is unknown if there were older sequences, however; there is evidence from Corn Creek Flat, Nevada and Catlow Valley, Oregon of contiguous dune-building episodes. In figure 29, the Bonneville lake level and the pollen record from Bonneville Estates Rockshelter show that one of the driest periods in the Goshute area occurred around 1,250 cal BP. This is coupled with other regional lake records from lakes Lahontan and Searles, as well as the Mojave Desert. At the same time, OSL records from

White Horse, but mainly Hardy Creek, show a period of dune-building, which is unique because there is no evidence of dune building at Corn Creek Flat, Nevada or Catlow Valley, Oregon. In short, there has been dune building in the Goshute Valley as far back as 5,000 cal BP according to this study. Although there is a gap in the accretion record between 4,250 cal BP to 3,000 cal BP, conditions may not have been conducive (not climatically stable) according to the pollen record from Bonneville Estates Rockshelter as indicated by the A/C ratio favoring chenopodium, suggesting drier and windier climate. However, even during the warmest and driest period according to the pollen record, there was dune-building. This may be attributed to a slow response to climate by the artemesia and chenopodium species in the area. In context of the climatic reconstructions from the Blue Lakes, Ruby Marshes, and Stonehouse Meadow pollen cores, dune accretion in the Goshute Valley corresponds to aridity during the latest and earliest dune building sequences. During the Late Holocene Dry period, there was less dune building which suggests that during the warmest period in the Holocene, climate conditions were too hot, dry, and possibly windy for dune accretion to occur.

3. GEOARCHAEOLOGY OF THE GOSHUTE VALEY

3.1 Results

The previous chapter discussed the aeolian geomorphology and sediments of the Goshute Valley by analyzing dune core samples from the Hardy Creek and White Horse Dune fields via granulometric analysis and thin section analysis. The chronology of dune building events was also determined in the previous chapter via OSL dating. Lastly, a reconstruction of the climate in the Goshute region was attempted. These objectives are key to understanding what the environment in the Goshute Valley may have been during human occupation and, how the environment shaped the site after its deposition. This chapter will focus on the final objective: the documented sites in the Hardy Creek and White Horse Dune fields and how artifacts were distributed, both horizontally and vertically in a dune-field setting.

The two study sites (Figure 30) yielded 33 surface sites and 27 isolated sites. Of the 33 sites, 27 will be recommended to the Nevada BLM, Elko Office for National Register of Historic Places (NRHP) based on their cultural significance. The Goshute Valley is prehistorically and historically significant for future work. The Goshute Valley has a chronological span from Paleoindian (13,000-10,000 BP) to the Late Archaic (2,000-0 BP) times.

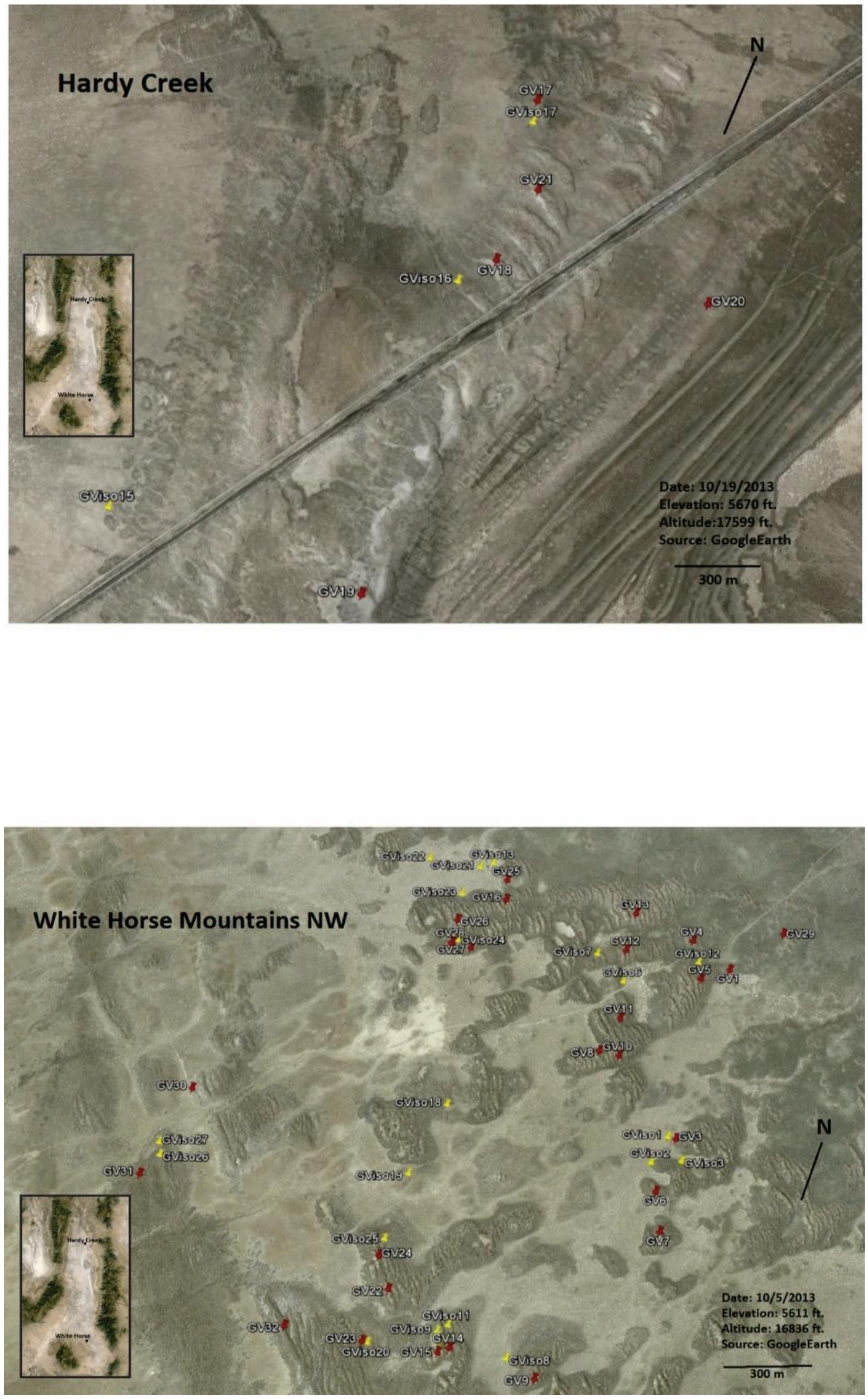


Figure 30. Map of archaeological sites (red pins) and isolated finds (yellow pins) in the Hardy Creek (top) and White Horse study area (bottom).

3.1.1 Site Descriptions

GV-1

GV-1 is a moderately sized lithic scatter measuring 38mNS by 67mEW and is located within the White Horse study area. The site is located N/NE of a small dune about 15 m away and extends S/SE towards a silt pan. The surrounding vegetation includes big sage, greasewood, sticky rabbit brush, shadscale, bunch grass, and snake weed. Documented artifacts include one black obsidian Elko projectile point base measuring 2.9 cm long by 1.8 cm wide by 0.3 cm thick, one chert stage 3 biface end fragment measuring 3.0 cm long by 4.4 cm wide by 1.1 cm thick, one exhausted brown/black chert multi-directional core fragment measuring 3.0 cm long by 4.4 cm wide by 1.1 cm thick, and flakes. The biface was knapped from chert of poor quality, demonstrated retouch along the edge, and exhibited a twisting fracture where it had been broken. The flake scatter is sparse with a maximum density of 3 flakes/m^2. Artifacts appear to be scattered in a S/SE through slope wash. Based on lithics, the site may have been a short term hunting camp where some local material was tested and bifaces underwent retouch and production.

GV-2

GV-2 is a sparse chert, obsidian, and basalt lithic scatter measuring 28m NS by 34 m EW, and is located in the White Horse study area. The site is situated 20 m NW from a small dune. Vegetation includes greasewood, shadscale, snake weed, and big sage brush. One tool is located in the middle of the southern portion of the site. One light brown chert Dersert Side-notched projectile point fragment measuring 2.6 cm long by 1.6 cm wide by 0.2 cm thick was documented. The flake scatter is sparse with a maximum density of 1 flake/ m^2. The artifacts are scattered across a silt pan which is cracked from post inundation drying. This site may be related to GV-1 and may have a diffuse scatter of fire cracked rock. It is possible that this site could be a hunting camp and demonstrate biface reduction and tool retouch.

GV-3

GV-3 is a moderately sized, but very sparse, lithic scatter measuring 60 m N/S by 35 m E/W and is within the White Horse study area. A small dune is situated about 20 m SE of the site. Vegetation is primarily shadscale and greasewood at the SE edge of the site and the SW side. No tools were observed. Artifacts are spread across a silt pan, likely via seasonal monsoon fluvial processes. The concentration of artifacts is clustered, ranging from a maximum flake scatter density of at about 3 flakes/m^2; although, most of the site is covered by about 1 flake/m^2. Most lithic material is basalt with some grey chert. Based on the artifacts, this is likely a local basalt reduction event.

GV-4

GV-4 is a moderately dense lithic scatter measuring 40 m N/S by 40 m E/W and includes chert, basalt, and obsidian artifacts. The site is located within the White Horse study area. Vegetation includes greasewood, sticky rabbitbrush, big sagebrush, and bunch grass. The artifacts are located on the southern edge of 2 dunes and extend from the dune edge, south into playa sediments about 15 m out. No tools were observed on the site. A number of small flakes were observed, however, so the site likely represents a small tool retouch and reworking area.

GV-5

GV-5 is a dispersed lithic scatter surrounded by multiple dunes measuring 40 m N/S by 30 m E/W. This site is located in the White Horse study area. Vegetation consists of greasewood, bunch grass, big sage brush, shadscale, and possibly horse bush. The dunes lie roughly N/S and the artifacts appear between the crests and where sand is blown-out. There are 3 primary concentrations between 4 dunes. Cultural material primarily consists of grey chert flakes with a maximum concentration of 5 flakes/m^2. Outside, of these concentrations, artifacts are low density (1 flake/m^2). No tools were observed on the site. The site probably represents a biface production/retouch location.

GV-6

GV-6 is a moderately sized sparse lithic scatter, measuring 30 m N/S by 53 m E/W, with a maximum density of 2 flakes/m^2. This site is located within the White Horse study area. The site extends onto a silt pan to the south with a vegetation change. Vegetation includes greasewood, big sagebrush, shadscale, bunch grass, ground succulents, and possibly horse bush.The site's cultural material includes basalt and chert flakes of moderate size. No tools were identified. The site abuts a small dune to the north. It is possible that the artifacts may have eroded from this dune as the dune deflated. This site may be a core reduction or tool retouch location.

GV-7

GV-7 is a moderately dense scatter measuring 13 m N/S by 10 m E/W and is located in the White Horse study area. Vegetation is comprised of big sage brush, greasewood, and bunch grass. This site is situated between two N/S trending dunes, primarily on silty dune blow out sediments on the lee side of the dune. It consists of artifacts with a maximum density of about 10 flakes/m^2. Most of the artifacts are basalt as well as the biface and core reduction tertiary flakes. A couple of chert flakes were also identified. No tools were noted. It is likely a tool retouch location.

GV-8

GV-8 is sparse lithic scatter measuring 8 m NS by 7 m EW. The site density is about 1 to 2 flakes/m^2. The site is located within the White Horse study area. The site is situated on the lee side of a dune previously recorded. Vegetation consists of rabbit brush and greasewood. Vegetation on the dune is sparse at the base and gets denser towards the crest. There are 8 flakes total, with the furthest flake located near the crest of the dune. All of the flakes are tertiary. Only one flake was found in the base of the dune. The material consists of red chert pressure flakes and a grey chert flake medial fragment. The site is most likely a core reduction site.

GV-9

GV-9 is located in the White Horse study area. The site is 25 m NS by 27 m EW and the density is 1 flake/m^2 at minimum and 3 flakes/m^2. The site is located on and between two dunes. There is a sand sheet is between the two dunes. Half of the site was found on the dune and the other half was found on the blowout. Vegetation is sage and greasewood and is mostly dense around the edges of the dune and is more isolated towards the crest. Artifacts consist of mostly chert flakes and one basalt flake. The flakes were mostly proximal and medial. Two flake core reduction flakes were found, one of which had flakes scattered around it. All but one flake was tertiary. The secondary flake had about 15% cortex. No tools were observed.

GV-10

GV-10 is a very extensive site located in the White Horse study area and has about 100 flakes, mostly chert, basalt, and one quartzite. The site dimensions are 70 m NS by 130 m EW. It is located in the White Horse study area. Vegetation consists of rabbit brush, sage, and greasewood. Most flakes were tertiary and no primary flakes were found. Flakes were of biface thinning and core reduction processes. The site is situated in and around five dunes. Between the dunes the vegetation is more dense in-between the dunes than on the crest and faces. The site density is about 15 flakes/m^2 towards the middle of the site. As the site spans out, however, the density becomes less dense, about 1-5 flakes/m^2. Most of the concentrations of flakes are found around the base of the dunes in between and on the stoss side. Very few flakes are near the crest. Both stoss and lee sides of the dunes had artifacts. The tallest dune is about 1.5 m. Dunes have intermittent silt pans.

GV-11

GV-11 is located in the White Horse study area and is 21m NS by 13m EW. The site is situated at the base of a dune and extends onto a deflated silt pan. Vegetation includes greasewoon and rabbitbrush. Minimum density is about 1 flake/m^2 and the maximum is 9 flakes/m^2. There were chert tertiary flake fragments: one medial and one proximal with retouch and a complex platform. Also among the artifacts were 11 pieces of Shoshoni Brownware. Nine pieces were found clustered together and the other two were together nearby about 2 meters away. No tools were observed.

GV-12

GV-12 is a large lithic scatter located in the White Horse study area and measures 90m NS by 80m EW. It is situated around 4 dunes. The site is vegetated by greasewood and rabbitbrush. Most artifact concentrations are located in between the dunes and around the bases where there is more silt than sand. Although there was one flake on top of a dune. The site had 100+ artifacts, mostly all tertiary with a few being secondary. The site has a density of about 8 flakes/m^2. The primary material is basalt with a few chert and even fewer obsidian and one quartz on a dune crest between greasewood. Tools include a basalt retouched flake measuring 3.5cm long by 2.5cm wide by 0.5cm tall closely resembling a side scraper, an obsidian projectile point distal end fragment measuring 2.0cm length by 1.5cm wide by 0.75cm tall, and a basalt biface with retouch on the side measuring 3.9cm long by 3.2cm wide by 0.4 cm tall.

GV-13

GV-13 is located in White Horse Mountain study area is situated around 3 dunes. The site is vegetated by rabitbrush, greasewood, and big sage. The site is dominated by obsidian flakes towards the northern end if the site and chert on the southern end. No basalt was observed. Most of the flakes were pressure flakes. One flake was found on the dune towards the center of the crest. The site has a density of 5 flakes/m^2.

GV-14

GV-14 is located in the White Horse Mountain study area and measures 50m NS by 31m EW. The site is vegetated by big sage, rabbitbrush, and greasewood. The site is mostly situated between two dunes. The site contains pressure flakes, complete flakes, and biface thinning flakes as well as medial, proximal, and distal flake fragments. The basalt flakes are concentrated in the middle of the chert concentration which is located throughout. The basalt is towards the southwest side of the site.

GV-15

GV-15 is located on a dune. It measures 30m NS by 10m EW and the density is about 2 flakes/m^2. The site is vegetated by big sage. The site is dominated by chert pressure flakes with two basalt artifacts, mostly on one dune with some artifacts located at the base. One basalt Elko eared point measuring 3.7cm long by 2.0cm wide by 0.4cm tall was found. The point was found at the base of a dune facing south from the point on the silty part with sand blown on top.

GV-16

GV-16 is located in the Hardy Creek study site situated in-between 3 dunes. The dimensions on the site measure 70m NS by 27m EW. Vegetation consist of greasewood, rabbitbrish, and big sage. The site is dominated by basalt. There is evidence of core reduction. Most of the flakes, fragments, core reduction, few Biface thinning flakes. The 50+ flakes are mostly all found in the blowouts if a dune in the silt playa. No tools were observed.

GV-17

GV-17 is located in the Hardy Creek study area. Most of the site concentration is located on the edge of one dune. The site measures 15m NS by 18m EW and the density is about 3 flakes/m^2. The sediment is very compact and no evidence of erosion. Vegetation consist of black sage and rubber rabbitbrush and winterfat. Out of about 30-50 flakes, the majority were cortex flakes in the primary stage. The site is most likely an experimental core reduction site of very poor orange cherty limestone. One multidimensional core fragment was found.

GV-18

GV-18 is located in the Hardy Creek study area and measures 7m NS by 3m EW. Vegetation consists of rabbitbrush. Two artifacts were found towards the base of the dune on the silty playa sediment with assorted gravel. It is a 9 m line possibly deflated on migrated dune. One flake obsidian tertiary, distal fragment was also found and had cortex. Recorded tools include one obsidian Gatecliff split-stem projectile point broken at the distal end measuring 2.6cm long by 1.6cm wide by 0.3cm tall, and one obsidian stage 3 biface fragment measuring 3.7cm long by 2.7cm wide by 1.0 cm tall. The Gatecliff dates to the Middle Archaic, roughly between 6 and 2 ka.

GV-19

GV-19 is located in the Hardy Creek study area and measures 16m NS by 8m EW. The site is situated on an eroded or deflated surface in front of a shoreline. Vegetation consists of winterfat, rubber rabbitbrush, and black sage. Site density is 1 flake/m^2. The site is primarily dominated by obsidian. One Elko corner-notched point measuring 2.1cm long by 2.0cm wide by 0.3cm tall was recorded.

GV-20

GV-20 is located in the Hardy Creek study area. The site is a moderately sized lithic scatter roughly measuring 47m NS by 50m EW. The site is situated between two dunes roughly two meters high. A graded road lies east of the site about 60 meters beyond a barbed wire fence. Vegetation includes big sage brush, sticky rabbit brush, bunch grass, rubber rabbit brush, Indian rice grass. The site includes obsidian and chert flakes between I flake/m^2. Chert flakes dominate the assemblage. These are brown, olive green, and tanish white chalcedony. Most of the material is moderate to high quality. The orange chert is a low quality chert limestone. Flake types include core reduction, pressure, and a couple of biface thinning flakes. Four tools were identified at the site including one obsidian Humboldt projectile point base measuring 1.1cm long by 1.4cm wide by 0.4 cm tall, one orange-brown chert expended unidirectional core fragment measuring 3.1cm long by 2.9cm wide by 2.8cm tall, one unifacial, unidirectional tan-white chalcedony/chert core measuring 5.3 cm log by 3.7cm wide by 2.6cm tall, and one multidirectional, brown chert expended core measuring 6.6cm long by 3.9cm wide by 2.9cm tall. The Humboldt point ranges in age between 10 and 2 ka.

GV-21

GV-21 is a small lithic scatter located in the White Horse Mountain study area measuring 25m NS by 22m EW. The site is situated south of the lee side of a dune. The surrounding sediment appears to be deflated. A road, fence, and railroad lie about 150m east of the site. Vegetation consists of rubber rabbitbrush, sticky rabbitbrush, buckwheat, winterfat, and big sagebrush, and black sagebrush. The majority of the material is low quality cherty-limestone. Artifact density is between 1 flake/m^2 and 6 flake/m^2. The ubiquity of the material suggests this a testing and core reduction locality. A single moderate quality chert flake and one multidirectional chert core, similar in quality and color, measuring 4.9cm long by 3.1cm wide by 2.1cm tall, were the only exceptions. Aside from the core, one banded brown-orange cherty-limestone stage 2 biface end fragment measuring 6.3cm long by 4.4cm wide by 1.2cm tall, was also identified.

GV-22

GV-22 is a sparse small scatter of artifacts southwest of a low dune and extending up the lee side. It is located in the Hardy Creek study area and measures 15m NS by 12m EW. Vegetation consists of big sagebrush, bunch grass, and sparse greasewood. The artifacts include 2 flakes and a single fire stained battered cobble measuring 9.5cm long by 8.2cm wide by 5.0cm tall. The two flakes are basalt about 12 meters apart. The battered cobble is a mafic volcanic material, possibly intermitted diorite, and may show some flaking/shaping. Battering appears as a fresh break in the fore staining.

GV-23

GV-23 is a small distribution of tools located between 2 N/S running dunes. It is located in the Hardy Creek study area. Vegetation includes rubber rabbitbrush, big sagebrush and bunch grass. The site is relatively small, measuring 20m NS by 13m EW, and only 2 flakes were found associated with it, situated on the eastern dune's lee side.

The flakes are small, pressure flakes, one flake is white, and the other is obsidian. Three tools were recorded: one complete white chert stage 4 biface measuring 7.2cm long by 401cm wide by cm tall, one nearly complete tan chert Large Side-notched projectile point measuring 4.3cm long by 2.1cm wide by 0.3cm tall and missing the tip and tangs, and one white quartz projectile point tip measuring 2.0cm long by 7.7cm wide by 0.3cm tall. The Large side notched point dates to the Early Archaic between 10 to 6 ka. A small scatter of broken rhyolite fragments may represent a tested cobble or an FCR scatter. Based on the artifacts, this appears to be a hunting/kill site.

GV-24

GV-24 is a large sparse lithic scatter situated on 4 low to moderately high dunes (0.5-2 m) that trend North/South. The site measures 110m NS by 90m EW. Vegetation consists of big sage brush, bunch grass, shadweed, and a yellow flower with pods. The artifacts tend to show up on the dune lee surfaces facing west and the blowouts between the dunes. This suggests they have been subject to aeolian transportation and/or deflation. The artifacts are sparsely distributed across the site area. The site had a maximum density of about 5 flakes/m^2. Pressure flakes, biface thinning flakes, and core reduction flakes occur on the site. The artifact types suggest a large tool workshop in the area or exceptional artifact redeposition. No tools were observed.

GV-25

GV-25 is a large lithic scatter located in the White Horse study area and situated on deflated sands with water cracks at the surface. Vegetation consists of greasewood, big sagebrush, shadscale, bunch grass, and snakeweed. The site artifacts are generally sparse at 1 flake/m^2 but in some areas, as dense as 5 flakes/m^2. No clear concentrations are present. One banded brown chert expended core measuring 5.3cm long by 3.1cm wide by 2.1cm tall was identified near the western end of the site. The core exhibits 40% to 60% cortex and has multiple unidirectional flake scars on the worked face. The site abuts a small dune at the northern end where small pressure flakes have accumulated. The rest of the lithics material is primarily a core reduction. Grey, brown, tan, and red cherts dominate the assemblage. A small amount of obsidian and basalt is also present. The site appears to be a core reduction and tool reworking location.

GV-26

The site is a moderately sized lithic scatter located at the western edge of a small north/south running dune. Vegetation is greasewood, big sagebrush, and bunch grass. Artifacts pimarily consist of small, obsidian pressure flakes. There are some small brown and white chert flakes as well. Most of the artifacts are on the dune's lee side and have a maximum density of about 4 flakes/m^2. One orange chert Eastgate projectile point fragment was recorded. It measured 2.2cm long by 1.7cm wide by 0.2cm tall. The stem is missing, but the tangs are present. The Eastgate dates to the Late Archaic between 2-0 ka. Based on the artifacts this appears to be a tool retouch location.

GV-27

GV-27 is located in the White Horse Mountain study area and is situated on the south edge of a low N/S trending dune measuring about 1 meter tall. The site measures 1m EW by 5m NS. Vegetation includes big sage, greasewood, and bunch grass.

The site is a very small lithic scatter consisting of two flakes and a Great Basin Stemmed projectile point midsection. Both of the flakes are obsidian and appear to be core reduction. The Great Basin Stemmed point is the oldest artifact found between the two study areas and dates roughly to the Paleoindian period (13-10 ka). It measures 3.9cm long by 1.9cm wide by 0.3cm tall. The projectile point appears to be edge ground, has a small lip on one side, flares slightly on one end, and has a square-like base. The Great Basin

Stemmed point is a significant find in the sense that it proves the utilization of the Goshute Valley. However, it was found on the surface in a deflated dune.

GV-28

GV-28 is a moderately sized lithic scatter measuring 27m NS by 38m EW. It is located in the White Horse Mountain study area and is situated at the southern end of 2 NS trending dunes. The site extends south of these dunes about 10 m and onto deflated sands. Vegetation includes greasewood, big sagebrush, and bunch grasses. The flake scatter is sparse with most of the site being about 1 flake/m^2. The maximum density is 3 flakes/m^2. The material includes orange, grey, and white cherts as well as basalt. One brown chert projectile point tip measuring 2.1cm long by 1.7cm wide by 0.3cm tall was found on the site. The site appears to be a tool retouch location.

GV-29

GV-29 is a large, but sparse lithic scatter measuring 95m NS by 52m EW. It is located in the White Horse Mountain study area and is associated with 3 dunes. The dunes are situated on the western margin of the site as well as the southeast corner and near the north edge of the site. Vegetation consisted of greasewood, shadscale, sticky rabbitbrush, bunch grasses, and prickly pear cactus.

The flake scatter has a maximum density of 4 flakes/m^2. Most of the site is 1 flake/m^2. Flaked stone material includes are core reduction and biface thinning. Some pressure flakes are present as well. Three tools were found on the site including one basalt Elko Corner-notched point missing the tangs and measuring 4.0cm long by 3.0cm wide by 0.3cm tall, one white chert stage 3 Biface fragment measuring 5.3cm long by 3.1cm wide by 0.8cm tall, and one orange poor quality chert biface end fragment measuring 4.0cm long by 3.0cm wide by 0.3cm tall. The Elko Corner-notched point dates to the Middle Archaic between 6 to 2 ka. Site distribution suggests artifacts are deflating/washing out of the dunes. This may be a tool workshop.

GV-30

GV-30 is located in the White Horse study area. The site appears to be washing out of a dune that lies about 45m east of the site. Vegetation includes shadscale, big sagebrush, and bunch grasses. The artifacts are on a deflated silt pan and all within 1 m^2. It is a discrete scatter of two flakes and one basalt stage 3 biface end fragment measuring 4.1cm long by 5.2cm wide by 1.3cm tall. No other artifacts were identified within 30m. One of the flakes was basalt and the other was a black and white chert. A broken white chert rock within the m^2. May be a flake but there were no diagnostic features.

GV-31

GV-31 is a relatively small, discrete lithic scatter located on a small NS running dune. The site measures 30m NS by 30m EW and is located in the White Horse study area. Vegetaion includes sage brush, rubber rabbitbrush, and sticky rabbitbrush. The site yielded about 50 to 100 flakes with a maximum density of about $4/m^2$. Most of the flakes have a density less than $1/m^2$. The artifacts are primarily grey chert core reduction and biface thinning fragments. No flakes appear off of the dune and most are too large to be windblown. Thus suggests the site was formed in the dune itself. The artifacts suggest this was a tool production site. No tools were found.

GV-32

GV-32 is a small scatter of lithic artifacts situated on a large NNW by SSE trending dune, measuring 2m high. The site is located in the White Horse study area. Vegetation includes big sagebrush, rubber rabbitbrush and sticky rabbitbrush. Two flakes, a small white chert pressure flakes and a small obsidian pressure flake, are on the site. These are on the lee side of the dune. On the dune crest, about 10 meters east of the chert flake, one complete Desert Side-notched projectile point made from an obsidian flake was recorded. The artifact is a Desert side-notched and measures 1.9cm long by 1.2cm wide by 0.2cm tall. The site appears to be a local tool retouch site with activity occurring on the dune itself.

GV-33

GV-33 is a moderately sized (60m N/S x 55m E/W) lithic scatter measuring 60m NS by 55m EW. It is located in the White Horse study area and is situated on the lee side of a NNW by SSE trending dune. The site extends west off the dune onto deflated sands and silts. Vegetation includes rubber rabbitbrush, big sage brush, bunch grass, and sticky rabbitbrush. The majority of artifacts are basalt core reduction and biface tinning flakes. Some chert is also present including a banded black and orange and white chert. The flakes have a maximum density of 3 flakes/m^2, but most of the site has an artifact density of 1 flake/m^2. One orange and white banded chert projectile point fragment, measuring 1.9cm long by 2.1cm wide by 0.3cm tall, was found at the site. The artifact is missing its stem base, although the tangs are present. As such, identification is difficult, however, we think the artifact is a Humboldt. The site appears to be primarily a basalt core reduction and biface production location.

Isolate Number	Description	UTM
GV-iso-1	5 Basalt, 1 Obsidian flakes	11T 0718915 4477529
GV-iso-2	1 Basalt flake	11T 071886 4477415
GV-iso-3	1 Basalt flake	11T 0718986 4477447
GV-iso-4	3 CCS, 2 Obsidian flakes	
GV-iso-5	1 CCS Multidirectional core	
GV-iso-6	1 CCS flake	11T 0718610 4478110
GV-iso-7	1 Basalt/Diorite flake	11T 0718486 4478199
GV-iso-8	4 Basalt flakes	11T 0718528 4476561
GV-iso-9	1 CCS flakes	11T 0718260 4476598
GV-iso-10	1 Basalt, 1CCS flakes	11T 0718284 4476555
GV-iso-11	1 CCS flakes	11T 0718293 4476630
GV-iso-12	1Basalt, 1 CCS flakes	11T 0718877 4478257
GV-iso-13	2 CCS flakes	11T 0717996 4478482
GV-iso-14	1 CCS flake	11T 0719524 4530947
GV-iso-15	1 CCS side scraper	11T 0718010 4529093
GV-iso-16	1 CCS flake	11T 0718968 4530175

Table 8. Isolated artifacts from Hardy Creek and White Horse study area.

Isolate Number	Description	UTM
GV-iso-17	3 CCS flakes	11T 0719083 4530841
GV-iso-18	1 Rhyolite flake	11T 0718074 4477455
GV-iso-19	1 CCS flake	11T 0718003 4477155
GV-iso-20	1 Obsidian, 1 Rhyolite flakes	11T 0718025 4476498
GV-iso-21	1 Basalt, 1 CCS flakes	11T 0717950 4478453
GV-iso-22	1 CCS flake	11T 0717746 4478442
GV-iso-23	1 Obsidian flake	11T 0717908 4478323
GV-iso-24	1 Basalt flake	11T 0717944 4478126
GV-iso-25	2 Basalt, 2 CCS, 4 Rhyolite flakes	11T 0717983 4476889
GV-iso-26	3 Basalt, 1 Obsidian flakes	11T 0717079 4477003
GV-iso-27	2 Basalt flakes	11T 0717062 4477051
GV-iso-28	Chert pressure flake flakes	Inside core taken from 11T 0718281 4476584

Table 8. Continued.

3.1.2 Goshute Valley Artifact Report

For the purpose of this research, artifacts have been grouped into three categories based on perceived activities: hunting, processing, and core and tool reduction activities. Artifacts used for hunting are projectile points and bifaces. Artifacts used for processing include scrapers and knives. Debitage is the refuse produced during the flintknaping process as flakes are removed from cores and tools.

When analyzing lithic artifacts, three terms are used to identify the manufacture method (Andrefsky 2009). Production refers to the process of pressure flaking and percussion flaking techniques. Pressure flaking is a method where the tool is worked by using a softer tool to apply pressure to the tool. Percussion flaking is a method where a harder tool is used to strike the tool and bust off flakes to shape the tool. Another term, reduction, is used to identify removed flakes from cores. Lastly, tool retouch broadly refers to the method of removing flakes from tools. Each time a tool is retouched, however, the tool diminishes in size. The purpose of retouch is to shape an edge for a specific use. Sometimes large flakes will have retouch on the side to create a scraper or similar processing tool such as a knife.

Tools are made with specific purpose; however, throughout the lifetime of a tool, that purpose can change, based on supply and demand of lithic raw materials and whether or not tools brake. Tools are re-sharpened and re-purposed, or re-formed, until they can no longer be of any use, and are eventually discarded.

For this purpose, raw material types play a crucial role in understanding procurement of raw materials and technological organization (Andrefsky 2009). Lithic raw materials indicate human knowledge of the lithic landscape, knowledge of where to locate raw materials. The lithic material can be used to better understand human productivity, migration, and trade. Tools made from igneous and siliciclastic materials have different functions. Igneous materials such as basalt are commonly made into scrapers and processing tools, while chert and obsidian is commonly used as a material for projectile points (Andrefsky 2009).

Analyzing lithic technology is analogous to analyzing a tool chest. By looking at the type of tools, one can understand what the most likely functions of those tools may be. Human activity can be interpreted by analyzing the tools people used to accomplish tasks such as hunting, processing, cooking, sewing, etc. However, as Andrefsky (2009) points out, mobile foragers may not have necessarily utilized formal tools, just as much as sedentary hunter-gathers may not have utilized expedient technology. The history and morphology of a tool set is influenced both by environmental and cultural factors (Andrefsky 2009).

As well as determining human activity, lithic scatters can be used to analyze land-use patterns at a site (Jones and Beck 1990). Isolated artifacts and artifact clusters have low temporal sensitivity (Jones and Beck 1990). Nevertheless, typological cross-dating is the most common way of dating artifacts found in the surface contacts that cannot be chronometrically dated. Distinguished artifact typology is crucial for understanding the typological spatial and temporal patterns among tool sets (Bettinger and Eerkens 1999).

The site of GV-1, GV-2, and GV-10 have Desert side-notched projectile points. The Desert Series are divided into three typologies: Desert side-notched, Cottonwood Triangular, and Cottonwood leaf-shaped (Grayson 2011). Desert side-notched points are typically small, triangular, and side-notched where the angle does not exceed 60°. The earliest recorded emergence of the bow and arrow in the eastern Great Basin is around 1,700 cal BP (Grayson 2011). Rosegate projectile points are usually associated with the earliest forms of the bow and arrow. About 600 cal BP, Desert side-notched points replace

Rosegate points (Grayson 2011). So these sites, GV-1, GV-2, and GV-10, post-date 600 cal BP.

Eleven pieces of Shoshone brownware pottery were found at GV-11. Pottery is not commonly present outside of the Fremont region in the Great Basin until 950 cal BP, but in some contexts brownware emerged as early as 1,150 cal BP, becoming common around 650 cal BP (Rhode 1994). The brownware pottery from GV-11 indicates an age of no earlier than 1,150 cal BP and likely it post-dates 650 cal BP (Thomas 1981).

At GV-18, a Gatecliff Split-stem projectile point was found. The Gatecliff Series projectile points are divided into two taxonomies: Gateliff Split Stem and Gatecliff Contracting Stem (Grayson). Both types are characteristic of triangular blades and moderate to large hafting stems. Gatecliff series are hefty projectile points which are wider at the base, measuring greater than 60°, and were hafted to tip darts (Grayson 2011). These projectile points are typically dated from roughly about 5,100-2,800 cal BP in the eastern Great Basin (Schmitt and Madsen 2005), placing the age of the GV-18 site into this time frame.

A single Humboldt projectile point was found at GV-20. Humboldt points are lanceolate, un-notched dart tips with concave bases (Thomas 1981). The Humboldt series dates to about 6,300-2,900 cal BP in the eastern Great Basin (Schmitt and Madsen 2005) and are difficult to use temporally because they are associated with such a long range of time. According to some (Pettigrew 1984), Humboldt points replaced Large side-notched points as human population increased and settlement patterns broadened to range from the uplands to the valley floors.

One Large side-notched projectile point was found at GV-23. Side notched points have a shoulder angle greater than 150° (Thomas 1981). These projectile points are often found on the playa indicating a low elevation hunting strategy with the few remaining marshes, however they have also been found in the uplands (Pettigrew 1984). These projectile point types generally date to about 8,300-4,500 cal BP in the eastern Great Basin (Schmitt and Madsen 2005).

GV-29 was the site where the Elko corner-notched projectile point was found on the crest of a dune. Elko Series, comprised of the Elko corner-notched and Elko forms, are mostly corner-notched with angles measuring less than 60° and are rather large. In the central and eastern Great Basin, Elko points range in age between 3,500 cal BP and 1,300 cal BP, while in the eastern Great Basin, Elko points range in age between 8,000 cal BP and 1,000 cal BP (Grayson 2011).

The oldest artifact found was a Great Basin Stemmed projectile point at GV-21. These points are large lanceolate-shaped points used to tip spears and can date to as early as 13,000 cal BP to 9,500 cal BP, and are a part of the Western Stemmed Tradition (Goebel and Keene 2014; Grayson 2011). The unfluted lanceolate points are usually edge ground for hafting, which means that their edges are ground and smoothed so they do not cut the binding material applied for hafting (Beck and Jones 1997) Sites with Great Basin Stemmed points found in open-air contexts suggest that early humans in the Great Basin situated their campsites along riparian zones during the Paleoindian or Paleoarchaic period (Madsen et al. 2015). Hunters used these points to procure a wide range of food (Hockett 2007; Pettigrew 1984). Aside from riparian habitats, the Western Stemmed Tradition has also been documented in association with pluvial lakebeds and at surface sites, such as the Sunshine Well, eastern Nevada, and shelters such as Bonneville Estates Rockshelter, Danger Cave, Hogup Cave, and Smith Creek Cave (Graf 2013). However, Grayson (2011) states that whereas the fluted points are associated with valley bottom settings conducive to marshes, the lanceolate points are associated with a broad use across the valley and uplands. Around 9,500 cal BP, this assemblage can no longer be traced in the archaeological record, implying that as climatic conditions became warmer, drier, and harsher, groups of people could no longer focus on large herd animals and had to expand their territory to the uplands to hunt solitary game (Pettigrew 1984). This lithic assemblage is one of the best dated in the Great Basin because of the amount of research that has been accomplished to discover and date these early archaeological contexts (Madsen et al. 2015).

One CCS multidirectional core was found at GV-iso-5 (Table 8). The core is indicative of core reduction, a method of tool making and is corroborated with the many hundreds of core reduction flakes at almost all of the 33 sites. One CCS side scraper was found at GV-iso-15 (Table 8). Side scrapers are processing tools. Since only one was found, it is likely that the occupational purpose of this part of the valley, specifically in dune fields, was not intended for campsites or villages, but instead intended as hunting sites where perhaps some food was processed before taken back to camps.

Figure 31. Paleoindian (13-10 ka): 1 Great Basin Stemmed point (GV-27-1); Early Archaic (10-6 ka): 1 Large Side-notched point (GV-23-2); Middle Archaic (6-2 ka): 1 Gatecliff split stem (GV-18-1), 1 Humboldt (GV-20-1), and 1 Elko Corner-notched point (GV-29-1); Late Archaic (2-0 ka): 1 Rosegate (Rosespring/Eastgate) (GV-26-1), 3 Desert Side-notched points/Cottonwood (GV-1-1, GV-2-1, & GV-32-1), and Brownware pottery (GV-11-1).

3.1.3 Geoarchaeological Significance

Site Formation Process in the Hardy Creek and White Horse Dune Fields

Site formation processes are the cultural and/or natural process of events that create an archaeological site, as well as the cultural and/or natural processes that affect an archaeological site after its deposition (Dincauze 2000). Not only is the geomorphological and sedimentary environment addressed, but to form a geoarchaeological interpretation, the archaeological record and depositional environment of these sites needs to be addressed. Even still, poor preservation and poor site detection hinder the understanding of how humans used dunes in semi-arid regions (Waters 1992).

Several dune fields have produced archaeological sites, and each of these situations is unique. My objective is to identify whether the sites in this study area were deposited before, coeval with, or after dune formation. The challenge lies in inferring the history of the dune in reference to the archaeological site.

The sites in the Goshute Valley were mostly located on the sandsheets between the vegetated dunes and in blowouts, while isolated finds were mostly found on the playa. There were 17 sites found in dune environments, mostly in blowouts (55%), eight sites on the sandsheets (21%), four sites in an edge environment between playa and sandsheet or dune (12%), three sites in interdune environments (9%), and one site was found on the playa (3%). Artifacts on the surface of dunes are found in a poor context because they could have been deposited either during or after dune formation. Likewise, sites in blowouts have no clear context because they may have been higher in the profile before dropping out as the blowout occurred or they may have been deposited before dune building. Lastly, sites on the sandsheet occurred as the sandsheet was forming and sites on the playa have absolutely no context since there are no geomorphological processes to relatively date with, except that it was deposited after Lake Waring desiccated (which is a large span of time that at its onset, predates all diagnostic artifacts by years).

Only two diagnostic artifacts were found at the crest of two dunes situated in the White Horse Dune Field: an Elko Corner-notched projectile point and an Eastgate projectile point. The Elko point dates roughly to the Middle Archaic, between 8,000 cal

BP and 1,000 cal BP, and the Eastgate dates to the Late Archaic, from 2,000 cal BP to present-day. Compared to the position of the Elko point on the dune, the position of the Eastgate point on the dune could possibly coincide with the late Archaic and a recent date. The oldest date from Dune 128 is 1,570 ± 190 cal BP, so the Eastgate point was probably deposited during or after this time. Since the ages of the Elko and Eastgate overlap and corroborate with the OSL ages of the dune, it is possible and quite probable that the Elko projectile point was deposited after the White Horse dunes formed. At any rate, the deposition of this site probably happened simultaneously with the accretion of the dune associated with the Elko projectile point. Therefore, it is likely that the whole dune field simultaneously followed the same process.

Location	Site	Site Environment	Diagnostic Point Form	Inferred Ages
White Horse Dune Field	GV-1	Edge of playa / sandsheet	Desert side-notched	1570±190
	GV-2	Edge of playa / sandsheet	Desert side-notched	1570±190
	GV-3	Edge of playa / sandsheet	N/A	N/A
	GV-4	Dune	N/A	N/A
	GV-5	Dune	N/A	N/A
	GV-6	Sandsheet	N/A	N/A
	GV-7	Dune	N/A	N/A
	GV-8	Dune	N/A	N/A
	GV-9	Dune	N/A	N/A
	GV-10	Dune	N/A	N/A
	GV-11	Dune	Brownware*	1570±190
	GV-12	Dune	N/A	N/A
	GV-13	Interdune	N/A	N/A
	GV-14	Dune	N/A	N/A
	GV-15	Dune	N/A	N/A
	GV-16	Interdune	N/A	N/A
	GV-22	Dune	N/A	N/A
	GV-23	Sandsheet	Large side-notched	>1570±190
	GV-24	Dune	N/A	N/A
	GV-25	Playa	N/A	N/A
	GV-26	Dune	Eastgate	1570±190
	GV-27	Interdune	Great Basin Stemmed	>1570±190
	GV-28	Dune	N/A	N/A
	GV-29	Dune	Elko	1570±190
	GV-30	Edge of playa / sandsheet	N/A	N/A
	GV-31	Sandsheet	N/A	N/A
	GV-32	Dune	Desert side-notched	1570±190
	GV-33	Sandsheet	Elko	1570±190
Hardy Creek Dune Field	GV-17	Sandsheet	N/A	N/A
	GV-18	Sandsheet	Gatecliff	5160±620
	GV-19	Sandsheet	Elko	5160±620
	GV-20	Dune	Humboldt	5160±620
	GV-21	Dune	N/A	N/A
*Brownware pottery is not a point form, however, it is diagnostic				

Table 9. Environmental context classifications of archaeological sites, diagnostic point forms/artifact, and inferred age.

From deposition to discovery, any one of these sites in the Hardy Creek and White Horse Dune Fields may have undergone major reconstruction such as burial, exposure, deflation, and reburial (Waters 1992). Archaeology that is found in the context of a migrating dune field has a high probability of being disturbed; however, rapid deposition in a stabilized dune field anchored by vegetation might be able to provide better context for preserved sites (Dincauze 2000). As mentioned in the previous chapter, vegetation acts as a buffer to aeolian processes and essentially protects archaeology from erosion (Waters 1992). Sites can also be preserved in dunes that are associated with paleosols, such as calcic and argillic horizons, because these geological deposits are more cohesive in nature and are not easily entrained (Waters 1992). Unfortunately there have not been many perfect situations like this to test this hypothesis, and the dunes in this study are not likely candidates because of the fields' tendency for blowouts, meaning they were constantly active.

Furthermore, these blowouts can largely affect the sorting of artifacts within a dune and cause a palimpsest situation to arise. A palimpsest occurs when artifacts from multiple ages are found in the same stratigraphic position. In the case for all sites in the Hardy Creek and White Horse Dunes Fields, the stratigraphic position is either the surface of the playa or the dunes. As deflation occurs, the artifacts will drop out according to their size, shape, and weight as lag deposits, much like coarser grains of sand. (Dincauze 2000; Waters 1992). The surfaces in which they are found have no association with the original deposition, therefore, these sites cannot be reliably dated.

Table 9 shows the various site environments which are classified as dune, interdune, sandsheet, and edge of playa/sandsheet. Sites from the White Horse Dune field found in dune environments yielded Elko, Eastgate, and Desert side notched projectile points, and brownware. Sites from the Hardy Creek Dune field in the same context yielded a Humboldt point. Dune environments encompass a span of artifacts over a broad spectrum of time from the Gatecliff point to the Desert side-notched point. In both dune fields, this array of artifacts can only determine that the artifacts were deposited during, after, and possibly before the dunes formed. A Great Basin Stemmed point was found in the interdune environment at White Horse Dune field which means that either this artifact was deposited before the oldest relict dune was formed or had either dropped out of the dune as a result of deflation or migration. At the White Horse Dune field, a Large side notched point was recorded in the sandsheet environment, while a Gatecliff point and an Elko point were found at the Hardy Creek Dune field. These artifacts are older and more uniform in age. Sandsheets were not dated, but these artifacts also suggest that they were deposited either before, during, or after at both sites. At the White Horse Dune field, Desert side-notched projectile points were recorded in the edge of playa/sandsheet environment. This means that they were deposited after the sandsheet developed.

Since dunes are well drained and oxidized, the preservation of organic material is low, therefore, typical dune soils are Entisols and Aridisols (Dincauze 2000). Entisols are newly formed soils that show weak development with pronounced sedimentary characteristics. Aridisols are soils usually formed in arid to semi-arid environments and sometimes exhibits calcified B horizons. Within the interdunes, ponding is possible during precipitation events which, if long-term, might be able to form soils and be a designated area for human activity (Dincauze 2000). Another way that sites are preserved in interdunes systems is by ponding which forms silts, clays, and marl (Waters 1992).

Unfortunately, all artifacts recovered were from surface contexts, but there is potential in finding sites in the dunes. One pressure flake was found in the 15 m core from Dune 128. The significance of this flake found in the dune proves the potential of finding other buried artifacts within the dune. The flake was determined to have been deposited in the dune, instead of blown into the dune, because of the juxtaposition of its shape and size to the shape and size of the sand grains buried within the same context. The shape is not easily subjected to saltation and the size is too large to be saltated since the grain size was medium and the flake exceeds 0.25 to 0.5 mm. However, because of the lack of an argillic or a calcic horizon, preservation is not likely, therefore, their credibility would be weak. The dune sampled from Hardy Creek did not have a true calcic horizon, since there is no pedogenesis involved, but since it had such high $CaCO_3$ percentages, it might have been able to preserve any buried sites if it could withstand further deflation. The base of this dune where the sediment samples were taken yielded a date of 5,090 ± 605 cal BP and a $CaCO_3$ equivalency between 21.2% and 44.3%.

Artifact mobility within a dune is a function of three criteria: artifact shape, condition of the sediment matrix, and climate (Waters 1992). As previously discussed, a flake was found in core 15 from dune 128. This dune would be a good candidate for further investigation, not only because of the flake from the core, but also because a large flake was found in the blowout and on the dune edge and a projectile Desert side notched point was found two dunes away. Perhaps excavation of the dune would yield a cultural horizon which could possibly provide context for the archaeology.

Figure 32. Top picture represents a playa environment, the middle picture shows playa-sagebrush/greasewood environment, and the bottom picture shows the dune/inter-dune environment.

3.1.4 Cultural Significance of the Goshute Valley

Human subsistence practices in the Great Basin throughout the Holocene were dependent on the environment and hunting and gathering strategies. Brian Hockett and others conducted several studies on trapping features in the Eastern Great Basin. Hockett et al. (2013) differentiate these features into three classes: drive lines and drift fences, corrals, and fences which led to a corral. They contribute the construction of these features to communal efforts, including possibly seven to ten families. It is also possible that the members of these groups could have been mixed genders or primarily male. The purpose of these large traps is thought to communal gatherings between families, or groups of people. People were hunting artiodactyls as early as 13,000 years BP. Mule deer, pronghorn antelope, and bighorn sheep were commonly trapped. Bison were also hunted in the Great Basin, however, their presence in the Great Basin was scarce. Hockett et al. (2013) suggests that if a high volume of artiodactyls are trapped, then the population of humans in the eastern Great Basin was relatively high.

When were people present in the Goshute Valley? According to Hockett (2005), Great Basin Stemmed projectile points have been dated between 13,000 cal BP to 9,500 cal BP. Large Side-Notched Projectile points have been dated between 7,500 to 5,000 cal BP. Likewise, Humboldt Projectile points have been dated between 7,500 to 3,500 cal BP, while Gatecliff Projectile points have been dated between 5,000 to 3,500 cal BP. The transition from the Middle Archaic to the Late Archaic is a transition into corner-notched and split-stem technology, although in the northeastern Great Basin, split stem points were manufactured prior to Elko points (Hockett 1995). Elko Projectile Points date between

8,000 BP and 1,000 cal BP, replacing the Gatecliff technology. Eastgate and Rose Spring projectile points date between 1,300 and 550 cal BP. Lastly, Desert Side-Notched projectile points range from 550 to 150 cal BP and are an adaptation used by the ancestors of the Goshute and Western Shoshone people. The Desert Side-Notched points mark the initial spread of the Numic-speaking people (Hockett and Morgenstein 2003). Although, side-notching will eventually lose popularity among hunters as corner-notching techniques prove to be more efficient (Beck 1995). Intermountain Brownware is defined as undecorated, brown, utilitarian Great Basin ceramic manufactured after 600 cal BP using the "coil and scrape technique" to create a rough surface (Hockett and Morgenstein 2003). The overlap of some of these artifact types, such as the Humboldt point and Elko point is contributed to a lack of stratigraphic context.

The artifacts imply that people were present in the Goshute Valley and specifically utilizing the dune fields from the Late Pleistocene/Early Holocene to the Late Archaic. What were people doing in these dune fields at this time? Based on artifacts found in various site environments reported, this study implies that people were hunting on the valley floor in the dunes throughout the Holocene. Bases on OSL ages, dune building events, and various climate reconstructions of the Holocene, people were most likely hunting seasonally. Three major dune building events were identified during the Medieval Climatic Anomaly, Late Holocene Dry Period, and during a drought before 5,000 cal BP. Based on the artifacts and their broad temporal resolutions, people utilized the Goshute Valley dunes during periods of drought, suggesting, that there might not have been a hiatus during Holocene droughts. It does imply, however, that people were hunting during cooler times of the year such as the fall and spring because of the aridity and heat during drought periods. Based on sediment size (recall the grains were larger than expected for dunes) and the distance from the sources (specifically the distance in White Horse), the environment on the valley floor would not have been ideal for hunting because of the intensity of aeolian pocesses. Furthermore, antelope/deer would most likely would have migrated to more temperate climates in the uplands of the Goshute, Pequop, or Dolly Varden Mountains.

3.2 Discussion

Many sites across the Great Basin, such as Hidden Cave, Hogup Cave, Mosquito Willie, Danger Cave, Buzzcut Dune, Oranjeboom Cave, and Bonneville Estates Rockshelter, show that there was neither a hiatus throughout the Middle Holocene nor during the oscillating harsher conditions of the Late Holocene. Human settlement in the northeast Great Basin was most likely seasonal. People were likely hunting in the Goshute Valley from the Paleoindian, as evidenced by a Great Basin Stemmed projectile point, to the Late Archaic, as evidenced by three Desert Side Notched projectile points.

It is evident that people changed their adaptive strategies based on the variety of points in the lithic assemblages found on the surfaces of the dunes in the Goshute Valley. Climate at the Pleistocene-Holocene boundary (13,000-9,500 BP) sustained an environment with large game which were hunted with large spears, like the Great Basin Stemmed point, by nomadic big game hunters. As climate became warm and dry Middle Archaic hunting parties may have only visited the dunes in the valley for hunting mammal resources (deer, antelope, hare) and perhaps for lithic procurement because we may expect retooling to be embedded in subsistence pursuits (Binford 1980). Additionally, there is plenty of water nearby because natural springs in the area have been dated to as early as 7,000 years BP and would have been a viable source of water for people within a 40-mile radius of the Goshute Valley (Janetski 2006). During the Late Archaic, around 1,100-970 BP, artifacts from the Fremont were recorded from Oranjeboom Cave (Buck et al. 2002). Oranjeboom Cave is no more than 12 km away from the White Horse Dune Field, and no more than 40 km from the Hardy Creek Dune Field. Though the Hardy Creek Dune Field did not yield many diagnostic lithic artifacts compared with White Horse Dune Field, from what was found, it is possible that the artifacts were deposited no earlier than 5,000 BP. Dunes of the White Horse Dune Field, however, would have been in close distance of Fremont hunters camping at Oranjeboom Cave. It is possible that the Eastgate projectile point found in the White Horse Dune field was left behind by the Fremont, who may have visited the valley. Late Archaic hunting parties may have used the dunes as natural "blinds" or cover when pursuing hare and antelope. The hunting parties could have also used the dunes to coral game, such as antelope. Although no evidence of corrals were observed in the survey area, there is evidence of antelope corrals near Spruce Mountain which is located approximately 30 km from the survey area. No processing tools were recorded in the survey areas with the exception of one isolated side scraper, which suggests that the people frequenting the valley were hunters and likely not carrying out other types of tasks. From the debitage, it is most likely that the core reduction and tool retouch were the two most common activities. The transition into the Late Archaic, as evidenced by the pottery sherds and arrow points on the playa floor, indicates that groups of hunter-gathers were traveling through the Goshute Valley perhaps foraging the vegetation and hunting (possibly deer, antelope, and hare or a combination thereof) along the stable, anchored dunes as they made their way to seasonal camps sites in the uplands of the Goshute Mountains. The mountains provided shelter, in the form of caves and rockshelters, spring water, and food such as deer, antelope, and pine nuts.

4. CONCLUSIONS

I characterized artifact distributions from the artifact maps, created from GoogleEarth, and qualitatively determined patterns in technological activities within each site and between each site to characterize human usage of two aeolian landforms. Using methods like GPR and OSL dating to record depositional sequences, I reconstructed the depositional history of the dunes and the relative paleoclimate associated with human use of dunes in the Goshute Valley.

The sediments from the Hardy Creek Dune Field represents a unimodal, moderately sorted medium sand, fine skewed, and platykurtic dune field. The sediments from the White Horse dune represents a unimodal, poorly sorted medium sand, fine skewed, and leptokurtic dune field. Both the White Horse and Hardy Creek Dune Fields are positively skewed, indicating that sediment grades course to fine, and unimodal, with predominantly medium sand. The dunes in the Hardy Creek Dune Field are characterized as deflated lunettes where sediment supply has been sourced to the Goshute Mountains, Pequop Mountains, and likely the nearby playa floor based from the high concentration of whole volcanic glass shards and carbonates as well as the fine sediment present. The White Horse Dune Field is characterized as vegetated linear dunes which were sourced to the Dolly Varden Mountain based from the high concentration of partial volcanic glass shards and heavy minerals. Both dune fields are deflating as a result of sediment starvation. The dunes in the Hardy Creek Dune Field exhibit relict dunes no older than 5,160 ± 620 cl BP, whereas the dunes in the White Horse Dune Field exhibit relict dunes are no older than 1,570±190 cal BP.

The A/C Ratio from the Bonneville Estates Rockshelter sediment samples show that climate throughout the Holocene was stable. Four OSL dates correspond with warm/dry periods, while three of the OSL dates correspond with cooler climatic conditions. The dune building sequence at the Hardy Creek Dune Field and the White Horse Dune Field occurred during both cool/wet and warm/dry cycles, suggesting that the fundamental driving factor of dune formation in the Goshute Valley is primarily affected by sediment supply and secondarily affected by climatic shifts. However, Figure 33 indicates that while dune accretion occurred during both cool/wet and warm/dry periods, they mostly correlated with warm and dry conditions.

Prior to 8,000 BP, the playa most likely deflated at the onset of increasingly arid conditions. Windier conditions enacted the mechanism by which deflated playa sandy loam/loamy sand to accumulate as dunes. Between 8,000 and 5,000 BP, a major drought triggered deflation and the deposition of carbonate-rich sands. During the Middle Holocene, the oldest dune-building sequence occurred in the Hardy Creek Dune Field and shows that dune accretion has been an ongoing event in the Goshute Valley as early as 5,000 BP. The A/C ratio from the early Middle Holocene Bonneville Estates sediment shows a shift to xeric plants such as chenopodium, sagebrush, and grasses, which is indicative of warmer winters and greater summer precipitation at the onset of monsoons. However, the late Middle Holocene shifted back to cooler mesic conditions at the onset of winter storms. Although there is a gap in the record between 4,250 cal BP to 3,000 cal BP ka, climate conditions may not have been stable according to the pollen record from Bonneville Estates Rockshelter. This may be accredited to a slow response to climate by the *Artemesia* and *Chenopodium* species in this area.

There was less dune building during the Late Holocene Dry period which suggests that during the warmest period in the Holocene, climate conditions were too hot, dry, and possibly too windy for dune building to occur. The Bonneville lake level and the pollen record from Bonneville Estates Rockshelter and the Blue Lake pollen record show that one of the driest periods in the Goshute area occurred between 750 cal BP to 1,250 cal BP. At the same time, OSL records from White Horse, but mainly Hardy Creek, show a period of dune-building. Recall the study by Tchakerian (2009), which demonstrated that dune building is correlated directly foremost with sediment supply and source, not climate.

It is likely that artifact deposition occurred before, during, and in accordance with dune accretion. Older artifacts were generally located in edge of playa/sandsheet and sandsheet site environments implying that these artifacts were deposited before the oldest relict dunes present today. The younger artifacts were found in dune and interdune site environments implying their deposition was concurrent or later than dune formation. However, it is indeterminate whether the dunes were present in the valley before 5,000 BP, although it is most likely that they have been present shortly after the desiccation of Lake Waring. From the archaeological survey results, people have been in the Goshute Valley from the Paleoindian to the Late Archaic since Great Basin Stemmed projectile points and Desert side-notched projectile points were recorded. It is possible that people were using the dunes as hunting blinds during cooler months of the year which was determined by the correlation of OSL dates to regional paleoclimate data indicating drought. It is believed that people were utilizing the dunes based from the quantity of sites in the dunes and versus the number of sites on the playa. Dunes would have been good for hunting since they provide water and food for animals, and cover for hunters. The high quantity of projectile points and retouch flakes relative to the low quantity of processing tools suggests that people were only hunting or possibly passing through the Goshute Valley.

Over the course of 20,000 years, the Goshute Valley has been a dynamic landscape from pluvial Lake Waring to modern day dunes. People sporadically used the valley for more than 10,000 years. Hospitable attributes such as springs, resources (both lithic and caloric), shelter, and possibly networks with other inhabitants of the Bonneville Basin area make the Goshute Valley an important archaeological area to investigate. Not much research was implemented in the Goshute Valley along the lines of archaeological survey and aeolian geomorphology exploration. No studies have previously investigated the ages of the dunes in the Goshute Valley either. For this reason, this research is unique and important for the understanding of aeolian geomorphology and archaeology in the northeastern Great Basin.

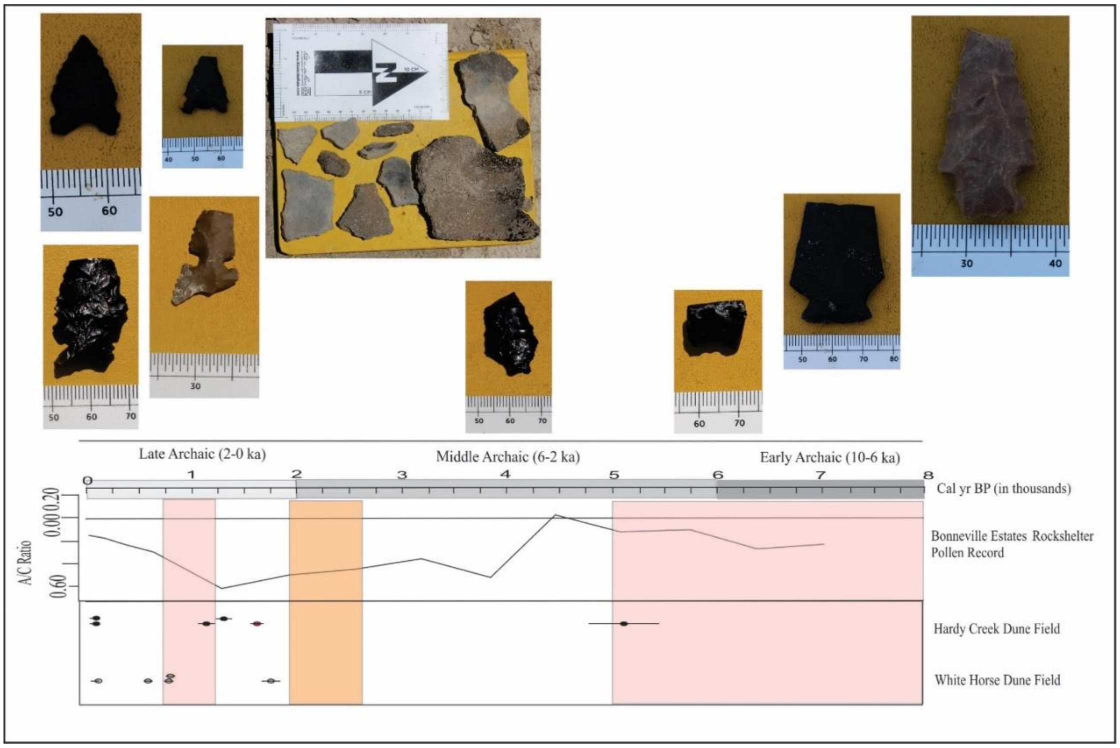


Figure 33. Stacked chart of OSL ages from Hardy Creek and White Horse Dune Fields, A/C ratio results, and artifacts found in relation to theses ages.

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