University of Nevada, Reno

If the Desert Blooms: A Technological Perspective on Paleoindian Ecology in the Great Basin from the Old River Bed, Utah

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Anthropology

by

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August 2011

University of Nevada, Reno
Statewide • Worldwide

THE GRADUATE SCHOOL

We recommend that the dissertation
prepared under our supervision by

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entitled

If The Desert Blooms: A Technological Perspective On Paleoindian Ecology In The Great Basin From The Old River Bed, Utah

be accepted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The earliest inhabitants of the Great Basin adapted to a well-watered environment that was already set to disappear. This much seems clear from paleoenvironmental data, but a good understanding of how the declining ecosystem affected Paleoindian peoples still eludes us. In the now-barren expanse of the Great Salt Lake Desert, the Old River Bed (ORB) delta existed as a sprawling distributary wetland at the Pleistocene-Holocene transition. At its peak, the system would have been one of the largest marshlands in the Great Basin. Paleoindians visited the distal reaches of the wetlands between about 12,100 and 9900 cal BP, when it finally dried up. My study tracks spatial and temporal variability in lithic technology across the distal ORB to address issues of how people coped with the regionally deteriorating environment. Patterns are compared between the west and east sides of the study area, which roughly date to sequential time frames of 12,100-11,200 cal BP and 11,300-9900 cal BP, respectively, based on dating of buried wetland organics. These subareas correspond with spatially distinct groups of distributary paleochannels.

Using a formal technological model, lithic data are examined in terms of reduction strategies, toolstone selection, and morphology as they relate to emphasis on transport efficiency. The results of the analysis show that people were more transport-efficiency conscious earlier in time than they were later. According to the model, this directly relates to occupation length—viewed here as time spent in the basin, not necessarily at a single site—whereby increasing mobility necessitates the need for transport efficiency in order to reduce the risks of not having enough stone on-hand and the costs of having to procure more. When the study subareas are compared, west-subarea assemblages indicate greater

emphasis on transport efficiency with streamlined toolkits made more often from obsidian than seen in the east subarea, where fine-grained volcanic (FGV) stone is more common. This strategy placed a buffer of toolstone into relatively large tools that were reduced bifacially through an extended sequence. Parman, Lake Mojave, and Cougar Mountain projectile points tend to be associated with the west subarea and this technological pattern.

The technology of the east subarea is "flakier," with smaller tools being made from transported flake blanks following a more local toolstone profile. This strategy shifts costs from the production and maintenance investments of transport efficiency to the transport of stone directly to its location of use. Bonneville and Pinto projectile points tend to be associated with the east subarea and this technological pattern. A second pattern found predominately in east-subarea sites is the extreme economization of obsidian. Various small biface fragments and irregular tools are seen, and the extensively reworked Stubby stemmed type is also more common in this subarea. This reduction pattern signals higher predictability in tool-use requirements and raw material acquisition.

These data are interpreted to represent shorter basin occupations earlier and longer basin occupations later in time. Assuming the total ORB delta was more or less always capable of sustaining people for long periods of time while it existed, any shift in settlement mobility should be driven by conditions in the other regional wetlands they visited. Being in such a large drainage basin, the ORB likely persisted while smaller basin wetlands succumbed to Early Holocene drying more rapidly. Thus, I argue that the shift in lithic technology seen on the distal ORB provides a dynamic model for how people responded to regional environmental decline that is currently missing from Paleoindian studies.

ACKNOWLEDGMENTS

I have many people to thank for pushing me toward getting this dissertation finished. My graduate committee was influential in keeping my mind centered on the issues, both directly through their assistance and indirectly by conducting their own brands of research. Drs. Gary Haynes, Bob Elston, Dave Rhode, Ted Goebel, and Anna Panorska all contributed invaluably to my learning, beyond what is reflected in this study. I regard each of them as true scholars who I will continue to look to in the future.

This research definitely could not have been completed without the full support of Jaynie Hirschi, Archaeologist at Hill Air Force Base, Utah. Through a litany of cultural resource management projects, she has facilitated just about every sideways research idea I wanted to put to the test. She is a good friend to me and to archaeology. I would also like to thank those working on the Army side of the Old River Bed. Rachel Quist, Archaeologist at Dugway Proving Ground, and the Desert Research Institute team—Dr. David Madsen, David Page, David Schmitt, and Dr. Jack Oviatt—who have all been collegial and gracious in sharing site visits, information, insights, and fun.

The folks at Far Western deserve special thanks for waiting this process out and providing some time and resources to help me get done. Dr. D. Craig Young is in this with me to some extent as we have together developed the research program for the Air Force. His geoarchaeological expertise is an important contribution, and I cannot overlook his covering for me when I came back to school. All the smart people at Far Western continue to inspire me as great examples of contract archaeology at its best. Sharlyn Anderson, Mike Lenzi, and Kasey O'Horo all helped with various data-collating and paper-chasing jobs as I closed in on finishing. I am also grateful to Heather Baron, Nicole Birney, and Wendy Masarweh for helping with the artifact figures and stitching this document together.

Finally, I would like to acknowledge my friends and family for their encouragement and support. Several had direct contributions. Jim Carter wove me into his ongoing work for the Air Force at the beginning. Tony Taylor and Sam Coffman were undergraduate lab rats who are rapidly catching up with me, but for at least some brief period at UNR I was able to make them do many of my least favorite data tasks. Mike Lenzi found himself in the same unfortunate position at Far Western. I hope each took something good from it, and I look forward to knowing them for years to come. Verla Jackson's help on the administrative end at UNR was crucial. Leticia Neal has listened to more conversations about obsidian hydration dating than anyone should be allowed to endure. For the many others who are not mentioned but shared this experience with me, know that you are all remembered fondly. My parents have always supported my career in archaeology, and my final thanks goes to them.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

In this dissertation, I use the surface lithic record of the distal Old River Bed (distal ORB) to clarify the relationship between Paleoindian technology and changing ecological conditions in the Great Basin at the Pleistocene-Holocene transition. My primary analytical question is a simple one: how does Paleoindian stone tool technology change through time? However, the broader aim of this study is to develop a model that predicts technological change based on the influence of ecological factors on residential mobility. Chief among these factors is the deterioration and loss of previously relied-upon lake-margin and distributary wetlands. Paleoenvironmental data directly indicate the environmental decline, and regional archaeological data are clear that significant cultural change occurred as the pluvial period closed out. How did people cope with an ecosystem that was increasingly at odds with their initial adaptation to it? They must have made adjustments. Recent studies interpret from the energetic cost-benefit tradeoffs necessitated by changing food resource distributions (e.g., Elston and Zeanah 2002; Madsen 2007; Pinson 1999). Lithic technology must also adhere to certain economic and physical rules and can therefore be modeled similarly to provide a better connection between behavioral ecological models and landscape-level patterning in the archaeological record.

Lack of chronological resolution continues to be a significant hindrance to gaining a dynamic understanding of Paleoindian adaptations in the Great Basin. The surface archaeological record is extensive but largely undated, and the dry caves and rockshelters that preserve dateable cultural features yield only limited artifact assemblages to link to the broad open-air patterns. As a result, research tends to present the Paleoindian period as a relatively stagnant cultural unit. This is an unfortunate portrayal that does more to separate Paleoindian peoples from later groups than it does to make sense of Paleoindian behavior in its own right. The early residents of the Great Basin were subject to the most marked environmental change in human experience in North America, and we should expect corresponding changes in land use and technology.

This study provides a model for Paleoindian technological change according to reduced inter-basin residential mobility. The model is evaluated using the distal ORB as a test case. As the Great Basin dried, people's total foraging territories expectedly became smaller and movements among basins became more restricted. This assumes that basin wetland habitats were subsistence focal points. Those basin wetlands that endured longer, such as the distal ORB, would have seen increased occupation by Paleoindian groups. As detailed in the next section, the distal ORB possesses a large-scale surface archaeological record that can be divided into two approximate time periods: one from 12,100 to 11,300 cal BP[1] and a subsequent other from 11,300 to 9900 cal BP. If use of the distal ORB intensified through time, then technological features representing high residential mobility, especially reduction strategies that maximize tool utility while minimizing tool size, should be more common in earlier sites and less common in later sites. Analysis of assemblages from the

[1] Calibrated radiocarbon dates are used in this study. These represent median calendar-year ages to the nearest 2σ using the IntCal09 curve in Calib 6.0 (Reimer et al. 2009). For general age estimates, an 80-year 14C standard deviation was assumed then the result rounded to the nearest 100 years for discussion. Reported radiocarbon dates from the ORB are provided in Chapter 2 and are calibrated using their true standard deviations.

Figure 1. Location of the distal Old River Bed and important Paleoindian sites in the Great Basin.

distal ORB support this prediction to indicate that this area did see more intensive use prior to its final desiccation about 9900 cal BP. This is interpreted as an important line of evidence supporting the deterioration and disappearance of basin wetland habitats as an important constraint on Paleoindian adaptation to the Great Basin.

Research Pertinence of the Distal ORB and Approach to this Study

The distal ORB study area (Figure 1) represents the distal portion of the larger ORB distributary delta that existed in the southern Great Salt Lake Desert at the Pleistocene-Holocene transition. This remote area has been protected by military range boundaries since the 1940s; thus, it was recognized only recently as a Paleoindian archaeological locality through cultural resource management surveys in the 1990s. Published efforts are limited to the 2000s (Arkush and Pitblado 2000; Duke and Young 2007; Duke et al. 2004, 2007; Oviatt et al. 2003; Rhode et al. 2005; Schmitt et al. 2007). The area has three primary traits that make it an exceptional test case. First, its location near the center of vast playa is farther removed from basin margins than anywhere else in the Great Basin (~30 km). This marks the distal ORB as a place where wetland habitat use was a certain focus, well away from upland areas and other alternative habitats. This distance also limits access to the preferred toolstones, for which the known sources are located 60 km away for fine-grained volcanics (FGV) and 90 to 175 km away for obsidian. What is additionally restrictive about these sources is that they are located in virtually all four cardinal directions from the study area—obsidian north-south, FGV east-west—making procurement directed at both material types problematic. The distal ORB should provide a record of extremes and an ideal place to study adaptive variability because settlement-subsistence decisions would have diverse techno-economic consequences.

Secondly, the distal ORB is big. As defined, the study area measures 200,000 acres, of which at least two-thirds can be considered viable as part of the old marshland at its maximum and may represent one third to one half of the entire distributary system extending from the south margin of the basin. This areal extent—the study area alone measuring roughly the size of the greater Salt Lake City metropolitan area—would swallow up most other estimated Great Basin wetlands at the time, providing a setting capable of sustaining comparatively long occupations. Combined with its remote location, the distal

ORB's size adds to its potential to exhibit the full range of variation in Paleoindian wetland use and technology. Artifacts can be found everywhere the distributary system is manifest.

Lastly, the distal ORB exhibits some chronological separation. While no directly dated cultural features have been found, numerous dates on organic deposits from the preserved wetland system provide a temporal structure to how Paleoindian use of the area could have shifted alongside the evolution of the distributary network. These dates provide a window of time between approximately 12,100 and 9900 cal BP that can be roughly divided into two units: an early one dating 12,000 to 11,300 cal BP and a later one dating 11,300 to 9900 cal BP. These time frames correspond with dates on distributary paleochannel groups that are located on the west and east halves of the study area, respectively, likely representing a shift through time in primary drainage output. These subareas are described in detail in Chapter 2.

Of further importance is that the earliest availability of the distal ORB to human use at about 12,100 cal BP post-dates the earliest Paleoindian use of the Great Basin by at least 1,500 years (Beck and Jones 1997, 2009). Far from being detrimental, this restricted temporal window represents a pivotal time near the close of the Younger Dryas climatic episode when paleoenvironmental data indicate that the decline of Great Basin pluvial systems ramped toward complete desiccation, perhaps as early as 9500 cal BP (Beck and Jones 1997; Hockett 2007). This great desiccation marks the end of the Paleoindian time period and its associated adaptive strategy. The distal ORB provides a glimpse of how human populations reacted to the change.

Research Approach and Theoretical Orientation

My general approach to this study is to identify evidence of long-term change through time in Paleoindian settlement and subsistence by examining patterns in lithic technology on the distal ORB. I have written elsewhere (Duke and Young 2007) that we should expect variability in Great Basin Paleoindian lithic technology to be expressed on any scale from seasonal/annual to across the Paleoindian time frame. The climatic volatility at the Pleistocene-Holocene transition was much greater than at any time since (Madsen 2002, 2007); thus, the flexibility to cope with habitat fluctuations should have been built into the technology. However, *if* Paleoindian adaptation centered on basin wetland habitats, and *if* the disappearance of these habitats represents the overarching trajectory of environmental conditions, then we should also expect that the full range of Paleoindian technological variation follows a long-term track representing people's ongoing adjustment to the decline.

Mobility provides the conceptual link between stone tools and the environment. It is well-established that hunter-gatherer lithic technology varies according to land-use priorities, which are sensitive to changing conditions in the ecosystem via people's reaction to corresponding changes in food resource structure. If Paleoindian groups were subjected to an ongoing loss of basin wetlands, then they would have had to intensify their use of those habitats that still existed, such as the distal ORB. This reduction in overall residential mobility should lessen reliance on the extended logistics and transport of stone tools, which should be evident on the ground in the form of different reduction strategies and raw material choices.

The rationale for this expectation comes from optimal foraging models in behavioral ecology. These are the subject of Chapter 3, but in short, they provide formal mathematical and graphical relationships in energetic tradeoffs between group movement and resource exploitation. For hunter-gatherers relying on patchily distributed basin wetland habitats, the most fundamental decision breakpoint in residential mobility is when to leave one patch for another. Obviously, loss of wetland options would represent a primary constraint on these decisions. This is a straightforward ecological correlation that serves as the primary basis for my technological analysis. More complex aspects of Paleoindian mobility and subsistence are the subject of debate among researchers in the Great Basin (e.g., Duke and Young 2007; Elston and Zeanah 2002; Jones et al. 2003; Madsen 2007; Pinson 1999, 2007; Smith 2010), and while an important aspect of this dissertation includes addressing these, my core goal is to establish a dynamic technological model that will yield further insight through application at other regional sites.

To this aim, the lithic analysis orients towards the *transport efficiency* of technology as an indicator of mobility priorities. Hunter-gatherers must coordinate the acquisition of raw material for stone tools with the sometimes incongruent demands of being in the right place at the right time to maximize food procurement. This is especially true of Paleoindian groups, who had larger territorial ranges than people later in prehistory (Jones et al. 2003; Smith 2010). Transport efficiency is defined as a cost-effective solution to maximizing tool utility while minimizing transport cost. Efficiency comes by minimizing unneeded mass throughout the reduction of stone tools, which directly translates into energetic savings.

This definition of transport efficiency is consistent with a behavioral ecological approach, where a specific currency evaluates the tradeoffs between decisions made according to certain constraints (Bird and O'Connell 2006). For Paleoindian groups in the Great Basin, the proposed constraint is the decline and loss of basin wetland habitats. When there were several wetland options, people should have put greater emphasis on transport efficiency to offset travel costs and reduce the need for unanticipated trips to gather toolstone. Transport efficiency should decline in importance when people rotate among fewer basins. With effectively reduced total foraging ranges, they would shift from being mobile more residentially among basins to mobile more logistically within them. This entails the tradeoff in lithic technology, where instead of taking on the production and maintenance costs of transport efficiency, toolstone can be transported in a relatively unrefined state and even stockpiled for ready use as needed at residences that are occupied for longer periods (cf. Parry and Kelly 1987; Surovell 2009). Even if people were residentially mobile within large basins, the longer the area served as a land-use hub, the more toolkits should lose transport efficiency owing to these tradeoff dynamics. The formal model used in this study is developed in Chapters 4 and 5, and more detailed technological expectations are provided later in this chapter.

Recent Perspectives on Old Objectives in Great Basin Paleoindian Research

The idea that the Great Basin's first inhabitants possessed an adaptation that eventually proved unsustainable reaches back to the earliest regional research. The situation of extensive lithic artifact scatters adjacent to the relict shorelines and dry drainages of long-dead distributary systems makes a profound statement against the now-desiccated backdrop. While this much seems obvious, these contexts are stubbornly unyielding when it comes to finding scientific evidence of their importance in people's lives. Were Paleoindian foragers inextricably linked to the productivity of Great Basin wetlands, or was this merely one aspect of a broader land-use strategy? This question continues to orient researchers.

The Interpretive Context of Paleoindian Studies: Data versus Theory

The Campbells' efforts in the 1930s (Campbell et al. 1937; also see Campbell and Campbell 1935) in the Mojave Desert of southern California brought the Great Basin Paleoindian record forward to archaeologists. They saw extensive scatters of artifacts at the highstand level of pluvial Lake Mojave, above what are now the dry lake beds of Soda and Silver lakes (previously fed by the now-desiccated Mojave River). Geologist Ernst Antevs worked with the Campbells at Lake Mojave and estimated that the cultural materials dated to the end of the last pluvial period when the lake began to regress.

Antevs (1948) provided the first explicit environmental model for change in human use of the Great Basin through time. His three-part sequence of "temperature ages" post-dating the pluvial period—the Anathermal, Altithermal, and Medithermal—was important to archaeologists for many years, with the Anathermal-Altithermal distinction being a primary point of contention (e.g., Jennings 1957). Antevs postulated that increased aridity and the disappearance of lakes by the Altithermal (~7000-4500 years ago; pre-radiocarbon era) made the Great Basin inhospitable to people, who likely abandoned the region before returning in the climatically friendlier Medithermal. Antevs' terminology is now outdated from an environmental standpoint, but the problem of the Altithermal remains for archaeologists. As decades of work continue to assert, the early to middle Holocene record is paltry to non-existent in some areas. By implication, the Great Basin's earliest inhabitants were doing something wholly different than those who came after them (e.g., Elston 1982; Elston and Zeanah 2002; Grayson 1993; Madsen 2002, 2007).

Between the late 1950s and early 1970s efforts to understand Paleoindian behavior in a broader sense were progressing quickly but spanned wide conceptual territory. The discipline of archaeology was transitioning from an emphasis on culture history to cultural process, and previous interest in tracing the age and geography of different artifact traditions was being supplemented by a desire to interpret these traditions according to their adaptive value to people in the Great Basin environment. Still, chronological information for the Paleoindian period remained limited, and these two approaches met awkwardly at times. Radiocarbon dating had then established the post-pluvial timing of the record to most archaeologists (see discussions by Beck and Jones 1997; Grayson 1993; Willig and Aikens 1988), but claims of earlier dates and cultures were not uncommon. Louis Leakey's dubious Calico Hills site—for which a touted Paleolithic component upwards of 200,000 years old was never demonstrated—provides the most extreme such case and highlights the uncertainty underlying some of the scholarly discourse.

Cultural ecological approaches addressed ethnographic models and the subsistence implications of a well-watered Great Basin. Jennings' (1957, 1964) "Desert Culture" concept projected the flexible hunting and gathering strategy observed ethnographically into the past. Rooted in Steward's (1938) observations of the early twentieth-century Paiute and Shoshone, Jennings contended that people always needed to be open to nomadic movements and sharing with their neighbors because the Great Basin environment is unpredictable. In his view, even in wetter and cooler times, the region was patchy, variable, and basically a forbidding desert. Jennings (1957) found a continuous record dating to earlier than 12,000 cal BP at Danger Cave, in western Utah, and thus was not convinced that Antevs' (1948) Altithermal was a great constraint on Great Basin residents.

Danger Cave sits on the margins of the Great Salt Lake Desert, however, and others have argued that this was not representative of much of the Great Basin, especially in the western and Mojave Desert portions. Warren and Ranere (1968) stated that although chronological control over surface sites remained elusive, there was, "…adequate evidence that the Desert Culture concept cannot explain the diverse cultural manifestations found in the Great Basin and the West at an early time period." These arguments foreshadow more recent regional debates where the absolute timing of activities does not necessitate refrain from discussing the large-scale behavioral patterning apparent on the desert's surface.

In this intellectual context, Bedwell (1970, 1973) proposed a wetland-oriented adaptation for early inhabitants that he referred to as the "Western Pluvial Lakes Tradition." Like Jennings, Bedwell's arguments were anchored by radiometric dates gathered from caves but meant to explain the broader regional surface artifact record. Dates from excavations at Fort Rock and Connley caves in south-central Oregon indicate the most intensive occupations somewhere between about 12,800 and 9000 cal BP, with a few equivocal dates earlier and several others that extend to 8000 cal BP; dated evidence then stopped and did not pick up again until more than 2,000 years later. Bedwell's interpretation was that as pluvial lake levels slowly dropped in the Fort Rock Basin, they eventually fell to an optimal point for humans where shallow lakes and distributary marshes became highly productive resource areas. Through this process, general warming and drying across the desert west would have focused the activities of both humans and animals, including large game, on lacustrine settings. Thus, people were actually refining an adaptation to an environment that was effectively set to expire on them.

This view diametrically opposes the coping flexibility that defines the Desert Culture, which Bedwell (1973:175) wrote, "…calls attention to similarities and ignores differences." Archaeologists at the time generally agreed and turned their interests toward the importance of big game hunting within this framework (e.g., Heizer and Baumhoff 1970; Irwin and Wormington 1970; Tuohy 1968, 1974; Warren and Ranere 1968; Watters 1979). Bedwell's argument was not explicit as far as the role of large game versus other resources in the wetlands, but he suggests that people relied more heavily on the latter as they came out of a more mobile hunting strategy in earlier times. Direct subsistence data remained nearly nil (Heizer and Baumhoff 1970), although stone tools (e.g., large knives, scrapers, and gravers) were viewed similar to those of hunting cultures elsewhere in North American (Tuohy 1974; Irwin and Wormington 1970). Moreover, there was the problem of what qualified as "big game"—did this connote Pleistocene species that became extinct about the time people entered the Great Basin, such as mammoth, camel, and horse, or did it also include ever-present deer, antelope, sheep, or perhaps bison (Heizer and Baumhoff 1970; Tuohy 1974; Watters 1979)? There was no consensus answer to this question.

These are the dawnings of a persistent problem whereby a lack of subsistence data and temporal control kept the debate couched in the adaptive aspects of various options. By the late 1980s, the tone had changed even more toward adaptive variability and the notion that any hard-line position promoting large-game hunting was bound to be wrong at its conception—people likely did both according to micro-regional factors that are not known (see Simms 1987, 1988). In a 1988 review volume, Willig and Aikens (1988:31; also see Willig 1989) harshly criticized any notion that Great Basin hunter-gatherers at the Pleistocene-Holocene transition were acting in a fundamentally different way than those who came later, stating, "But if we interpret the 'desert' less literally, and focus more on the basic concept—the inception of 'Archaic' broad-spectrum strategies—it becomes apparent that [the Desert Culture] still retains its original value and explanatory power." Simms (1988) argued similarly in the same volume, pointing out that hunter-gatherer subsistence in the Great Basin is best considered as a trajectory of strategies and technologies that are easily oversimplified when treated as sociocultural stereotypes. These are necessary and crucial perspectives that carry well into current evolutionary ecology-based research yet also shy away from distinguishing the unique aspects of Paleoindian archaeological patterning.

Recent Research

Recent studies have circled back toward the view that the earliest Great Basin foragers faced a unique environment and should not be considered analogous to later "Archaic" peoples (e.g., Elston 1982; Elston and Zeanah 2002; Jones et al. 2003; Madsen 2007). Important data from new cave excavations and theoretical insights drawing from optimal foraging theory are prevalent.

Excavations at Bonneville Estates Rockshelter and Paisley Caves are contributing a flurry of new data on Paleoindian chronology and subsistence (Goebel 2007; Goebel et al. 2007; Graf 2007; Gilbert et al. 2008; Jenkins 2007; Rhode and Louderback 2007; Hockett 2007;

Goebel et al. 2011). Bonneville Estates Rockshelter sits just above the Great Salt Lake Desert on its west side, essentially overlooking the ORB delta (Figure 1). More than 50 hearth features date the early deposits to between 13,000 and 9600 cal BP (Goebel et al. 2011). Flaked stone tools are accompanied by bone artifacts (needles, awls), cordage, and various macrobotanical and faunal dietary evidence. Hockett (2007) describes a faunal assemblages that includes sage grouse, artiodactyls (sheep), and grasshoppers. Rhode and Louderback (2007) describe various small seeds and cactus pads as part of the food record. The seeds, such as ricegrass, goosefoot, and dropseed, are often burned suggesting their presence in the diet. Intensive seed processing, as seen in the Archaic and evidenced by ground stone, is not observed in the rock shelter until 8400 cal BP.

Paisley Caves data are also still forthcoming, but Jenkins (2007; Gilbert et al. 2008) reports a series of 14 radiocarbon dates on human coprolites and extinct Pleistocene mammal bones (camel and horse) ranging between about 14,500 and 11,500 cal BP. The earliest end of this range would be the earliest in North America and remains the subject of scrutiny, but the dates generally align with the Younger Dryas and times pre-dating it. Protein residue from one of the coprolites indicates that bison was part of the paleo-diet (Jenkins 2007).

Ecology-based research centers on optimal foraging models and the driving energetic motivations behind residential movement. Both the models and actual subsistence data suggest that the focused big-game strategy often associated with Paleoindian foragers is not tenable. Paleoindian subsistence likely relied heavily on various plants, small mammals, fish, eggs, and waterfowl of marshlands, even if their residential mobility choices turned on the pursuit of large-game animals, such as deer, sheep, antelope, and maybe bison (Elston and Zeanah 2002; Madsen 1982, 2002, 2007; Simms 1987, 1988). Paleoindian foragers rarely, if ever, used ground stone, and there is certainly no evidence of this on the distal ORB.

Madsen (2007) applies the assumptions of a patch-choice model to argue that people using wetland habitats in a serial manner would always use the largest ones first and stay in them as long as they could, i.e., until return rates on resources fell below those generally expected elsewhere minus the extra traveling time. People would therefore be more mobile among basins when these patches were small and scattered as opposed to when they were larger. In the latter case, one exceptionally large marshland would reduce inter-basin settlement mobility in a foraging territory. It follows that fluctuations in expected returns across patches would also affect mobility. In good years, people may quickly move through patches extracting a boon of the highest ranking resources in their diet, while in bad years, they would intensify use of lower ranked resources. Thus, for Paleoindian foragers, a particular basin wetland of certain size and productivity did not represent a set caloric store taken before moving away was warranted; rather, subsistence returns would always be relative to other options.

Elston and Zeanah (2002) argue that the motivation for people to stay highly mobile among basins lay in their desire to maximize encounters with large terrestrial game. Adding consideration of the sexual division of labor, they suggest that most of the caloric intake would be provided by the near-residence, lower-ranking marshland resources primarily collected by women, while men pursued high-ranking game animals in upland areas. In this scenario, as long as lower-ranking resources provided dietary stability, basin to basin, then large-game abundance would drive the decision of when to move to a new basin. Put another way, the reliability of marshland resource base warranted the increased costs and risks associated with moving to pursue the added caloric payoffs of large game.

Pinson (1999) also sees the expanded wetland habitats of the Pleistocene-Holocene transition as a resource base, but argues that people relied on them for primary staples because the climatic variability of the times would have been detrimental to large game. Fluctuating large-game populations would have been unpredictable, and thus risky for people to maintain as a subsistence focus. This view does not address the high residential mobility that appears to characterize Paleoindian settlement, but it is consistent with the limited subsistence record that indicates the presence of small game and plant resources in the early diet.

The Elston and Zeanah (2002) and Pinson (1999) models both fall within the scope of optimal foraging theory, and thus there is the potential for both to be right depending on the circumstances. These views characterize the nature of debate in Paleoindian studies that centers on singular generalizations about an adaptive strategy which we still know little about. Any dynamic aspect that can be related to overarching constraints can be useful in recognizing how people's strategies could have varied, and how this variability should be manifest archaeologically. To the point of the current study, if the environment in which Paleoindian foragers developed and refined a specific adaptation to wetland habitats began to decline, then this should have predictable effects on Paleoindian land use and technology that can be observed archaeologically.

The Role of Lithic Studies

Lithic analysis has always been part of the Paleoindian discussion and is suited for studies of variability (Amick 1993, 1995, 1999; Beck and Jones 1990, 2009; Beck et al. 2002; Amsden 1935, 1937; Bryan 1980; Davis et al. 1969; Duke and Young 2007; Estes 2009; Goebel 2007; Graf 2001; Jones et al. 2003; Pendleton 1979; Rogers 1958; Tuohy 1970, 1974; Tuohy and Layton 1977). Much of this work has focused on typology, especially in earlier studies, but more technological assessments are not uncommon. Hunter-gatherer mobility remains of primary interest because the surface record is amenable to addressing the issue at a landscape scale (see Duke and Young 2007; Jones et al. 2003; Smith 2010). Such research can be highly benefited by identifiable change through time. Add geochemical sourcing studies, and there is a potentially sensitive record of behavioral variability on the ground surface.

However, some take issue with the use of lithic studies in Paleoindian research. Willig and Aikens (1988:28) complained regarding the Western Pluvial Lakes Tradition (WPL): "The term 'WPL' is now entrenched in the literature as a synonym for all Great Basin and California complexes containing stemmed points, regardless of their proximity to fossil lakeshores. The facile application of an economic (adaptation-based) term to technological (typologically-based) complexes is a dangerous leap to make, especially since we know that cultures possessing nearly identical lithic complexes in the Plateau and elsewhere were clearly not lake-oriented by any means." Commenting on the potential diversity of land-use strategies at the early end of the Pleistocene-Holocene transition, Grayson (1993:243) states with regard to the WPL, "…if the term can be said to apply well to anything, what it applies best to are not the stemmed point occupations, but the fluted point ones."

Lithic technology is not a direct indicator of subsistence, but it is distributed across the landscape in ways that are indicative of land-use priorities. We know that technology was sensitive to various microeconomic factors as people changed their location in step with fluctuations in the environment. Studies oriented toward reduction strategies and lithic resource use provide more of a dynamic element to Paleoindian lithic technology (e.g., Amick 1999; Beck and Jones 1990, 2002; Duke and Young 2007), but their lack of direct connection to ecological theory can be a limitation. For example, Beck and Jones (1990) find that Paleoindian toolmakers selected different types of stone for different types of tools—usually chert for tools that required toughness and flakeability and FGV for more heavy duty items. This has important implications, but when applied as a rule of thumb, it can be difficult to duplicate in places where alternative varieties of toolstone are available or different technological strategies are in order.

Formal Modeling of Lithic Reduction and Analytical Approach

A better theoretical connection between lithic data and prevailing ecological constraints is needed. As mentioned earlier in this chapter, behavioral ecology provides a formal platform on which to model and evaluate lithic data. For this study, basin wetlands are assumed to be core habitats for Paleoindian peoples. The paleoenvironmental trend indicating that these areas degraded and effectively vanished as early as 9500 cal BP can be used to gauge residential mobility via the relative duration of occupation at different times. While it is unquestioned that other areas were not off limits to Paleoindian groups, the perspective here is that their exploitation follows secondarily from that of basin wetland habitats.

For Great Basin Paleoindian technology, this issue can be addressed by looking at the differential investment placed on bifaces. When concerned with the transportability of tools brought on by high residential mobility among several basin, Paleoindian toolmakers should have taken care to thin bifaces, minimizing unneeded mass in the tool midsection, and designing them to generate smaller and/or different tools through a sequence of reduction. Alternately, people staying in a select few basins for longer periods could simply generate suitable flake blanks and roughed-out bifaces alongside a shifting priority toward providing needed stone to a reliable location of use.

My analysis follows from a model developed in Chapters 4 and 5 that centers on the various costs, benefits, and tradeoffs of these reduction options. This formal approach is gaining traction in lithic studies because reduction relationships can be described mathematically using physical properties (e.g., Kuhn 1994; Prasciunas 2007; Surovell 2009), and integrated into formal models of cost-effectiveness and risk that are analogous to those used in optimal foraging theory (e.g., C. Beck and Jones 2009; R. Beck 2008; Elston 1990, 1992; Elston and Brantingham 2002).

Both typological and technological differences are targeted. The distal ORB exhibits distributary branches that appear to date to earlier and later ends of a mid- to post-Younger Dryas time range of about 12,100 to 9900 cal BP. The distribution of Great Basin Stemmed (GBS) and Pinto projectile point styles provide the crucial typological connection to finds from other parts of the Great Basin. The typology used in this study is compared to other collections to assess its validity. From this, it is possible to associate technological patterns, which are less comparable to published data.

The technological model predicts responses to cost and risk in reduction strategies, centering on the concept of transport efficiency (cf. Kuhn 1994; Surovell 2009). The key distinction is established between how people made tradeoffs between the use of thin bifaces or transportable flake blanks. Bifaces are often assumed to represent mobility, but this is a very general class of artifacts and there is much that can be learned from differences in how they are flaked (Duke and Young 2007; Duke and Haynes 2009; Prasciunas 2007; Surovell 2009). I examine bifaces according to how much investment is put into thinning (i.e., making them proportionately thin through controlled flaking on either face) versus the transport of already-thin flake blanks that can be roughed out into bifaces or otherwise. The distal ORB is appropriate for this kind of analysis because its distance from toolstone sources removes the bias of low-cost production from immediately available stone. The microeconomics of how choices are made between these reduction strategies are specified in the model and can thereby be linked to broader ecological considerations.

Terminology and Study Organization

Use of the Term "Paleoindian"

The term "Paleoindian" has fallen out of favor among Great Basin archaeologists owing to concerns that the apparent broad-spectrum diet of early people tends more toward Archaic adaptations than those usually ascribed to the Paleoindian lifeway (i.e., big-game hunting, especially of now-extinct Pleistocene megafauna) (Beck and Jones 1997; Elston 1982; Simms 1988; Willig 1989; Willig and Aikens 1988). Elston (1982; Elston and Zeanah 2002) offers "Pre-Archaic" to reflect something in-between but distinctly different from the Archaic, when people began to more diversely exploit the Great Basin and use intensive seed processing. The label "Paleoarchaic" has come into accepted use of late and was originally proposed by Willig (1989; also see Willig and Aikens 1988) to frame early strategies as the foundation for later traditions. Beck and Jones have used this term in several seminal works since the 1990s (Beck and Jones 1997, 2009; Jones and Beck 1999; Jones et al. 2003).

A recent volume titled *Paleoindian or Paleoarchaic?* (Graf and Schmitt 2007) contains several papers in which the issue is addressed, although in few direct ways. Madsen (2007) cites the lowland habitat preference, lack of Pleistocene megafauna use, and the likely broad-spectrum diet used by early peoples to maintain use of the term Paleoarchaic, and this is the term researchers have tended to default to, including myself (e.g., Duke and Young 2007). Haynes (2007) argues, however, that there is much about the earliest Great Basin foragers that resembles North American Paleoindian traditions, such as sophisticated technology using high quality stone and a lack of ground stone and corner-notched points.

With due respect to the alternative terminology, I use "Paleoindian" in this study. There still seems to be no demonstrated reason why any alternative label must be made, unless solely on the premise that extinct Pleistocene megafauna were not the target diet. This likely was not the case, although recent data from Paisley Caves (Jenkins 2007) and the Sunshine Locality (Beck and Jones 2009) provide close stratigraphic relationships for cultural material and extinct camel and horse. Even if such animals were not encountered and emphasis was on more-familiar large game, such as deer, elk, or bison, such a single-driven resource focus is unlikely to represent the past. Surely, early people had broader diets—they would have needed them from a nutritional standpoint (Hockett 2007, 2009)—but the adaptive pattern, regardless of how well we can yet explain it, still seems distinctive from that of Archaic groups that moved among various upland and lowland habitats and incorporated intensive seed processing into their adaptation (Elston 1982; Grayson 1993). My perspective in this study comes from the distal ORB, where there is no evidence of intensive seed processing—i.e., there is no ground stone—against an extensive early record. Such associations may exist in the Great Basin but remain to be demonstrated for all but perhaps the latest end of the Paleoindian period in some places (see discussion by Beck and Jones 1997).

Chapter Organization

Eight chapters follow this introduction, beginning with detailed chronological and geoarchaeological context for the distal ORB delta in Chapter 2. Chapter 3 focuses on the theory and various ideas related to the use of wetland habitats by Great Basin hunter-gatherers. The research design for the lithic analysis is presented in two parts in Chapters 4 and 5; Chapter 4 describes lithic technology to overarching risk factors in stone tool design and the physical constraints of stone reduction, and Chapter 5 emphasizes the microeconomics affecting lithic technology during use. The end of Chapter 5 offers expectations for lithic assemblages according to these factors. Chapter 6 presents methods and materials detailing the source of my collections and how artifacts were analyzed; this includes descriptions of different tool types and the various quantitative and qualitative attributes I used to address my expectations. Chapter 6 also contains some analytical data related to my classification system for GBS artifacts. I present my analysis results in Chapters 7 and 8, which focus on temporally diagnostic tools (i.e., GBS and Pinto) and whole assemblages, respectively. I discuss my findings in the final chapter, Chapter 9.

CHAPTER 2

CHRONOLOGY AND CONTEXT OF THE DISTAL OLD RIVER BED

The modern setting of the Great Salt Lake Desert bears little resemblance to the wetland environment present when the ORB distributary system was active. Remnant distributary channel features attest to an area measuring over 1,000 square kilometers, within which an associated archaeological record can be found nearly throughout. Drainage from Fish Springs, the Cedar Mountains, and the Deep Creek Range may have contributed to an even larger area, but this has yet to be explored. Encircling the total extent of remnant geomorphological features surely over-represents a system which would have shifted and fluctuated within this space, but it serves to express the large scale at which human activities played out in the largest endorheic basin in the desert west.

My study focuses on a 200,000-acre (825 km^2) block area overlaid on the distal portion of the ORB delta, near the center of the southern Great Salt Lake Desert (Figure 2). With the small exception of the Wildcat Mountain, the area is as far from substantial mountain uplands as anywhere in the Great Basin. From the study area boundaries, the Cedar Mountains 20 km to the east are closest, and the Deep Creek Range is 30 km to the southwest. Granite Peak is 20 km to the south and is largely bare. The minor Knolls and Grayback hills extend from the northeast corner of the study area. The early archaeology is largely unmixed with later-period material, as people had little reason to visit the distal ORB once it disappeared.

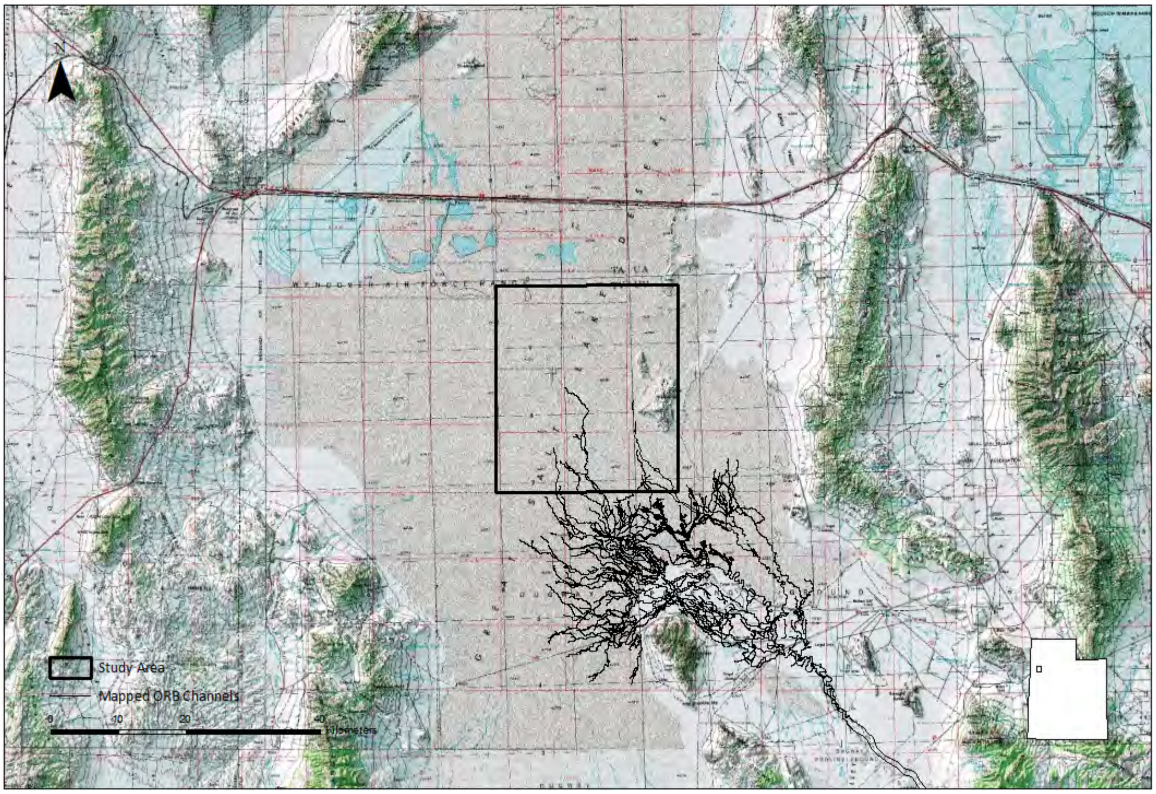


Figure 2. Overview of the study area showing mapped distributary channels from Madsen et al. (2011).

The study area shown in Figure 2 is located within the U.S. Air Force-managed lands of the Utah Test and Training Range (UTTR). My work has focused here since 2001, largely via contract archaeology for Far Western Anthropological Research Group, Inc. (Far Western). The south study area boundary lies on the shared border with the U.S. Army-managed Dugway Proving Ground (DPG), which extends over 30 km to the south and encompasses the proximal portion of the delta. A team of archaeologists from Desert Research Institute (DRI), led by Dr. David Madsen, have worked extensively in this area. Collaborative efforts have proven valuable to understanding the geochronology of the system as a whole, and radiocarbon dates and geomorphological data are now summarized in an as-yet unpublished synthetic document by Madsen et al. (2011; also see Oviatt et al. 2003; Oviatt et al. 2005) upon which much of the following discussion is based.

While the military boundary is arbitrary, it proves an effective break point between distal and proximal portions of the ORB delta. My study area lies in the distal region which contained braided networks of low-energy sand channels that are now difficult to track. High-energy gravel and coarse sand channels were more restricted to the proximal delta. Evidence of their position on the landscape is more definite, with efforts at mapping by DRI archaeologists stopping roughly at the UTTR-DPG boundary. This does not represent a limitation on wetland potential in the distal region, which would in fact be enhanced in a network of slow-moving streams and ponds, nor does it mean that similar conditions did not exist at different times in the proximal delta. It does indicate, however, that at times when the distributary system was highly active, prominent channels and streams were largely restricted to the proximal delta. This aspect has implications for both the chronology and archaeology of the area, as described below.

Chronology of the Old River Bed and its Delta

Overview of the Old River Bed

The "Old River Bed" (ORB) refers to an eroded, USGS-mapped dry-drainage approximately 40 km long that connects the Sevier basin, in the Delta, Utah vicinity to the Great Salt Lake basin. The ORB delta represents the network of stream channels splayed across the southern Great Salt Lake Desert, where the river debouched into the open basin. The ORB formed when Lake Bonneville dropped from its Provo shoreline level during the Bølling-Allerød interstadial to below a threshold where it separated from waters in the Sevier basin. The decoalesced Sevier basin lake—Lake Gunnison—began to overflow northward at that time or shortly thereafter, entrenching a narrow valley (see Figure 2).

The de-coalescence of the lakes could have taken place as early as 14,600 cal BP (Godsey et al. 2005; Oviatt 1988; Oviatt et al. 2003), but it is not known if overflow lasted long, as Lake Gunnison also appears to have regressed below the threshold (Charles Oviatt, personal communication 2011). Madsen et al. (2011) estimate that Lake Bonneville could have dropped onto the floor of the Great Salt Lake basin by about 13,400 cal BP, at which point portions of the ORB distributary delta could have formed if water was being discharged into the system. However, if Lake Gunnison also regressed below its threshold then this water would have had to be groundwater from the basin margins rather than from ORB river flow. Thus, it is possible that there were streams after 13,400 cal BP, perhaps in narrow channels extending all the way north to the regressed extent of Lake Bonneville—but little evidence of this exists—or that the ORB delta was not being formed in any substantial way prior to the beginning of the Younger Dryas at about 12,900 cal BP, as detailed in the next section of this chapter (Madsen et al. 2011). Figure 3 summarizes these relationships.

The Old River Bed Delta and Paleochannel Chronology

A rough chronology for the ORB delta archaeological record can be derived from the dating of the distributary system, as no dateable cultural features have been found. As mentioned, DRI researchers working south of the study area have made extensive efforts to map the prominent paleochannels. Combining aerial imagery, surface ground-truthing, and targeted backhoe trenching, they have established primary cross-cutting relationships and gathered numerous radiocarbon dates on organic remains to anchor the relative ordering

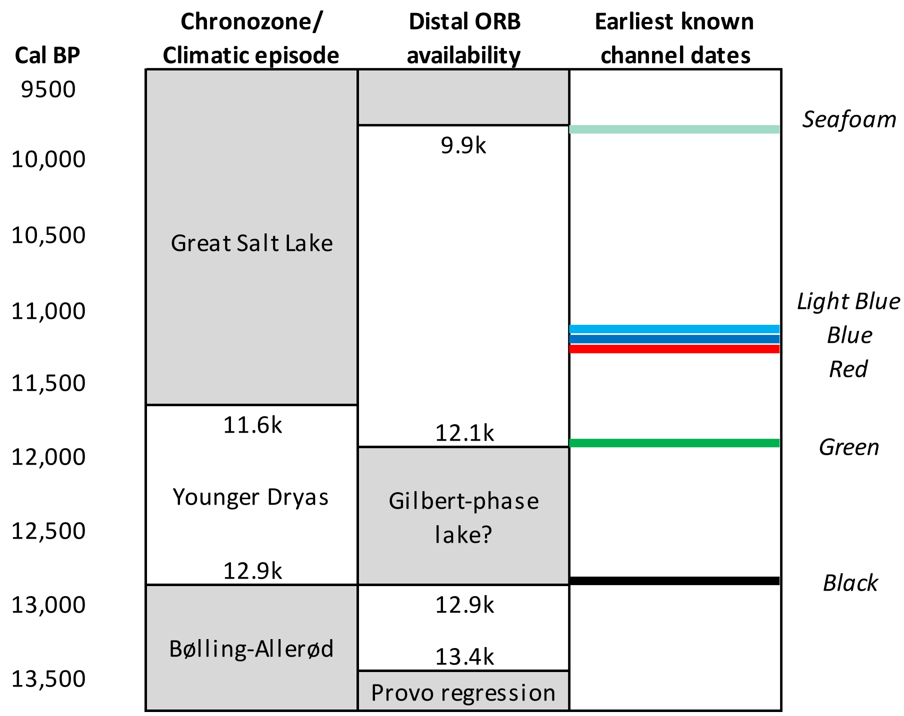


Figure 3. Estimated geochronological relationships related to the distal ORB delta. In the Distal ORB Availability column, white areas represent times when the distal delta portion could have contained distributary wetlands based on existing black mat dates and geomorphological interpretations from Madsen et al. (2011). The duration of a Gilbert-phase lake remains unknown, and the 12,900 to 12,100 cal BP range shown above should be considered a maximum. Earliest known dates for the relevant color-coded paleochannels are shown in the third column. All of the date assignments in this figure are approximate and thus only represent a general representation of events.

of the channels. From this, geomorphological evidence from my study area can be traced "upstream" with some confidence to provide a working chronology for the archaeological record.

Figure 4 shows the mapped channels for the ORB delta according to color codes indicating their overlapping relationships, as defined in Madsen et al. (2011). A typical view of the landscape is provided in Figure 5. The color-coded channels represent those that are most prominent, i.e., indicative of relatively high-energy flow. A complex network of

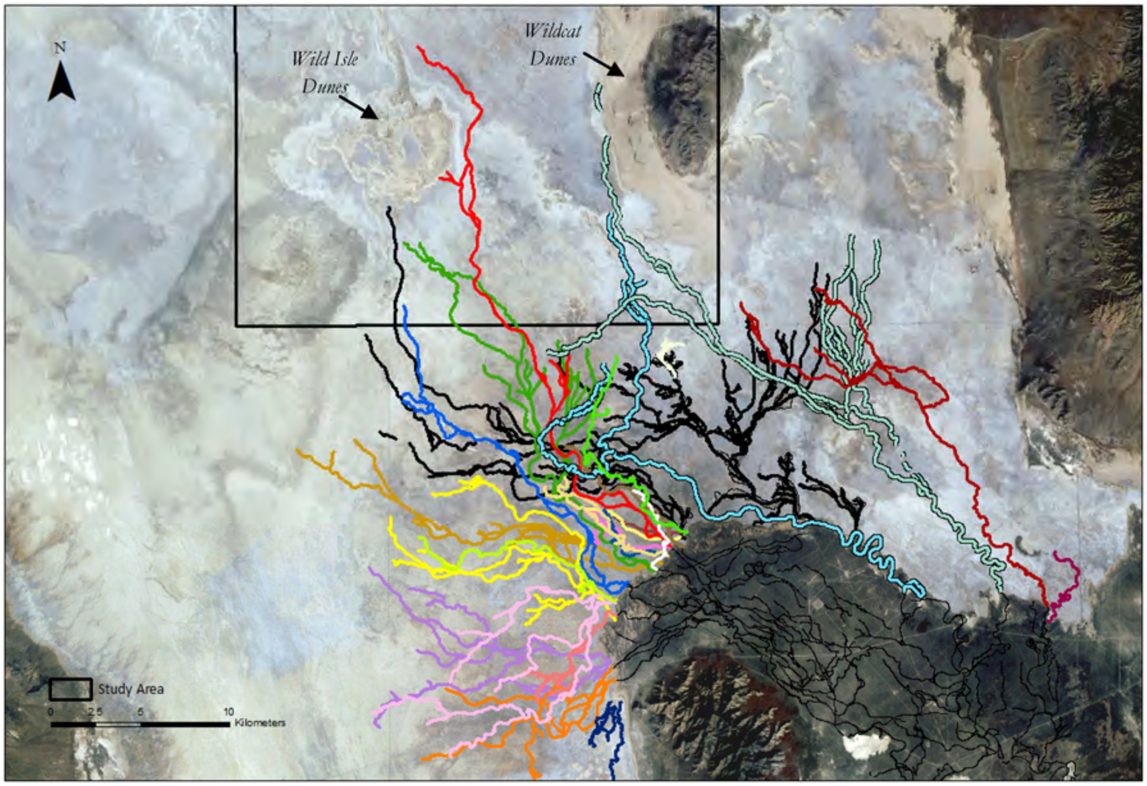


Figure 4. Color-coded paleochannels of the ORB delta as described by Madsen et al. (2011). Each color represents independently-defined channel tracks. Cross-cutting relationships are represented by overlapping lines, but not all lines overlap.

unmapped, ephemeral and/or eroded channels can also be found among the color-coded channels and well into the distal ORB study area. The extent to which the mapped distributary system is representative of how water moved through at any given time is unknown, but the cross-cutting relationships imply that when the prominent channels flowed, only some of the numerous stream tracks we can now identify represented main arteries.

Figure 5. Mudflat environment east of Wild Isle Dunes. The dissected terrain owes to the differential deflation between lake-bottom sediments and sand and/or gravel-filled paleochannels. The channels can vary between being partially intact and entrenched, as shown above, or topographically inverted with the erosion-resistant channels and levees sitting above the more rapidly deflating mudflats.

As described above, there is a general window for channel formation between 13,400 and 9900 cal BP, but geomorphological work further restricts the early side of this time frame to approximately 12,900 cal BP. This is substantiated by 43 radiocarbon dates on organic sediment and plant remains collected on the delta so far; these are charted in Figure 6. The potential must exist for distributary flow between 13,400 and 12,900 cal BP based on the pre-Gilbert lake channels and slack-water deposits seen in trenches, but there is only sparse evidence for this. The earliest date seen on the ORB delta of 13,300 cal BP (Figure 6:Beta-131590) is regarded as unreliable by Madsen et al. (2011) because it was collected in channel

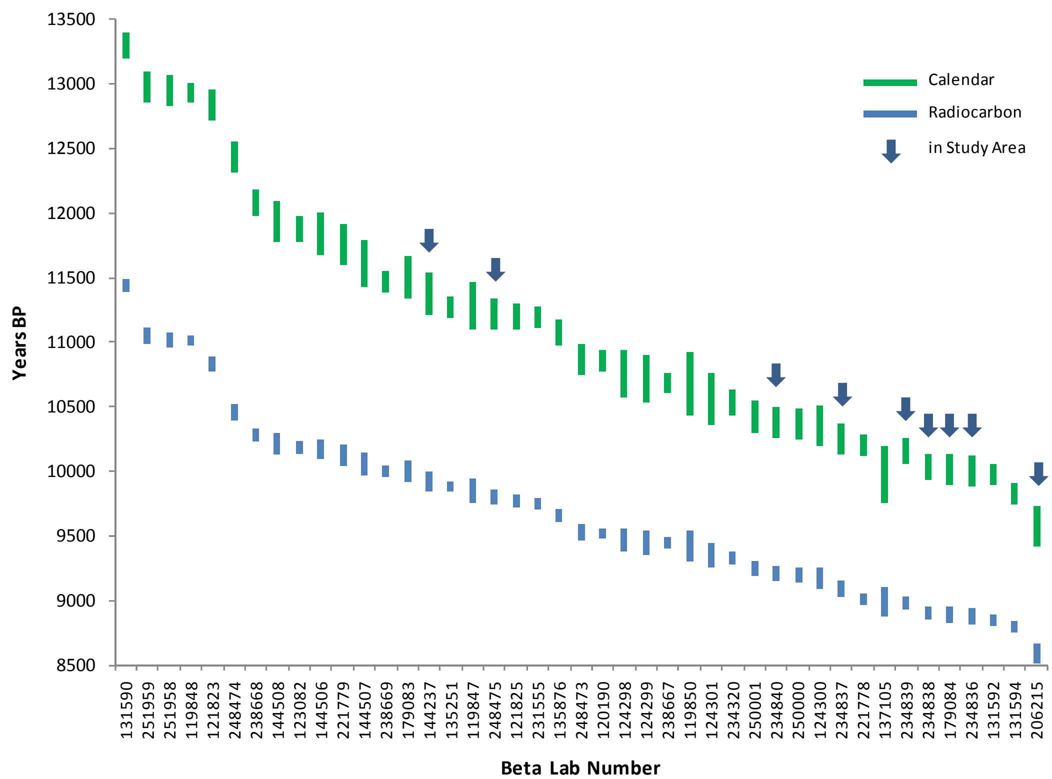


Figure 6. Radiocarbon and calendar year dates from 43 samples of plant material or organic sediment collected on the ORB delta, from Madsen et al. (2011). The calibrated dates represent median ages to the nearest 2σ using the IntCal09 curve in Calib 6.0 (Reimer et al. 2009).

fill alongside four other dates ranging between 11,900 and 11,000 cal BP (Figure 6:Beta-135876, -144506, -144507, -144508).

The mapped channels represent periods of higher-energy flow into the basin, most of which do not appear to have been controlled by fluctuating lake levels—i.e., the distributary system did not necessarily reach a lake margin at all times. The only exceptions to this are the "Black" channels, which exhibit bulbous ends indicative of overbank deposits generated during lake transgression back toward these features. The Black channels are among the oldest on the ORB delta, with two dates of roughly 12,900 cal BP (Figure 6:Beta-251958, -251959) collected by DRI on organic sediment underlying the northernmost Black channel. These channels could not have formed before this time, with a date of 12,100 cal BP (Figure 6:Beta-238668) on the Green channel, which crosscuts the Black channel, just prior to which must be the latest time for their formation. This range is interpreted by Madsen et al. (2011; also Oviatt et al. 2003) to correspond with lake fluctuations during its Gilbert phase, when levels rose following an intense regressive period, during which it may have retreated to almost the current level of the Great Salt Lake (Broughton et al. 2000; Madsen et al. 2001).

An important point to this discussion is that a Gilbert-phase lake likely covered the distal ORB study area during some amount of time between 12,900 and 12,100 cal BP (see Figure 3) while only the proximal ORB delta would have been available for human occupation. A Gilbert-phase lake likely did not persist for this entire 800-year period (Madsen et al. 2011) and could have existed for a substantially less amount of time (Charles Oviatt, personal communication 2011). Also, even during a generally stable lake phase, fluctuations could have brought levels back into the study area for brief periods prior to 12,100 cal BP. These possibilities notwithstanding, the best interpretation of the channel dates and physiography of the distributary system as a whole is that there is more limited potential for Younger Dryas-age archaeological sites on the distal ORB than in the proximal delta.

Evidence from the Distal Old River Bed Delta

Six of the 23 DRI-mapped paleochannels extend into the distal ORB study area, and their dating and distribution indicates that they can be grouped into earlier and later

Figure 7. The study area showing mapped paleochannels and Paleoindian sites on the distal ORB delta.

manifestations of the distributary system, roughly corresponding to southern Wild Isle and Wildcat Dunes, respectively. These are shown in Figure 7, with the Black, Blue, Red, and Green channels draining into the west side of the study area at Wild Isle Dunes, and the Seafoam and Light Blue channels to the east alongside Wildcat Dunes; the White channels are separately mapped by Dr. D. Craig Young, Far Western, who has served as the geoarchaeologist on all efforts in the study area. Paleoindian sites can be found along these channels, in and adjacent to large dune fields anchored by the remnant channel features. Archaeological surveys indicate the realness of these distributions (see Methods chapter), and that few sites and little wetland evidence is present in the open mud flats.

Little is known about the nature of the distributary system in Knolls Dunes area, and it may represent separate flow from the ORB originating to the east in the Cedar Mountains. If so, at their maximum extents the two distributary systems would meet north of Wild Isle Dunes. This seems plausible from the aerial imagery and limited archaeological surveys, but closer examination is necessary.

West Channel Group. The western channel group is indicative of earlier distributary wetlands in the distal delta, beginning about 12,100 cal BP, but possibly as early as 12,900 cal BP. The Black channels were discussed above, and represent a more complex network than the other mapped channels, fanning out across the proximal delta (see Figure 4), likely in response to a fluctuating Gilbert-phase lake margin. Madsen et al. (2011) report a date of 12,900 at the terminus of one of the Black channels on the proximal delta, and Black channels cut across the Mango and Mocha channels (two of the three oldest observable channels on the proximal delta, alongside Gold), which they argue date as early as 13,200 cal BP. Thus, the channel extending into the study area could represent either a temporary retreat of the Gilbert-age lake northward between 12,900 and 12,100 cal BP or the final retreat of the lake at about 12,100 cal BP. This single Black channel could also be unrelated to the more proximal main branches (David Madsen, personal communication 2011), but it is cut by the Blue channel described below.

The Green channel provides the late-limiting date on the Black channels of 12,100 cal BP. Madsen et al. (2011) suggest that it flowed until 11,500 cal BP (Figure 6:Beta-238669) based on the association of the dates with *Anodonta* shell and small fish bones, indicating flowing water.

The Red channel is difficult to distinguish from the Green by cross-cutting relationships and the two may be related (Madsen et al. 2011). A single date of 11,200 cal BP (Figure 6:Beta-248475) comes from black mat sediments on the channel surface, just inside the study area.

There is no point where the Blue channel crosses the Green or Red channels, but it does cut through Black. Three dates from black mats in the channel fill (Figure 6:Beta-231555, -248473, -238667) that overlap when calibrated put the initiation of this channel at about 11,200 cal BP. The fill dates should post-date the initiation of the channel but indicate marshy conditions and low surface flow continued to about 10,800 cal BP.

The White channels are described by Young (Madsen et al. 2011) as a set of low-energy sand- and silt-filled meanders that tend not to be as prominent as the DRI-mapped channels. White-channel features are ephemeral but have been tracked through dune blowouts on the surface and via backhoe trenching. These appear to branch off of or continue from the Red channel in a few places, and a notable point of divergence appears just into the east side of Wild Isle, where a date of 11,500 cal BP (Figure 6:Beta-179083) was collected on a black mat layer that is cut by the primary channel. From here, a further network of small channels extends toward the north and west. A date of 9900 cal BP (Figure 6:Beta-179084) was collected from a black mat on the north dune arm of Wild Isle along the main White channel, suggesting a later time frame for the wetlands in this part of the dune field.

Together, the west channels suggest a time frame for stream flow between about 12,100 and 11,200 cal BP, immediately following recession of a Gilbert-phase lake that previously covered the study area. Later dates from channel fill may indicate that marshy conditions in the southern Wild Isle vicinity continued to perhaps 10,800 cal BP. Dating of the various White channels underlying Wild Isle Dunes remains unknown, but Paleoindian sites correspond to them (see Figure 7; Hirschi 2006), and it should be expected that the wetlands would be optimal for human use when flow was robust.

East Channel Group. The Seafoam and Light Blue channels compose the east channel group, and represent stream flow toward the west fan of Wildcat Mountain. Madsen et al. (2011) report five dates ranging between 11,300 and 9900 cal BP (Figure 6:Beta-119847, -124298 to -124301) on organic material from the Light Blue channel, but these are from the proximal part of the delta to the south where it enters the mudflats. These dates are over 30 km up the mapped channel from its northern extent, and Madsen et al. (2011) note difficulty in tracing through the dunes. Thus, dating on the Light Blue channel remains tenuous, but its general track is more similar to that of the Seafoam channel than the other mapped channels.

The Seafoam channel combines with the Rust channel to define the easternmost edge of the mapped ORB delta, but only it can be seen to extend into the study area. Chronology on the Seafoam channel comes solely from within the study area at one of the analyzed sites—the Cache Site—indicating that it flowed variously along the west margin of what is now Wildcat Dunes between approximately 10,400 and 9900 cal BP, as described in the section on the excavations below.

Early-Middle Holocene Dune Formation and Site Formation Processes

Dune formation appears to have begun immediately following the desiccation of the distributary system, if not earlier in some areas. The xeric conditions and salinity of the area would have limited the development of grasslands or other entrenched vegetation beyond emergent saltgrass fingers along still-damp channels. Aeolian forces on the newly exposed ground surface would have rapidly moved loose sediments from the sandy channels and deposited them at catch-points (old channel levees, Wildcat Mountain alluvium, etc.) that would ultimately build and merge into large dune fields. Deflation of the lakebed surface would have accelerated with the broadened exposure in such a large basin. Prevailing winds are westerly, and this is evident in the morphology of the dunes (see Figure 7). My review here largely follows Young (2008; also see Madsen et al. 2011), and focuses on several factors that support this characterization.

The dunes are anchored by the ORB distributary system, which provided the original topographic relief in the form of channel swales, levees, etc. While the dunes have evolved and diminished, their occurrence alongside the archaeology is not coincidental, but rather both mark the rough extent of the ancient system. Where the dunes are present, they protect and preserve this system. This is most apparent at Wild Isle Dunes (Figure 8), where the entire landform is pedestaled above the surrounding mudflats. Alternating blowout areas contain archaeology eroding out of the dune sides, sometimes in the vicinity of old marsh sediments, or black mats, doing the same. Madsen et al. (2011) estimate that several meters have eroded from the playa surface since the early Holocene, and Young

Figure 8. View south from Wild Isle Dunes toward Granite Peak showing blowout mudflats alternating with low stable dunes covered with saltbush.

(2008) notes at least three centimeters of deflation at experimental locations within the study area in just a year and a half.

Young (2008) proposes that the current dune fields represent a sequence of at least four dune-building periods that are currently undated. Dunes 1 and 2 are the earliest and can be difficult to separate. Both are characterized by silt cores that would have formed as soon as the basin began to dry and fine channel sands were exposed. Dune 1 sometimes contains aquatic snail shells and black mat sediments that suggest it may have formed prior to inundation by a Gilbert-phase lake or perhaps formed alternately with the distal ORB delta as dry and wet conditions fluctuated. It is Dune 1 that exhibits the closest association with the archaeology, and the areas of potential for stratigraphic relationships, where it is

Figure 9. Late Holocene dunes (i.e., "Dune 4") at Wildcat Dunes as viewed looking southeast toward Wildcat Mountain in the distance.

exposed at the dune-playa interface. Dunes 2 and 3 represent further middle Holocene dune formation that became stabilized and covered with vegetation. This largely characterizes Wild Isle Dunes (Figure 8), and a small dune field referred to informally as "Lone Dunes" (see Figure 7). Dune 4 consists of fine to coarse sands and represents the highly active, non-stabilized dunes that are dominant at Wildcat Dunes and Knolls Dunes (Figure 9).

Playa Processes and Surface Archaeological Integrity

Since the distal ORB began to dry, natural processes have been acting on the archaeological assemblages and continue today. Primary among these is wind. Where dunes did not form, the surface has been deflating at a quick pace. The Great Salt Lake Desert sits in the largest drainage basin in the Great Basin where aeolian processes can operate at an extensive scale.

Also, unlike other hardpan dry lakes in the region, the playa of this basin consists of moist to dry mud flats thinly covering a high water table. During wet periods, variable sizes of shallow ponds can form several inches deep, where there are low points on the playa surface. The Great Salt Lake may have even inundated the area at times during the late Holocene.

Young (2008) conducted a short-term experiment within the study area that provides some insight into how these processes work. He set up six locations between Wild Isle and Wildcat dunes where he placed a rebar datum and six "artifacts" made from glass at 20-cm intervals from the datum. The glass items ranged in maximum dimension from four to eight centimeters in size and are generally bifacial. A cluster of small flakes, with each flake less than two centimeters in size, was placed at one of the test locales. For a roughly 1.5-year period between 2005 and 2007, the sites were visited every four to six months and measurements from the rebar datums were taken. Movements of at least 30 cm on the non-flake items were documented at each test locale, but most artifacts did not move at all. Those that did move experienced this movement within the first four months of their placement. All moved in an easterly direction consistent with the prevailing winds.

Young interprets these findings as indicative of a punctuated process by which artifacts can be transported. In relatively short order, objects can become encased in the precipitates that develop on the mudflats, securing them in place. Prior to this, they are subject to relatively quick movement from the wind and, likely, wet conditions on the surface that can facilitate its effects. He also notes deflation of the playa up to three centimeters in some places, as measured from marks on the rebar datums. Precipitate-encased items were sometimes pedestaled above the surface. A complex of processes can be seen to operate on artifacts where movement might be substantial between periods of stasis. Artifacts may sit perched until deflation is extensive enough for a collapse, at which point the artifacts would be mobile again until the process repeats. According to the timeline of this experiment, this could happen hundreds or thousands of times depending on the context and duration of time since deposition.

Artifacts could theoretically proceed across the playa over time according to these findings, but there is no indication of this in the study area. The ORB delta provides an undulating to markedly variable terrain that keeps artifacts close to their original locations. Surface Paleoindian sites in the study area are therefore not substantially displaced horizontally, although their boundaries and the arrangement of artifacts within them must be considered approximations.

By contrast, flakes can be small enough to become completely moved by the wind-related processes. In Young's (2008) experiment, most of the flakes exited the test locales early. It is unlikely that wind by itself removes anything but the smallest flakes from the surface, but as wind speed increases larger sediment grains become mobile and initiate the movement of larger objects by hitting against them (Carter et al. 2004; Maiklem 1968; Reid et al. 1995; Sharp and Glazner 1997).

I examined this issue in 2004 using archaeological data collected during test excavations at 22 sites at Wild Isle Dunes (Carter et al. 2004). Most of the sites are included in the current study and are found in one of three primary settings: 1) east, or leeward, side of peninsular dunes extending from the main body of Wild Isle; 2) west, or windward, side of peninsular dunes extending from the main body of Wild Isle; or 3) within the blowouts of the main body of Wild Isle.

Leeward sites consist of lag artifacts from sites that remain largely intact but suffer from relatively recent exposure from the dunes. Smaller items, especially flakes, have blown away, while larger flakes and tools remain generally in place. The flake-to-tool ratio at these sites is 1.2. Windward assemblages contain a larger proportion of small artifacts, wind-rowed up against the dune face. Such concentrations extend linearly along the dune arms extending north and south from the main body of Wild Isle, and only large items extending out onto the playa can indicate human activity areas. The flake-to-tool ratio at these sites is high at 13.8. Finally, sites within the Wild Isle dune field retain the greatest horizontal integrity because they are more protected from the wind. They exhibit a flake-to-tool ratio of 10.6. These dunal sites also contain flake sizes that fall between those of the leeward and windward sites, as shown in Figure 10. A chi-square comparison shows a statistically significant difference between the 1/4-1/2″ and 1/2-1″ size grades at a five percent significance level (χ^2=25.9, df=2, p=<.01).

The focus of the current study is on tools only, so these factors are not expected to have significantly affected the analysis. More suspect are the boundaries used to delineate sites, which may group some assemblages, but it appears that sites are generally representative of their original location.

Geoarchaeology at the Cache and Com Sites

Two sites—the Cache (42To2622) and Com (42To1016) sites—were excavated in the summer of 2007 in an effort to clarify stratigraphic relationships between archaeological materials

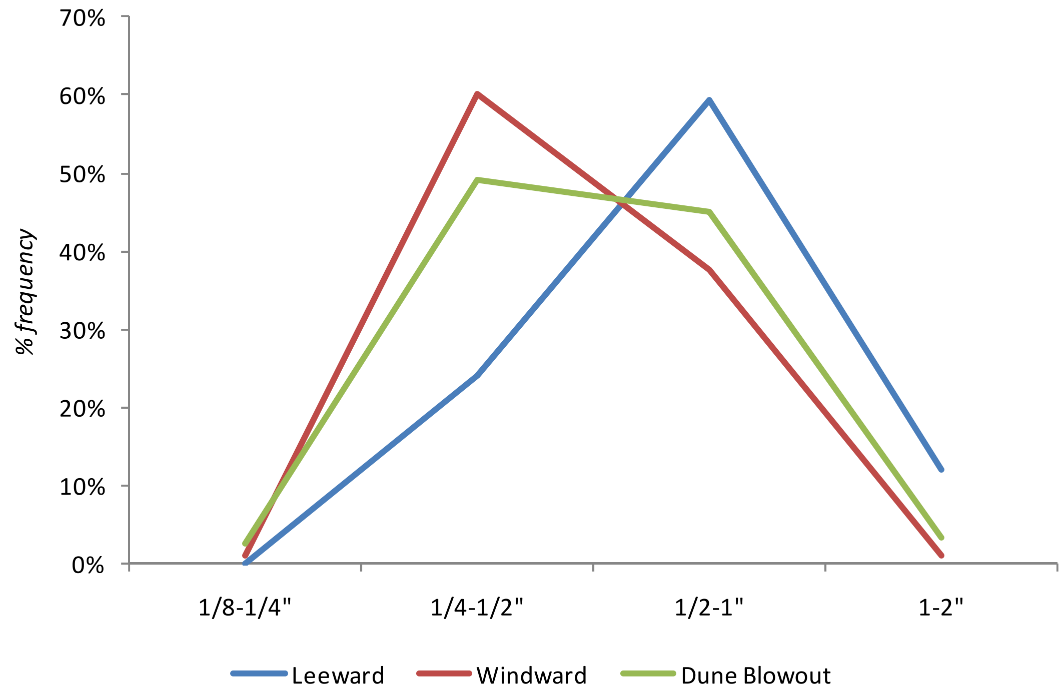


Figure 10. Flake size profiles for debitage based on relative position to Wild Isle Dunes.

and preserved wetland sediments (Figure 7). The work was conducted under UNR's Sundance Archaeological Research Fund. Distal ORB buried site potential lies in preservation under the stable dune fields. While many of the sites in this study are sure to extend into the dunes, few possess concentrated assemblages at the dune-playa interface. In these rarer cases, excavations can be expected to yield artifacts in sufficient numbers to ascertain their stratigraphic position reliably. Both efforts proved successful in establishing stratigraphic relationships between the wetland and cultural deposits.

Excavations were most fruitful at the Cache site, which is situated immediately adjacent to the mapped Seafoam channel (Figure 7). As indicated by a surface concentration, flakes were collected in and just above black mat deposits. Excavations consisted of 2-x-2-m units taken down in 10-cm or natural levels as warranted. These

Table 1. Radiocarbon and Calendar Date Estimates from the Cache and Com Sites.

Site	Feature	Beta Lab No.	Radiocarbon Years BP	Calendar Years BP*	Material Dated
Cache Site	Overbank wetland	234840	9210 ± 60	10,380 ± 120	Organic sediment
Cache Site	Overbank wetland	206215	8590 ± 80	9580 ± 160	Organic sediment
Cache Site	Channel 2	234837	9090 ± 60	10,250 ± 120	Organic sediment
Cache Site	Channel 3	234839	8980 ± 50	10,160 ± 100	Organic sediment
Cache Site	Channel 4	234838	8910 ± 50	10,040 ± 100	Organic sediment
Com Site	Overbank wetland	234836	8880 ± 60	10,000 ± 120	Organic sediment

*Represents median ages to the nearest 2σ using the IntCal09 curve in Calib 6.0 (Reimer et al. 2009).

extended on a line from the area where artifacts were observed into the dune, as shown in Figure 11. Additionally, backhoe trenches were excavated perpendicular and parallel to the dune to take a broader look at the geomorphic context and search for buried cultural features. The stratigraphic profile is provided in Figure 12.

The black mat deposits associated with artifacts provide an early limiting date of 10,390 cal BP (see Table 1, Figure 6). Two dates were taken from this level, but the second date of 9580 cal BP is not considered reliable; it was taken in a near-surface shovel probe (the other is from the backhoe trench) prior to excavations and is inconsistent with the sequence of dates from the site. This layer represents the standing-water context of an overbank wetland, which was unlikely to be a preferred place of residence for people. FGV flakes were found in the black mat layer, which is about 10 cm thick, and up to 20 cm above it, indicating that it was likely dry when people were on it, with some dune formation already underway.

Three additional dates come from an overlapping sequence of channels seen to cut the overbank wetland layer (Figure 12). As expected, these yield slightly later dates and likely represent the reason for human activity at the site. The channels are situated within an

Figure 11. Black mat sediments extending into the dune as observed at the Cache site (Wildcat Mountain is in the background). These are observable in the excavated units and in the backhoe trench sidewall. Artifacts were found in and immediately above this layer, which provided a date of 10,380 ± 120 cal BP.

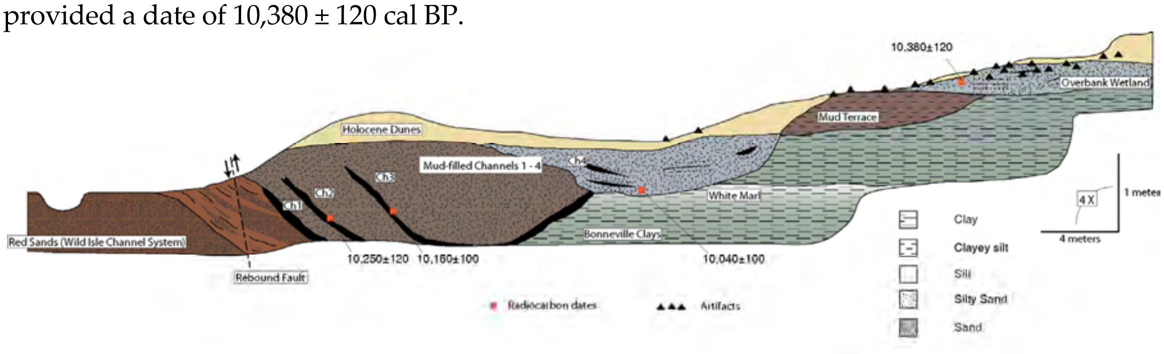


Figure 12. Stratigraphic profile of the Cache site (by D. Craig Young). Artifacts were found at the dune-playa interface in the black mat sediments of the overbank wetland and in the overlying dune immediately above. This layer is the oldest, crosscut by a series of overlapping channels that indicate a frequently shifting stream system. It is likely that these were the focus of human interest in the site, the overbank deposits being dry and amenable to occupation. Dates are in calendar years (cal BP). Illustration by D. Craig Young.

older main channel mapped by DRI as the Seafoam channel. Channel 1 is the stratigraphically earliest and is undated, but channels 2, 3, and 4 follow a predictable sequence from early to late that spans less than 300 years between 10,250 and 10,040 cal BP. The calibrated dates for channels 2 and 3 overlap in error by 10 years, but taken together the series appears to be a good representation of the short-lived dynamics of stream flow in a low-energy distributary system. Thus, while the dates are taken from organic sediments, which roughly provide an average of the range of time that the organics were active, their resolution in this context should be good. The most parsimonious interpretation of the site is that people occupied the dry land alongside the flowing streams between about 10,000 to 10,300 cal BP.

Excavations at the Com site yielded similar results. The site is located on the west margin of a peninsular dune that defines the northwest portion of the Wild Isle dune field (Figure 7). I observed FGV and chert flakes concentrated at the dune-playa interface during earlier site testing (Carter et al. 2004), and a shovel probe at that time revealed small flakes with no weathering (i.e., flakes that would otherwise be gone from the playa by the processes described above). No organic deposits were seen at that time, but a black mat layer, again defined as an overbank wetland by Young, was observable in the 2-x-2 units and backhoe trenches excavated during the SARF project. As at the Cache site, flakes were observed stratigraphically in and above the black mat layer. A date of 10,000 cal BP was derived from the black mat sediments. This date is the youngest from Wild Isle Dunes, and indicates that there was water in both the east and west portions of the study area, at least in the Com site vicinity. As at the Cache site, occupations at the Com site must be later than the sediment date, but there is no demonstrable channel chronology in the stratigraphic profile from which to interpret how long-after this may have occurred.

Obsidian Hydration Dating

A large-scale obsidian hydration dating (OHD) project was conducted in an attempt to find relative chronological patterning in the lithic assemblages. Unfortunately, this was not as successful as hoped, as temperature-affecting context factors affect results to such an extent that they overwhelm the true hydration rate. The effects not only limit resolution, but even upend relative temporal placement; that is, within narrow time frames, relatively younger artifacts may return hydration values that represent older dating than values from truly older artifacts. Still, obsidian hydration dating (OHD) has become a valuable tool in the western United States for its ability to separate out major cultural periods (e.g., Beck and Jones 1994, 2000; Gilreath and Hildebrandt 1997; Hull 2001). To this extent, the results do distinguish Paleoindian artifacts from later periods (Duke 2008; Duke et al. 2007), although separation within this time period is as yet impossible. The limitations provide some insight into the geoarchaeological processes affecting assemblages on the distal ORB.

A relative chronology was established by submitting projectile points from all time periods to hydration analysis. A sample of 548 is discussed here, which consists of 335 GBS and 59 Pinto specimens representing a combined 72 percent of the total. This is the largest such sample submitted for hydration analysis in the desert west, with the most comparable data coming from the Mojave Desert (see Gilreath and Hildebrandt 1997). The remaining 154 items from later periods represent nearly all that were available from the area, highlighting the dominance of the archaeological record of the area by early-period assemblages. The large majority of specimens (n=525), including all of the GBS and Pinto points, were sent to ArchaeoMetrics for examination by Tim Carpenter. The remaining items went to Craig Skinner at Northwest Research Obsidian Studies Laboratory (NWROSL). X-ray fluorescence (XRF) sourcing was conducted on all artifacts by NWROSL prior to hydration analysis in order to control for source-specific hydration rates.

Hydration Sample Selection and Rim Measurement Methodology

The sample is not limited to the distal ORB, although about two-thirds are from here (n=368), and includes specimens from throughout the ORB delta and areas along the basin margins within military boundaries. The OHD study has progressed through a series of cultural resource management projects for the Air Force. Also, artifacts from the proximal ORB were generously provided by Rachel Quist, DPG Archaeologist, and Dr. David Madsen, DRI. Early results from Air Force lands are detailed in Duke (2008), and some results inclusive of DPG artifacts are presented in Duke et al. (2007). This study brings the sample up-to-date with all the data thus far collected.

The final sample of 548 artifacts is selected from a total sample of 668 for which the additional 120 are excluded for various reasons. These reasons include: unreliable rim values according to the hydration analyst (see discussion below), typology that is indeterminate or indistinctive, and specimens made from unknown or otherwise irrelevant obsidian sources for current purposes. Also, the selected sample excludes outliers (n=21; Table 2), defined here as any reading outside of two standard deviations of the mean. While these outliers could represent truly unusual ages, they more likely reflect extensive temperature-related variability in the results, as is detailed below. For the purposes of this

Table 2. Basic Statistics for Obsidian Hydration Rim Values from the ORB Delta Vicinity.

Projectile Point Type and Obsidian Source	n	Mean (µ)	SD	CV	Min	Q1	Median	Q3	Max	No. of Outliers
Great Basin Stemmed										
Topaz Mountain	198	8.92	1.08	0.12	6.36	8.10	8.92	9.70	11.52	2
Browns Bench	112	12.16	1.45	0.12	8.50	11.48	12.10	13.31	15.38	9
Black Rock Area	8	8.08	0.77	0.10	7.15	7.28	8.16	8.70	9.32	1
Malad	7	8.51	0.83	0.10	7.16	7.90	8.50	9.24	9.71	-
Wild Horse Canyon	6	10.87	1.03	0.09	9.47	9.97	10.85	11.78	12.30	-
Modena	2	7.50	0.74	0.10	6.97	-	7.50	-	8.02	-
Ferguson Wash	1	9.10	-	-	9.10	-	9.10	-	9.10	-
Paradise Valley	1	7.33	-	-	7.33	-	7.33	-	7.33	-
Pinto										
Topaz Mountain	40	9.18	1.26	0.14	6.75	8.31	9.14	10.27	11.53	4
Browns Bench	7	9.93	1.75	0.18	7.30	8.03	10.40	11.27	12.11	-
Black Rock Area	6	9.42	1.59	0.17	6.92	8.34	9.31	11.06	11.14	-
Malad	3	7.06	0.13	0.02	6.96	6.96	7.00	7.21	7.21	-
Ferguson Wash	1	7.29	-	-	7.29	-	7.29	-	7.29	-
Modena	1	9.58	-	-	9.58	-	9.58	-	9.58	-
Wild Horse Canyon	1	8.67	-	-	8.67	-	8.67	-	8.67	-
Humboldt										
Topaz Mountain	11	6.67	1.21	0.18	5.00	6.00	6.68	6.90	9.00	-
Browns Bench	6	8.40	0.97	0.12	7.10	7.63	8.32	9.17	9.90	-
Large Side-notched										
Topaz Mountain	7	8.33	0.81	0.10	7.11	7.60	8.51	8.85	9.53	-
Browns Bench	2	11.67	3.44	0.29	9.24	-	11.67	-	14.10	-
Elko Series										
Topaz Mountain	31	5.64	1.13	0.20	3.50	4.74	5.55	6.73	7.56	-
Browns Bench	15	6.43	0.95	0.15	5.15	5.85	6.28	7.20	8.31	-
Rosegate Series										
Topaz Mountain	55	3.43	0.76	0.22	1.68	3.02	3.51	3.70	5.42	-
Browns Bench	15	4.75	1.07	0.22	2.77	3.90	4.68	5.66	6.31	-
Desert Series										
Topaz Mountain	8	2.62	0.34	0.13	2.16	2.31	2.60	2.97	3.00	-
Browns Bench	4	3.54	0.14	0.04	3.38	3.40	3.54	3.67	3.69	-

Notes: SD=standard deviation, CV=coefficient of variation study, the discussion is best directed at the sample means without influence by outliers. Regarding the obsidian sources, Table 2 shows statistics for all known sources for GBS and Pinto items, but only for Topaz Mountain and Browns Bench for the other projectile point types, which are represented by too few for statistical comparisons. The sourcing information should not be considered proportionately representative, as the two most common sources—Topaz Mountain and Browns Bench—were targeted for analysis based on visual characteristics.

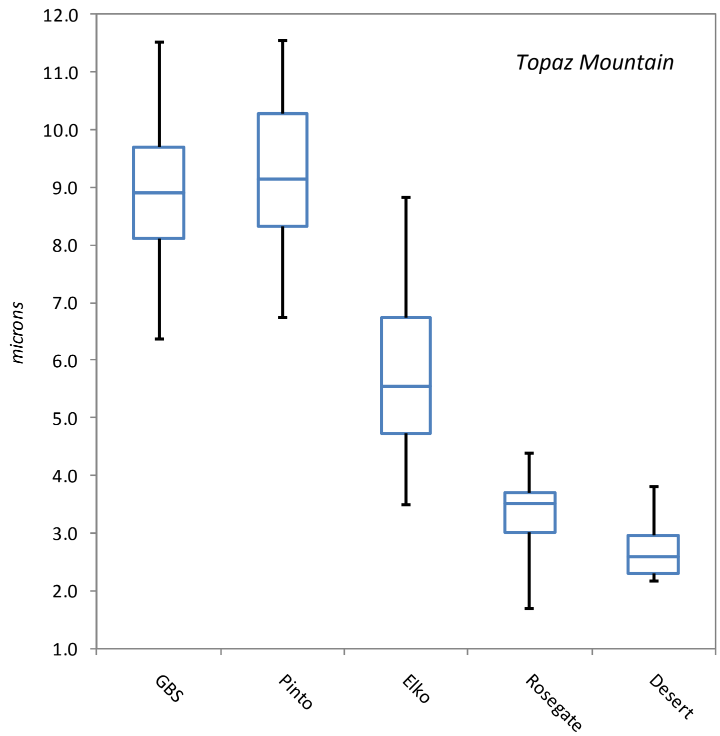
Finally, most of the GBS and Pinto assemblage exhibits light to heavy surface weathering (largely from aeolian sand blasting) and require special techniques to acquire reliable rim measurements. For this study, step fractures observed along the edge of the artifact were targeted for thin-section removal. In most instances, a small fracture can be observed microscopically that continues into the artifact beneath the visible "step." This micro-fracture is created through flaking or use when the combination of force and angle are not sufficient to release a feather-terminated flake but are adequate to create some partial separation into the tool mass. Hydration is visible in two bands extending from either side of the fracture. These cracks are protected from exterior weathering but remain subject to ambient temperature to the same extent as the artifact surface. This is apparent by comparison of step fracture rims to surface rims on individual, unweathered artifacts. Examination of step fractures is not standard practice in modern hydration analysis but has been recognized as an important way to circumvent the problems of surface weathering (Ambrose 1994; Pierce et al. 1976; Stevenson et al. 1996). All step fracture measurements were taken by Tim Carpenter, ArchaeoMetrics, who had a 71 percent rate of success (Duke 2008).

For this study, only readings taken from step fractures are accepted for GBS and Pinto artifacts. Surface readings are included for the later period items, as differences between step fracture and surface readings are generally negligible. The limited weathering observed on the later artifacts is attributed to their recent age, for one, but also their context on dunes, where the effects of wind are substantially dulled by the topography compared to the playa setting of most GBS and Pinto items.

Hydration Chronology and Geoarchaeological Implications

As mentioned, the hydration data do a nice job of separating Paleoindian artifacts from later periods but further clarification remains elusive. Boxplots of the data for the primary projectile point types and obsidian sources are shown in Figure 13, which shows a predictable trend of declining average hydration rim values through time. The basic statistics for the entire selected sample are provided by projectile point type and geochemical obsidian source in Table 2.

Topaz Mountain obsidian dominates the assemblage, followed by Browns Bench. As indicated in Figure 13 and Table 2, GBS and Pinto mean rim values are virtually identical, with Pinto rims slightly thicker than GBS rims. The point types are not statistically different at a five percent significance level (t=-1.19, df=51, p=.24). Collectively, GBS and Pinto artifacts have a mean rim value of 9.0 microns (μ). A more pronounced difference is superficially seen for Browns Bench specimens, but there are only seven Pinto artifacts for comparison. The average GBS/Pinto rim value for Browns Bench is 12.1 μ. The Browns Bench hydration



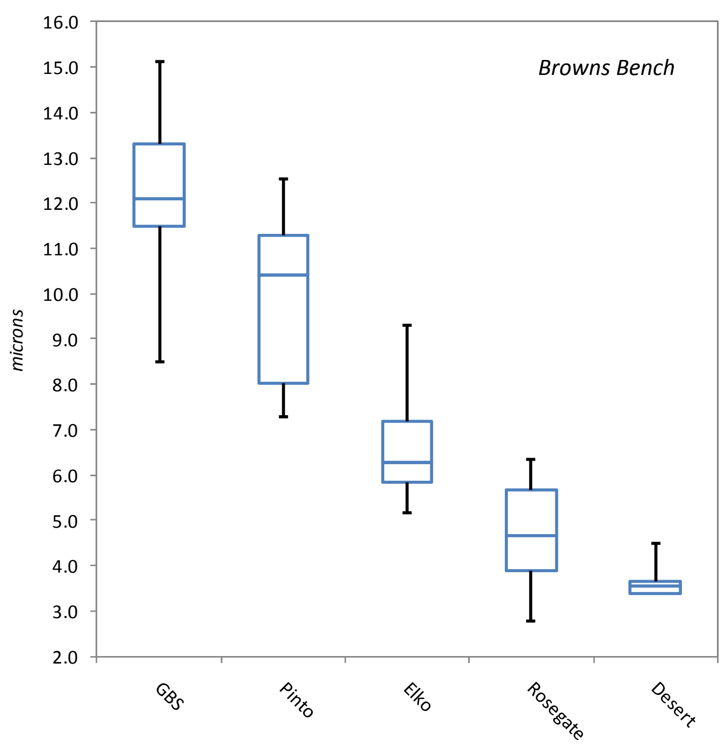


Figure 13. Boxplot summaries for Topaz Mountain and Browns Bench projectile points.

rate is clearly faster than that for Topaz Mountain, so the two datasets cannot be combined. Elko series projectile points represent the Middle Archaic, dated roughly 6000 to 1300 cal BP (Thomas 1983), and exhibit rim values averaging 5.6 μ for Topaz Mountain and 6.4 μ for Browns Bench. Thus, the hydration data support a marked gap in time between Paleoindian use of the ORB delta and significant Archaic occupation.

There is, however, some evidence of early-middle Holocene activity. Large Side-notched and Humboldt projectile points represent the Early Archaic period for which the chronology is not well established, but is widely accepted to begin as early as 9000 cal BP and to continue until the onset of the Middle Archaic ca. 6000 cal BP (although Humboldt can also be found in later contexts). The sample includes seventeen Humboldt and nine Large Side-notched which represent 57 percent (n=26 of 45) of those that have been found to date on Air Force lands. Sample sizes are too small to make any strong statements about their chronology other than they generally date between the Paleoindian and Middle Archaic periods, as would be expected, but the data hint that Large Side-notched points may be older than Humboldt. These point styles are technologically very dissimilar to each other and to GBS and Pinto.

The distribution of Large Side-notched and Humboldt projectile points on the landscape is more telling, suggesting different land use patterns and an already-different geomorphic setting in the study area. Of 14 Large Side-notched points collected to date, 10 are located outside of the distal ORB, mostly on the west margins of the basin near Blue Lake. By contrast, only three of 31 Humboldt points are found outside of the distal ORB. Most Humboldt points are located in low dunes and blowouts near the dune-playa interface along the west margin of Wildcat Dunes. Thus, their distribution resembles much of the Paleoindian archaeology, but without restriction to the playa. This suggests that dune formation was quickly underway following desiccation of the ORB delta. What the draw to the area was for Humboldt-point-users is difficult to say. There may have been water availability at times, but there are no data to indicate that the ORB distributary system was functioning. Users of Large Side-notched points apparently had little reason to enter the basin despite utilization of its margins.

Because the distinguishing temporal trends among GBS and Pinto artifacts seemed to generate unexpected and conflicting results,[2] an attempt was made to understand how temperature-related context issues may be affecting the hydration results. A separate study was conducted with Alexander Rogers, Maturango Museum, to determine a rate of hydration for Topaz Mountain obsidian. The details of the study are reported by Rogers and Duke (2011). Two rates were developed: one based on experimentally induced hydration in the laboratory and the other using hydration rim-radiocarbon pairings from dated archaeological deposits in Camels Back Cave. Camels Back Cave is located 20 km southwest of Dugway, Utah, and 40 km northeast of the Topaz Mountain source. Recent excavations reveal a continuous deposit extending to 8100 cal BP and containing a lithic assemblage dominated by Topaz Mountain obsidian (Schmitt and Madsen 2005). A laboratory rate of 0.0711 $\mu/yr^{1/2}$ was found to be in close agreement with the archaeologically derived rate of

[2] This statement refers to attempts to find chronological patterning among point types that could be associated with the technological and distributional patterns described in the forthcoming analytical chapters. These problems are explained by the geoarchaeological processes detailed in this section, so there is no further use of obsidian hydration dating in this study.

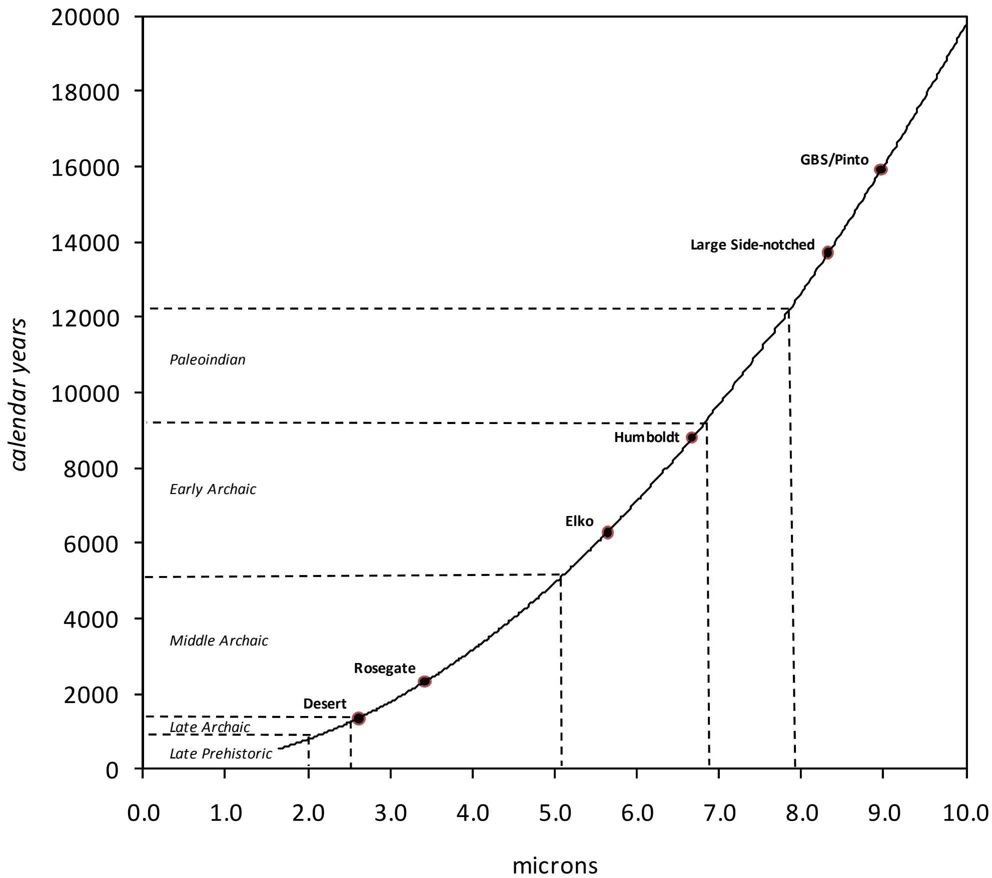


Figure 14. Hydration curve based on Topaz Mountain laboratory rate. Approximate cultural period time ranges are shown with dashed lines. Dots on the curve represent dates calculated from the laboratory rate for the mean rim thickness of each projectile point type from the current study.

0.0753 μ/yr^{½}. The laboratory rate translates into an age coefficient of 197.8 yrs/μ^2 that can be used to calculate calendric dates from hydration rim values.

This rate produces excessively old dates when applied to the current sample of surface artifacts. The discrepancies are shown in Figure 14 where the actual mean rim values for projectile points in the sample sit well outside of the temporal ranges for cultural periods as defined by the laboratory rate. By this math, the average GBS/Pinto rim of 9.0 μ would equal 16,022 calendar years. As a cave, Camels Back Cave provides a stable, buried context within which artifacts would hydrate according to cooler ambient temperatures (Rogers 2007). Heat accelerates the process and can be expected to have a pronounced effect on exposed, dark-colored (i.e., heat-absorbing) artifacts that have lain on the desert surface for long periods. Assuming a mid-range date of 11,000 cal BP for GBS/Pinto artifacts in the current sample, an average rim value of 7.5 μ would be expected in Camels Back Cave. Problems with the application of experimental rates to surface assemblages have nagged researchers for some time (see Friedman and Long 1976; Hall and Jackson 1989; Hull 2001; Ridings 1996; Rogers 2007; Stevenson et al. 1989), and the Camels Back Cave study provides an archaeologically-validated benchmark from which to examine these issues.

Mathematical hydration theory holds that regardless of when temperature fluctuations occur after the deposition of an artifact, these fluctuations should have an equal effect on ultimate rim thickness. This being the case, the potential for fluctuations to overwhelm the true hydration rate increases with time as their influences compound. An examination of the hydration data against archaeological context robustly indicates how temperature is controlling the hydration rate in the study area. Two proxy measures of exposure were used to compare rim values: artifact weathering and distance from dunes. The analysis is limited to artifacts from the distal ORB only.

Weathering was estimated for each artifact as light, moderate, or heavy. Light weathering represents artifacts exhibiting from none at all (so uncommon it was not distinguished) to a modest patina. These items otherwise possess sharp edges as if freshly flaked. Moderately weathered artifacts exhibit a dulled appearance. Edges and arrises have lost their sharpness but are still readily distinguishable. This is the result of aeolian

Table 3. Mean Rim Values for GBS and Pinto Artifacts from the Distal ORB by Extent of Weathering and Obsidian Source.

Weathering	Obsidian Source	
	Topaz Mountain	Browns Bench
Light	8.5 (n=71)	11.3 (n=17)
Moderate	9.1 (n=78)	12.0 (n=65)
Heavy	9.3 (n=31)	12.6 (n=17)

sandblasting on the open playa. Specimens may also possess some pitting over their surface, visible with the naked eye or with a hand lens. Artifacts that are heavily weathered exhibit substantially sandblasted surfaces, with flake scars at times being nearly unrecognizable. Pitting is common. Heavy weathering on artifacts can be so extensive even distinguishing obsidian from FGV can be difficult without experience. The results are presented in Table 3 and indicate a straightforward relationship between levels of exposure and hydration rim thickness. A series of t-tests shows all of these mean values to be statistically different at a five percent significance level with the single exception of moderate- to heavy-weathered items made from Topaz Mountain obsidian.

Distance from dunes was used to cross-check the above results against their position on the ground. This was calculated as the distance in meters of artifacts from the dune margin using soil layers (NRCS 2007) in ArcMap 9.3. The margin was defined by distinguishing three soils that effectively represent the open mud flats—Playas, Salt Flats, and Playas-Saltair (0-1% slope)—from the remaining soil categories of the dunes and solid rock. This does not create a perfect match between the actual and the modeled dune margin but is suitable for current purposes. From the distances, artifacts were grouped into three categories: 1) Playa (>100 m from dune margin), 2) Margin (within 100 meters either side of dune margin), and 3) Dune (greater than 100 m into the areas defined as dune). Regarding this last group, a worthwhile reminder is that Paleoindian artifacts on the distal ORB are not observed "on" dunes but they can be in them where blowouts reach the underlying playa. Such contexts are still assumed to be relatively recent exposures for this exercise. This is one among a few reasons why distance from dune should be less sensitive to true artifact exposure levels than weathering, the others being the broad scale of the GIS soil layers and the fact that the exact locations of artifacts are not always known (site datum coordinates were used for many).

The weathering results for Topaz Mountain obsidian are presented by distance group in Table 4. The expected pattern is apparent with thicker hydration rims on artifacts that are both more weathered and farther from dunes, albeit subtly, owing to the biases mentioned above. The least distinctive or inconsistent differences are found in the middling categories of moderate weathering and dune margins. A low mean value for heavily weathered artifacts within the dunes only represents two specimens. A similar cross-tabulation for Browns Bench artifacts provided varying results, but sample sizes are under 10 items for each category except for the problematic moderate weathering and dune margin categories. Overall, however, the results strongly suggest that temperature factors related to artifact context in or out of the dunes are driving hydration rim thickness on Paleoindian artifacts on the distal ORB. Similar site contexts (e.g., heavily weathered/playa or lightly weathered/dune) may hold potential for comparison, but such situations with sufficient sample size are uncommon in the current dataset, and the few comparisons that could be made yielded no meaningful differences.

Table 4. Mean Rim Values for Topaz Mountain GBS and Pinto Artifacts from the Distal ORB by Extent of Weathering and Distance from Dune.

Weathering	Dune Group		
	Dune	Margin	Playa
Light	8.2 (n=17)	8.4 (n=23)	8.8 (n=26)
Moderate	9.1 (n=11)	9.1 (n=44)	9.2 (n=16)
Heavy	7.5 (n=2)	9.0 (n=17)	10.2 (n=11)

The distal ORB data support the mathematical theory that with greater time depth even small temperature variances can compound into large chronological errors, overwhelming the true hydration rate. Based on the hydration rate developed for Topaz Mountain obsidian (Rogers and Duke 2011), Rogers (personal communication, 2011) estimates that even a slight difference in effective hydration temperature (EHT) on the order of ~1-2°C could produce error on the order of several thousand years for artifacts over 10,000 years old. The apparent influence of exposure-related EHT differences makes it virtually impossible for OHD to temporally distinguish Paleoindian artifacts on the distal ORB. These findings have important cautionary implications for the interpretation of obsidian hydration data from early assemblages across the desert west.

Paleoindian Versus Post-Paleoindian Site Context and Distribution

The obsidian hydration studies provide initial insights into the nature of the prehistoric record in the study area, but a broader understanding comes from assemblage differences across geomorphic contexts. While artifact weathering alone is enough to separate out mixed components in many instances, further distinction can be made by observing how artifacts are distributed between the dunes and playa. Paleoindian assemblages are restricted to the playa and dune blowouts extending to the playa across the study area, and

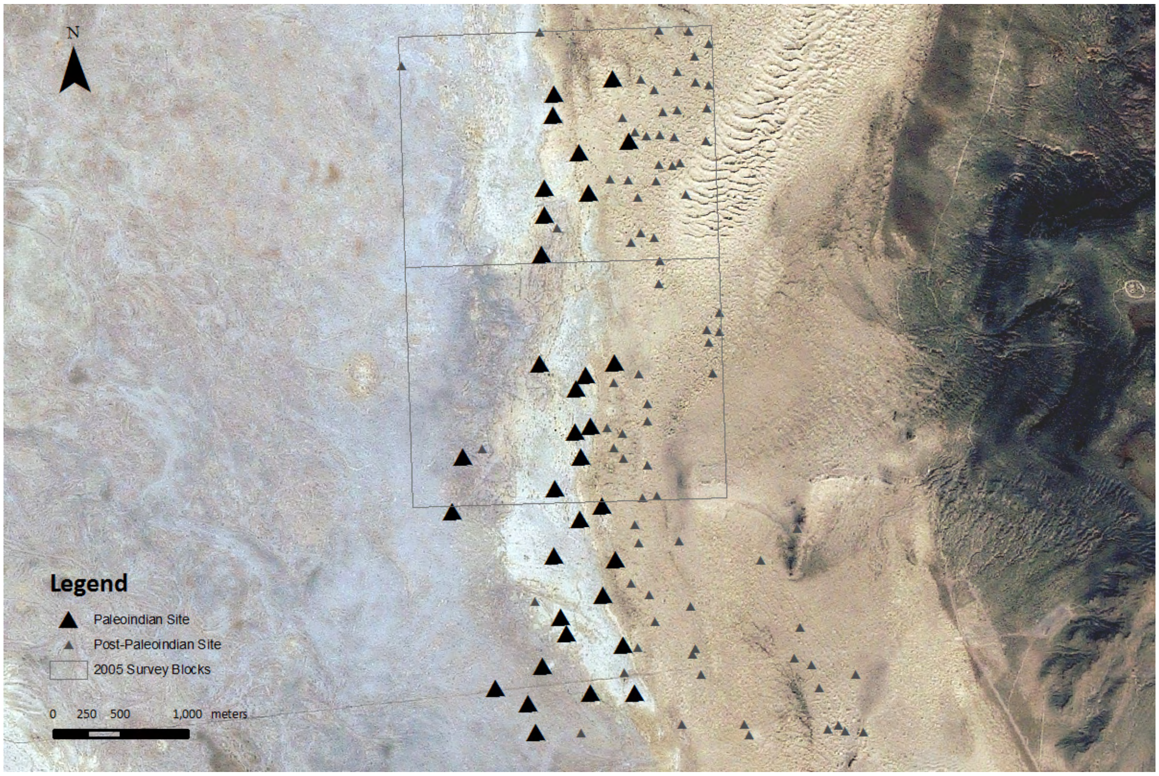


Figure 15. Distribution of archaeological sites along west margin of Wildcat Dunes by primary temporal component. The two 1,000-acre blocks represent survey conducted in 2005 (the other sites were recorded in 2006).

post-Paleoindian sites are usually found on the dunes, especially Wildcat Dunes. Certainly, Paleoindian tools look different from post-Paleoindian tools in general, but when made from the same materials, some artifacts are ambiguous (e.g., flake tools, small bifaces). Archaeological survey in 2005 transected dunes and playa for a roughly five-kilometer north-south stretch along the east margin of Wildcat Dunes (Figure 15), providing me an opportunity to examine this patterning across 68 recorded sites (Young et al. 2006).

Raw material selection was identified as the best discriminator of Paleoindian versus post-Paleoindian components. Fine-grained volcanic toolstone generally equates to Paleoindian activity while the use of chert is largely limited to post-Paleoindian assemblages.

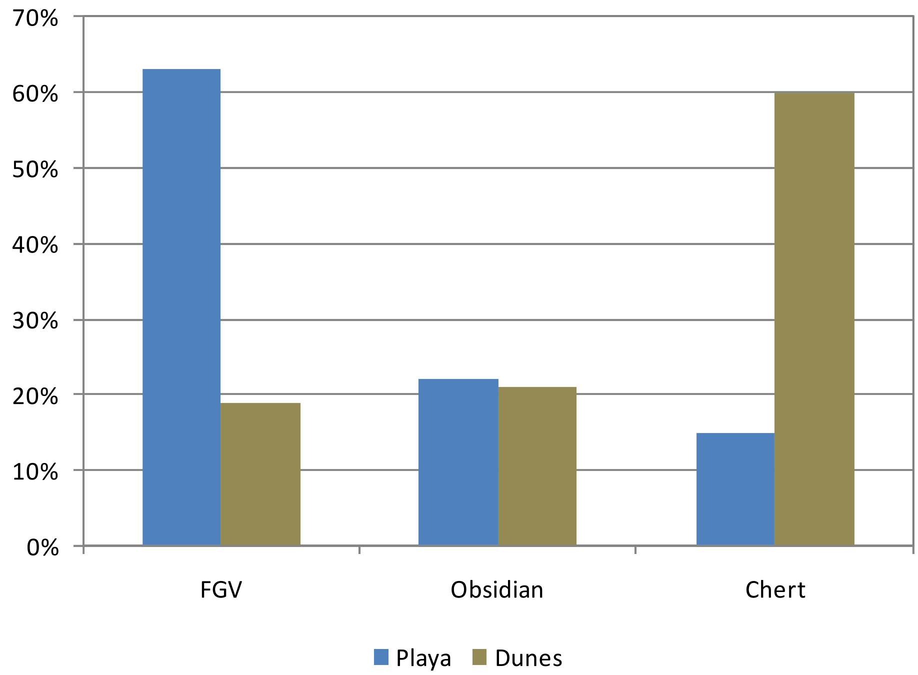


Figure 16. Debitage proportions for the three primary raw material types by site context from the 2005 Wildcat Dunes survey.

Obsidian was used in both time periods, with later-period peoples often scavenging the early material as evidenced by fresh flake scars on otherwise weathered artifacts. Debitage from the 68 sites shows this pattern to be distinctive between the playa and the dunes, as seen in Figure 16. This patterning is reinforced across the rest of the study area, which generally lacks substantial post-Paleoindian occupations and where FGV and obsidian dominate the assemblages. Projectile point distributions further evidence these relationships.

Summary

The archaeology of the distal ORB is laid out across the floor of the Great Salt Lake Desert alongside remnant geomorphological features of a dead distributary system. A date range of ca. 12,100 to 9900 cal BP is proposed for primary human occupation prior to desiccation of the system. While further research could alter these beginning and end dates, existing radiocarbon dates on wetland black mat deposits suggest that the range is generally representative of a window of time that opened up sometime during the latter part of the Younger Dryas climatic episode and endured until 9900 cal BP, or shortly thereafter. The distributary system was fed by groundwater discharge after the Younger Dryas, Gilbert-phase, lake receded and the actual Old River ceased flowing into the basin.

The distal ORB represents the distal extent of the broader ORB distributary system, where prominent channels transitioned into a network of low-energy, braided streams. The prominent channel tracks have been mapped by other researchers working on the proximal ORB (Madsen et al. 2011), and these can be traced to some extent into the distal ORB where they fall into earlier (ca. 12,100-11,200 cal BP) and later (ca. 11,300-9900 cal BP) groups that run through the west and east sides of the study area, respectively. This provides the basis for identifying temporal differences in the Paleoindian archaeological record.

When the distributary system disappeared dunes began to form quickly, drawing sediment from the dry sandy channels and facilitated by the exposure of such a large basin to aeolian processes. Excavations at the Cache and Com sites show artifacts stratigraphically overlying black mat sediments dating between 10,000 and 10,400 cal BP and situated below the extensive Wild Isle and Wildcat dunes. The distribution of later period archaeology on dunes indicates that these formed for several thousand years before people took notable interest in the area again. Combined with artifact weathering, the Paleoindian components are relatively easy to separate from later assemblages based on these geoarchaeological considerations. This is also supported by changes in toolstone preference that are differentially distributed between the dunes and playa. While obsidian is used throughout prehistory, FGV is largely restricted to Paleoindian assemblages on the distal ORB (i.e., the playa) and chert to post-Paleoindian activity on the dunes.

Obsidian hydration dating was used to further clarify the chronology, but proved incapable of discriminating between early and late Paleoindian components. However, the method is useful for distinguishing Paleoindian from post-Paleoindian artifacts and supports the close temporal association of GBS and Pinto projectile point types. The obsidian study also provides further evidence that many Paleoindian artifacts were buried in relatively quick order in the Early Holocene as dunes began to form, with those items exposed on the playa surface for longer times exhibiting hydration rim thicknesses that are greater than those that eroded out of the dunes more recently.

While Paleoindian sites have moved on the playa surface to some extent, they maintain general integrity to their original location. An examination of debitage distributions relative to the dunes shows that artifacts over under about 1/4" in size have the potential to move considerably across or even off the playa into the dunes or perhaps the basin margins. These flakes can be found windrowed against the windward side of dunes (the west side, in this case) while only larger artifacts—usually the actual tools—remain as lag deposits on leeward dune sides. Sites in dune blowouts maintain the greatest integrity for debitage assemblages. Even larger artifacts can slide across the playa, as demonstrated by geomorphological experiments, but the topographically undulating surface of alternating playa and remnant ORB channel features keeps these artifacts from moving to any substantial degree. Thus, the tool assemblages that are the subject of this study are considered representative.

CHAPTER 3

HUNTER-GATHERER USE OF GREAT BASIN WETLANDS

Lack of water is an obvious constraint on organisms living in arid environments, but debate remains as to how this has influenced human adaptations. Desert ecosystems are sensitive to even slight climatic fluctuations. To study human beings in such a context means to recognize at the outset that adaptive variability often signals critical steps taken by people to ensure survival. This is clear both ethnographically and archaeologically in the Great Basin (see Fowler 1992; Grayson 1993; Heizer 1967; Heizer and Napton 1970; Janetski and Madsen 1990; Jennings 1957; Madsen 1982, 2002; Madsen and Lindsey 1977; Kelly 2001; O'Connell 1975; Steward 1938; Thomas 1985).

The wide view of Great Basin hunter-gatherers is one of regional nomads suited to exploit all corners of a marginal environment (cf. Jennings 1957; Steward 1938). This does not appear to be the best characterization for Paleoindian peoples, who were adapted to a cooler and wetter Pleistocene-Holocene transition environment (e.g., Antevs 1948; Bedwell 1970; Elston and Zeanah 2002; Pinson 1999; Schmitt et al. 2007; Simms 1987; Warren and Ranere 1968; Willig and Aikens 1988). This chapter begins with a description of Great Basin wetlands and their importance to regional hunter-gatherers, followed by a discussion of recent research on Paleoindian adaptations.

Great Basin Wetland Ecosystems

Wetlands form when runoff moisture reaches a terminus where it expands across the ground surface from a saturated core area until it can be taken in by the surrounding sediments. In the Great Basin, rivers, streams, springs, and subsurface mountain runoff can contribute to extensive wetlands in internally drained basin bottoms. These catchments sometimes produce persistent wetlands and are literally oases that stand in sharp contrast to surrounding alluvial piedmonts, which usually receive less than 25 cm of precipitation in a year (Sowell 2001:12; Whitford 2002:11; also see Currey 1991; Madsen 2002). The nature and amount of annual precipitation in the mountains therefore affect the resource structure of adjacent basins. This makes basin wetland ecosystems dynamic in nature, with seasonal to annual fluctuations shaping the abundance and distribution of plants and animals.

Because the lack of water can be so limiting, the survival of desert organisms is best ascribed to accommodations to this condition rather than specific adaptations to it (Noy-Meir 1973, 1979/80; Sowell 2001:104; Whitford 2002:12). Any changes to the amount of water present in wetland areas directly impact the abundance of associated wildlife, and large wetlands are capable of systematically altering the annual movement and well-being of both local and non-local fauna. For example, Carson Valley's Stillwater Marsh and adjacent Humboldt River sink in western Nevada and the Great Salt Lake in northwestern Utah represent important stops along the Pacific Flyway for migratory birds in spring and fall. In good years, when the wetlands are big and productive, more birds are available to resident predators—including humans—and they maintain strong population numbers. In poor years, waterfowl may stay briefly or move to other areas, vegetation is less diverse, and certain fauna may suffer population crashes or even die-offs.

When wetlands are at their most energetically productive, freshwater charges biotically lively marshlands, providing food for organisms at every trophic level. Emergent and submergent marshes form in water up to roughly six feet deep, at which point vegetation potential is more restricted (Hamilton and Auble 1993; Smith and Monte 1975). Wetlands may form in open distributary networks or along lake margins where their extent is dictated by ground slope into the standing water. These habitats are key for human populations. As described in Fowler's (1992; also Fowler 1982a, 1982b) detailed account of the Cattail-eater Northern Paiute, plants such as cattail, bulrush, and sago pondweed, ducks and shorebirds and their eggs (e.g., canvasback, coot, snow goose, killdeer), fish (e.g., tui chub, Tahoe sucker, speckled dace), small mammals (e.g., muskrat, beaver), and various invertebrates (e.g., insects, mollusks) anchored year-round settlement in good years, supplemented by logistical trips to acquire large mammals in nearby uplands (also see Kelly 2001; Zeanah 2004). Additionally, the non-food related values of these resources—especially plants—for housing, clothing, tools, and weaponry should not be underestimated. When active, wetlands serve as rich food patches to hunter-gatherers against an arid backdrop, providing nutritionally diverse dietary items and technological materials on a seasonal cycle.

Theoretical Aspects of Hunter-Gatherer Ecology

In the last few decades hunter-gatherer studies have shifted from a directed search for defining characteristics to a determined emphasis on the variability possible within this lifeway. This is an outgrowth of theoretical advancement in evolutionary ecology, which places importance on this variability as evidence of socioeconomic priorities rather than sets of generalized traits (Bettinger 1991; Bird and O'Connell 2006; Kelly 1995). More specifically, optimal foraging models initiate much of this work by relating behaviors to explicit decision-making scenarios with cost and benefit implications. Hunter-gatherer research fits into the domain of "behavioral ecology," or more currently "HBE" (Human Behavioral Ecology), which distinguishes the study of human-oriented complexities from those of other organisms for which optimal foraging was originally developed (see Cronk 1991; Smith and Winterhalder 1992; Winterhalder and Smith 1981, 2000).

It is in its formality and specificity that behavioral ecology separates itself from "cultural ecology," which has dominated hunter-gatherer studies in archaeology since the mid-twentieth century. While the broad interpretive aim of both orientations is effectively the same—to understand human adaptations to environmental conditions—studies rooted in cultural ecology, although rarely stated as such, rely heavily on informal arguments and implied logic about why certain adaptations or behavioral strategies would be preferable to others. In this sense, emphasis tends to be placed more on behavioral results (e.g., trait lists) limiting the capacity to explain why given factors produce the behavioral responses they do according to changing influences (see Bettinger 1987, 1991:113-220; Kelly 1995:41-51). Such interpretations are not necessarily incorrect, and may even hinge on various factors, but they beg the explicit measures by which they can be assessed. Behavioral ecology represents a move toward explanations of behaviors expressed as a balance between energetic tradeoffs, a distinction that formally ties adaptations to evolutionary processes.

Great Basin Hunter-Gatherers and the Importance of Wetlands

Perhaps nowhere have theoretical considerations of hunter-gatherer use of desert wetlands been as thorough as in the Great Basin, especially for prehistory (Fowler 1992; Hemphill and Larsen 1990; Janetski 1991; Janetski and Madsen 1990; Larsen and Kelly 1995; Madsen 2002; Raven 1993; Raven and Elston 1989; Thomas 1985; Zeanah 2004; Zeanah et al. 1995). Rapid growth of this research over the past 25 years coincides with the theoretical development of evolutionary ecology, giving researchers the ability to add new insights to longstanding questions about the importance of wetlands in hunter-gatherer settlement and subsistence strategies.

Much of what is known about hunter-gatherers in the Great Basin originates with the ethnographic works of Steward (1933, 1938, 1955) and the archaeological insights of Jennings (1957, 1964). Steward developed cultural ecology in the Great Basin, where he saw native groups using residential mobility and food storage to offset seasonal and spatial differences in resource availability. Because this desert environment may vary greatly in its productivity seasonally and annually, Great Basin peoples incorporated flexible land use strategies and social systems to offset potential shortfalls. Small family units represent the most common social groupings, often joining with others to perform certain activities (e.g., pinyon harvest, rabbit drives). Under this social structure, it was relatively easy to help or be helped by neighboring peoples as resource availability fluctuated.

Jennings' (1957, 1964) "Desert Culture" concept extends Steward's model into prehistory. Jennings argued that the hunter-gatherer lifeway described by Steward basically remained stable in the Great Basin for most of prehistory. In contrast to Antevs' (1948) portrayal of dramatic social change driven by climatic variability (see Chapter 1), Jennings thought that environmental changes had little effect on the flexible strategies of humans and that those adaptations which are materially evident (e.g., bow-and-arrow) did not have significant impacts on overall cultural systems.

According to Jennings, the Desert Culture is then a lifeway necessitated by the marginal environment of the Great Basin. This model has been criticized as non-representative given the importance of large wetlands to people in some parts of the Great Basin (e.g, Baumhoff and Heizer 1965; Bettinger 1977, 1978; Heizer 1967; Janetski 1991; Jennings 1973; O'Connell 1975; Thomas 1985; Warren and Ranere 1968). Another criticism of the Desert Culture model is that it is static and does not explain the directionality of cultural change (e.g., increased diet breadth, upland occupation, resource intensification) (Elston 1982; O'Connell et al. 1982). Elston (1982; also see Bettinger 1977, 1978) argues that population pressure was a primary factor affecting cultural change alongside climatic shifts. For example, early peoples in the western Great Basin may have abandoned the area as resource-rich lake-margin and distributary wetlands disappeared, as suggested by Antevs (1948), because the sparse human population permitted them to do so. Later groups had to intensify their subsistence strategies alongside higher population densities, and they reoriented themselves toward more varied habitats.

In any case, it is clear that wetlands have always served as attractive habitats that were exploited by people whenever possible. The role of wetlands in any particular time and place, however, has been something of a moving target to researchers. A slew of specialized terms and concepts have been proposed to express this variability, such as "Lovelock culture," "limnosedentism," "lacustrine adaptation," "lowland strategy," and "Western Pluvial Lakes Tradition" (Bedwell 1973; Heizer 1967; Loud and Harrington 1929; Janetski and Madsen 1990; Madsen 1982, 2002; Napton 1969), and studies have taken place in many Great Basin wetland contexts (e.g., Bettinger 1977, 1978; Cannon et al. 1990; Hattori

1982; Janetski 1991; Jones and Madsen 1989; O'Connell 1975; Raven and Elston 1993; Rhode 1990a, 1990b).

Case Example: The Carson and Humboldt Sinks

Extensive research has taken place in the wetlands of the Carson Desert vicinity, providing direct archaeological data alongside well-developed ethnographic and theoretical studies. This area contains the sinks for two Great Basin rivers: 1) the Humboldt River, which originates in northeastern Nevada and serves as a primary northern Great Basin waterway, and 2) the Carson River (and at times in the past the Walker River), which originates in the Sierra Nevada less than 100 miles to the west. These rivers enter the region from opposite directions to their termini in adjacent basins separated only by the low, narrow southern arm of the Humboldt Range. Together, these basins form part of the bottomlands of pluvial Lake Lahontan, and an extensive record of the last 5,000 years exemplifies changing use of the wetland since the Middle Archaic.

Archaeological work in the lower Humboldt Valley began with excavations of Lovelock Cave, first formally excavated in 1924 as a culmination to inspections by L. L. Loud acting on direction from A. L. Kroeber in 1912 (Fowler and Fowler 1990). Loud and Harrington (1929) found a rich material culture centered on wetland resources, forming the basis for what was referred to as the Lovelock culture for several decades. Artifacts including muskrat fur blankets, fishhooks, various textiles made from marsh plants (e.g., tule, cattail, rush), and the now-famous Lovelock Cave duck decoys demonstrate the fundamental importance of the wetland to local culture, and later analysis of human coprolites from the cave attest to its dietary significance (Napton 1969). Similar deposits from nearby Humboldt Cave (Heizer and Krieger 1956) and Hidden Cave along the southeast margin of the Carson Desert (Thomas 1985) further evidence this lifestyle.

Heizer (1967:7; also see Heizer and Napton 1970; Napton 1969) proposed "limnosedentism" to distinguish the wetland focus of people living in the Carson Valley vicinity from the more flexible mobile strategy epitomized by Jennings' (1957) Desert Culture. Limnosedentism represents a near-sedentary way of life, rarely requiring (but not precluding) movement to other areas. This was a widely accepted view at the time (also see Barrett 1910; Jennings and Norbeck 1955) but it has fallen out of favor. What is better appreciated in recent studies is both the unpredictability of wetlands between seasons and years, which necessitates some level of residential mobility (Kelly 2001; Kelly and Hattori 1985; Mehringer 1977; Thomas 1985:19; Zeanah et al. 1995, 2004), and the basic difficulty in meaningfully applying the concept to archaeological studies (Aikens 1978; Fowler 1982b; Fowler and Fowler 1990; Hattori 1982; Janetski 1991; Madsen and Janetski 1990; Rozaire 1963).

Kelly (2001; also see 1995, 1997) uses a generalized foraging model to examine sedentism and mobility in the Carson Desert according to net food returns after certain costs are weighed (e.g., harvesting, processing, and traveling), and argues that wetland productivity only encourages people to reduce residential mobility when regional uplands are by relation unproductive (Kelly 2001:303). Kelly's work (also see Thomas 1985) addresses a guiding presumption by earlier Great Basin anthropologists—and North American anthropologists in general—that sedentism would be taken up where resource abundance permitted it (e.g., Beardsley et al. 1956:134; Heizer 1967:7; Jennings and Norbeck

1955:3; Madsen 1982:207), a view referred to by Binford (1983:199) as the “Garden of Eden” hypothesis. As Kelly (2001:5) states: “Sedentism does not save energy; it reorganizes it,” and any transition toward sedentism likely has more to do with the disadvantages of moving—especially in the face of population pressure—relative to food abundance or distribution than it does by the nature of food resources alone (Binford 1983:205; Kelly 2001:289).

The archaeological data from the Carson Desert extending back about 5,000 years generally support this as higher residential mobility coincides with times of better climatic conditions (Kelly 2001). These data primarily come from cave sites that are widely interpreted as caches rather than habitation sites because they contain few hearth features or common habitation debris, such as lithic artifacts and faunal remains (Kelly 2001:12-13; Thomas 1985:375; also see Heizer and Krieger 1956:5; Heizer and Napton 1970:43). The paleoenvironmental record indicates that the area was relatively dry between 4700 and 4000 cal BP, then improved over the next 2,000 years (Kelly 2001:33-36). At Hidden Cave, materials were placed as early as 5400 cal BP, but most of the earliest dates range between 4000 and 3500 cal BP, followed by dated occupations post-dating 2000 cal BP (Thomas 1985:363-364). Three cultural dates are reported between 4000 and 2000 cal BP at Lovelock Cave, with primary use indicated between 2000 and 1200 cal BP (Heizer and Napton 1970:39).

Kelly (2001:64, 289-297) argues these data reflect shifts in upland return rates. In good years it should be most cost-effective for people to move as necessary to hunt upland game (e.g., bighorn sheep), or even to access higher-ranked resources across several regional wetlands, but in bad years they can do better by focusing on immediately available fish, waterfowl, and reliable small upland mammals and pinyon (Kelly 2001:59). These factors play out seasonally and in the longer term. The use of primary caves to cache high-investment tools and resources is better explained as behavior necessitated by residential mobility away from a particular marsh rather than long-term use of the wetlands exclusively.

Kelly's (2001) work suggests that at any given time there would be optimal locations for residences from which to maximize upland and basin resource returns, but he does not address this directly, and it is not clear what kinds of proximate decisions would be made in choosing where to move or stay. Zeanah (2004; also see Zeanah et al. 1995) stresses these factors, especially the importance of the sexual division of labor to hunter-gatherers. Supported by ethnographic data, Zeanah argues that the decision to reside in or near a marsh represents an emphasis on women's diet contribution for its caloric value over the singular and unpredictable (by comparison) returns of upland game hunting; in fact, there should be little in the way of a hunting-oriented land use strategy over the past 1,250 years, and possibly earlier, although men would have always hunted uplands or nearby valley settings as much as was viable from residences. Ultimately, both the Kelly (2001) and Zeanah (2004) models can be applied with few archaeological differences, but it is clear that an appreciation for the division of labor provides additional sensitivity to any human-oriented optimal foraging model. Changing resource structures can create conflicts in men's and women's subsistence aims; thus, adjustments in land use strategies are needed to resolve these discrepancies. Overall, a hunting-oriented settlement pattern will not be sustained if it does not produce sufficient returns to sustain primary caloric requirements for the group as a whole (Zeanah 2004).

Paleoindian Foragers and Wetlands at the Pleistocene-Holocene Transition

Paleoenvironmental Overview

The disappearance of lakes and wetlands throughout the Great Basin in the early Holocene presented a shift to arid conditions not previously experienced by its inhabitants. At their most recent highstands over 15,000 cal BP, pluvial lakes covered upwards of one-third of the Great Basin (Grayson 1993:86; Madsen 2002). These waters were receding as people first entered the region, but this may have been to the benefit of the new inhabitants, generating shallow lake-margin wetlands and exposing spring and marsh systems that released freshwater from a high groundwater table (Bedwell 1973; Madsen 1982, 2002). An initial drying period was abruptly reversed during the Younger Dryas climatic episode (12,900-11,600 BP), after which conditions moved toward those we see today as early as 9500 cal BP (Beck and Jones 1997; Hockett 2007).

Paleoenvironmental data (e.g., packrat middens, pollen) from the Pleistocene-Holocene transition are incomplete, but general patterning is apparent. In the southeastern Great Basin, packrat middens from the Death Valley area indicate substantially cooler average temperatures from today, on the order of 10 °C, alongside a three- to four-fold increase in precipitation that persisted to a reduced degree to approximately 12,900 cal BP (Grayson 1993:126; Hunt 1966, 1976; Van Devender 1977; Wells and Berger 1967; Wells and Woodcock 1985; Woodcock 1986). During this climatic regime, a network of lakes existed along the Owens River (e.g., Owens Lake, China Lake) and Mojave River (e.g., Lake Manix, Lake Mojave) which drained into Death Valley and pluvial Lake Manly. Notable vegetation indicators include Whipple yucca, which requires July temperatures of less than 29 °C and is no longer found in Death Valley (Wells and Woodcock 1985; Woodcock 1986), and Joshua tree and Utah juniper, which have moved upslope 800 m (2,600 ft) and 1,400 m (4,600 ft), respectively, in the adjacent Panamint Range (Spaulding 1980, 1983, 1985, 1990a, 1990b; Spaulding and Graumlich 1986; Wells and Woodcock 1985).

The available data suggest that the primary transition to a near-modern environment, including white bursage, creosote bush, and brittlebrush, took place in the southeastern Great Basin between 12,900 and 11,600 cal BP, with both white bursage and brittle brush appearing at 425 m (1,395 ft) in the Panamint Range by 11,900 cal BP (Woodcock 1986). Spaulding found white bursage alongside Utah juniper, shadscale, and limber pine in northern Eureka Valley at 9800 cal BP, which is seemingly at odds with significantly warmer temperatures after 10,800 cal BP (Koehler and Anderson 1995; Wigand and Rhode 2002), but additional data from southern Nevada indicate that there was a resurgence of these communities alongside increased summer monsoonal moisture from 10,800 to 9600 cal BP (Quade et al. 1998; Spaulding 1977, 1985; Spaulding and Graumlich 1986; Wigand and Rhode 2002).

The pattern of woodland communities (e.g., limber pine, whitebark pine, and Utah juniper) near valley floors after 10,100 cal BP gives a distinct mark to the early Holocene vegetative transition across the Great Basin (Mehringer 1977; Rhode 2000; Wigand and Mehringer 1985; Van Devender et al. 1987; Wigand and Rhode 2002). In the northwestern Great Basin pollen records show a retreat of juniper farther upland by 11,100 cal BP in the Steens Mountain vicinity alongside the expansion and formation of local lakes (Mehringer 1985, 1986). Conditions approaching modern are seen in south-central Oregon in Warner

Valley by 10,100 cal BP, and extensive wetlands disappeared in the Alkali Lake basin by 10,800 cal BP. (Wigand and Rhode 2002). This latter date appears to represent a threshold in the Lahontan basin area as well, corresponding with the latest dates on lithoid tufa at Pyramid Lake (Benson et al. 1995; Wigand and Rhode 2002). On the margins of the Carson Sink, the pollen record from Hidden Cave suggests the presence of pine and sagebrush after 11,500 cal BP. Replacement of these plants by greasewood and saltbush in modern proportions occurred by approximately 10,100 cal BP (Wigand and Mehringer 1985; Wigand and Rhode 2002), and probably earlier, as indicated by pollen in fecal matter from the Spirit Cave burial dated 10,600 cal BP (Wigand 1997).

In the eastern Great Basin, the regression of Lake Bonneville from its Provo level about 17,000 cal BP provides a benchmark from which to discuss changing biotic patterns (e.g., Benson et al. 1992; Currey 1990; Currey and Oviatt 1985; Madsen and Currey 1979; Oviatt 1997; Oviatt et al. 1992; Wigand and Rhode 2002). Packrat middens and pollen data from various areas in the Bonneville basin vicinity indicate an expanding woodland community after the lake began to recede (Rhode and Madsen 1995; Rhode 2000; Wigand and Rhode 2002). Much cooler and slightly moister conditions than today (but warmer than Provo times) allowed for the proliferation of limber pine, prostrate juniper, and sagebrush down to the basin margins from 15,600 to 12,900 cal BP. Increasing shadscale, rabbitbrush, and other xeric shrubs signal the move to a more modern desert setting shortly thereafter (Bright 1966; Beiswenger 1991; Rhode and Madsen 1995; Wigand and Rhode 2002). Rhode and Madsen (1995; Rhode 2000) suggest temperatures prior to 12,900 cal BP may have been

6-7°C cooler than at present, although they appear to have been slightly warmer than during Provo times.

Data representing the Younger Dryas are limited, but it appears that the period was cooler and wetter for at least some period of time before resuming a warming and drying trend (Grayson 1998, 2000; Louderback and Rhode 2009; Madsen and Currey 1979; Rhode and Madsen 1995; Rhode 2000). Wigand and Rhode (2002; also see Bright 1966; Grayson 2000; Rhode 2000; Spencer et al. 1984; Thompson et al. 1990) suggest that it was perhaps warmer and moister conditions during the Younger Dryas that pushed woodland communities upslope in favor of desert shrubs. Grayson (2000, also see 1998) argues that the abundance and diversity of certain small mammals at Homestead Cave—such as bushy-tailed woodrats, yellow-bellied marmots, Great Basin pocket mouse, pygmy rabbits, and voles—indicate cooler, moister conditions all the way until about 9300 cal BP. These fauna disappear or drop off considerably after this date. Although a subtle declining trend is apparent prior to this date, the change was abrupt after it. Hackberry was present at Homestead Cave alongside the small mammals above, and likely disappeared by 9000 cal BP (Rhode 2000).

Further evidence of transition to a distinctly xeric shrub community has been found at other regional sites—Blue Lake (Louderback and Rhode 2009, Grays Lake (Beiswenger 1991), Swan Lake (Bright 1966), Ruby Marsh (Thompson 1992), and Snowbird Bog (Madsen and Currey 1979)—and indicate that a close-to-modern floral profile was in place by 9500-8800 cal BP. This timing is repeated elsewhere in the Great Basin (Grayson 1993; Hockett 1998; Nowak et al. 1994; Wigand and Rhode 2002).

From the perspective of the ORB delta, all these data support the wetland dates described in the previous chapter that indicate its existence from approximately 12,900 to 9900 cal BP, and perhaps several hundred years later, but there are few other details. The Gilbert lake transgression occurred during the Younger Dryas in this period, implying a pronounced cooler, wetter interval. Recent pollen data from Blue Lake provide some insight (Louderback and Rhode 2009). Blue Lake is a spring-fed marsh system that drains onto the open playa the margin of the basin 40 km to the west. Louderback and Rhode (2009) find that pine, presumably limber pine, existed at this location to approximately 12,000 cal BP, at least several hundred years later than indicated in other records, and that it declined abruptly before rebounding shortly thereafter to persist until about 11,000 cal BP. For the interval of approximately 11,800 and 11,300 cal BP, Louderback and Rhode (2009) interpret the presence of aquatic snails, ostracods, and brine shrimp fecal pellets in their Stratum 6 to indicate a shallow marsh associated with a Gilbert-phase lake. Overlying peat suggests that the Gilbert-phase lake retreated and that the Blue Lake wetland was again in place by 10,800 cal BP. What is especially intriguing about the Blue Lake record is that the marsh began to decline near 9800 cal BP to the point of virtual desiccation by about 8000 cal BP (Louderback and Rhode 2009). Considering that Blue Lake currently maintains a robust marshland, this is a pointed reflection of the scale of regional wetland habitat loss during the Early Holocene.

Models for Paleoindian Wetland Adaptation

People may have abandoned some areas of the Great Basin by 9500 to 8500 cal BP, and distinctly overhauled their strategies for land use and technology in others (cf. Antevs 1948; Beck and Jones 1997; Elston 1982; Grayson 1993). An important aspect of this transition was a broadened subsistence approach that more fully exploited alluvial plains, fans, and upland environments alongside still-available wetland habitats (Aikens and Madsen 1986; Elston 1982, 1986; Fowler and Madsen 1986; Grayson 1993; Jenkins et al. 2004; Thomas 1985; Warren and Crabtree 1986). Notably, this transition included intensive seed processing using ground stone milling equipment.

Debate continues as to whether the Paleoindian adaptation in the Great Basin represents a variation on a large-game hunting strategy, or if it is a more distinctive wetland-oriented lifeway much like that described in the previous section for people later in time, albeit at a larger scale (see Beck and Jones 1997; Bedwell 1970, 1973; Campbell and Campbell 1935; Campbell et al. 1937; Jenkins et al. 2004; Jennings 1957, 1964; Jones et al. 2003; Willig 1989; Willig and Aikens 1988). The association with wetland habitats implies subsistence settlement strategies more akin to Archaic adaptations, prompting connective labels such as "Paleoarchaic" or "Pre-Archaic" (Beck and Jones 1997; Elston 1982, 1986; Elston and Zeanah 2002; Graf and Schmitt 2007; Jennings 1986; Simms 1987; Willig 1989). However, consistent with Paleoindian practice elsewhere in North America, the early inhabitants of the Great Basin were highly mobile, used little to no ground stone, and had reduced diet breadth compared to later peoples (Haynes 2007). This suggests regional variation from an essentially Paleoindian adaptive pattern, but hard evidence either way remains limited. A key question that has emerged is: what subsistence priority was driving settlement mobility decisions (Elston and Zeanah 2002; Madsen 2007; Pinson 1999, 2007)? Was it the high-payoff pursuit of large game animals or the maximization of diverse and reliable but lower-payoff plants and small animals available in wetlands? Surely, worrying about labeling people as

Paleoindian, Archaic, or otherwise can miss the point of understanding behavior in its own right (see Willig and Aikens 1988), which is the subject of recent ecological research; nevertheless, a marked adaptive shift seems apparent archaeologically, and it remains convenient to couch the problem in these terms.

Among Great Basin Paleoindian peoples, a distinction must be made between those using fluted projectile points and those using GBS-series points. Although a cultural distinction cannot be demonstrated (Beck and Jones 1997, 2010; Jones and Beck 1999; Willig and Aikens 1988), these technologies appear quite different in design and occurrence, the former being typical of the North American Paleoindian pattern. Sites with fluted points are sparsely found in the Great Basin. Stemmed technology is obsidian- and FGV-oriented, and scattered ubiquitously (by comparison) along old shorelines and distributary systems. This pattern endured to the end of Paleoindian times and is reflective of a fully regional adaptation (Beck and Jones 1997; Bedwell 1973; Willig and Aikens 1988). This adaptation and its association with stemmed points is usually implied when the wetland strategies of Great Basin Paleoindian groups are discussed (Bedwell 1973; Elston 1982; Elston and Zeanah 2002; Simms 1987, 1988; Willig 1989; Willig and Aikens 1988).

Despite some evidence that Paleoindian groups used upland areas and ate large game (e.g., Elston 1994; Heizer and Elsasser 1953; Jenkins 2007; Rusco et al. 1979), other data support a wetland-oriented strategy. In recent work, Pinson (1999, 2007) finds the use of upland ungulates to be reduced by comparison to Archaic groups, with settlement focused on lakeside areas, where it is implied that people could maximize marsh resources. Other data from across the Great Basin suggest a similar diet (e.g., Dansie 1997; Delacorte 1999; Fry

1976). Indeed, the 10,600 year-old Spirit Cave burial reflects an individual tied to the wetlands in the Carson Sink (Dansie 1997). Coprolite analysis indicates that fish, including tui chub, dace, and sucker, were important (Eiselt 1997), and residual pollen consists of marsh plants, such as cattail and sedge (Wigand 1997). The burial is also associated with a rabbit-skin blanket and unique tule matting, further demonstrating a close relationship to the wetlands (Dansie 1997; Fowler et al. 2000).

Pinson's (1999, 2007) findings suggest a land-use model similar to that seen for people in the late Holocene at Stillwater Marshes. She emphasizes the great variability in wetland productivity at the Pleistocene-Holocene transition to argue that Paleoindian foragers must have been sensitive to starvation factors and thus would tend to rely on the stable wetland resource set over centering their subsistence on unreliable large-game populations (Pinson 1999). As Madsen (1999, 2002, 2007) further points out, although many basins were well-watered and may have possessed wetlands, there was likely great volatility and seasonal equability in the climate of the Younger Dryas (also see Mayewski et al. 1993; Zielinski and Mershon 1997). This would have had the secondary effect of creating volatility in resource availability, especially in large game numbers. Pinson's (1999, 2007) analysis of faunal assemblages from several sites in the northern Great Basin indicates that lagomorphs were important to early diets, and that dependence on artiodactyls does not come until the early-middle Holocene. The sites used in her investigation date between roughly 10,800 and 9900 cal BP, making them relatively late in the Paleoindian time frame. Pinson (1999) argues that people at the time were concerned about unpredictability in resource availability and thus minimized food-getting risks by focusing on the most reliable resources in the most reliable and biotically diverse habitats (i.e., wetlands).

Still, lithic sourcing studies indicate that Paleoindian peoples moved faster and farther than people in the middle and late Holocene (Jones et al. 2003). Paleoindian groups also did not have the same population constraints as those later in prehistory, thereby allowing them to move at a large scale from basin to basin rather than use single basins intensively (Beaton 1991; Elston 1982, 1986; Elston and Zeanah 2002). Wetlands could well have provided a stable subsistence base full of resources used throughout Great Basin prehistory, but the abundance of these resources in wetter times (regardless of their variability) combined with low population densities may have made it worthwhile for people to move frequently to access high-ranking large-game animals, using staple wetland resources to buffer this behavior. As discussed earlier in this chapter, greater regional productivity should promote greater mobility among resource patches.

Elston and Zeanah (2002) take this perspective in assessing Pinson's (1999) model. Pinson (1999) argues that the environmental variability in a watershed from year to year would have more impacts on associated large-game animals than the wetlands themselves, making hunting a risk to be mediated or avoided. Elston and Zeanah (2002:116-117) doubt the importance of risk avoidance in Paleoindian strategies and see priority given to large-game hunting as the primary reason people would move at all given the reliability of wetlands at the time; in this context, hunting solves some resource scheduling issues related to the sexual division of labor, alleviates food-storage needs, and allows for the dietary benefits of high-ranked prey (cf. Kelly 2001; Zeanah 2004). Wetlands also contained readily accessible resources for women and children to gather and provide the bulk of caloric intake; upland resources, especially large game animals, would be more efficiently taken logistically and brought home by task groups predominately comprised of men (Elston and Zeanah 2002; Kelly 2001; Zeanah 1996, 2004; Zeanah et al. 1995). From this perspective, Paleoindian foragers were willing to take on procurement risks for the higher payoffs of large game because they were already surviving well-ahead of variances in resource availability.

Madsen (2007) proposes that if the Elston and Zeanah (2002) model is correct, then the high mobility often inferred from the long-distance transport of obsidian (cf. Jones et al. 2003) may only reflect the movements of the task groups that are away from home rather than the regular movements of the whole group. Paleoindian strategies may have been much like those of people later in time whereby they would stay in productive basin wetlands as long as they could. He refers to this as a "lowland" strategy as opposed to the more upland-expanded adaptation used in the Archaic. This follows from the ecological literature in which people should only move from one patch to the next when the return rates for the one they are in fall below what could be expected elsewhere (Madsen 2007:18). Thus, we should expect that the primary mechanism for Paleoindian residential movement would be the size of the wetlands being used: if they were large, people would not have to move much (or they would move short-distances within the patch), but if they were small and widely scattered, high mobility would be necessary. The low population and variable climate of the times would have made this a viable strategy. These factors would be relative to expectations for resources across the mobile territory; that is, if the highest-ranking resources could be expected across several patches, then the point of diminishing returns at any given patch would come more rapidly than when these expectations were lower.

Summary

While wetland habitats were important to Great Basin hunter-gatherers throughout prehistory, Paleoindian adaptations appear represent a unique dependence. Never since has there been as much water as at the Pleistocene-Holocene transition, and the earliest inhabitants of the region were in a better position than anybody afterword to optimize use of it at a large scale. This chapter provides a description of wetland habitats, an overview of archaeological research on their role in human use of the Great Basin, their place in Pleistocene-Holocene-transition environment, and a discussion of current models for the role of wetland resources in Paleoindian adaptation to the region. The presence of wetlands in the various internally-drained basins of the region and the apparent Paleoindian emphasis on them suggests that examining settlement mobility at a basin-to-basin scale is appropriate.

As water sources in a desert, the importance of wetlands is fundamentally obvious, but previous research indicates that their significance to settlement-subsistence strategies is always relative to the broader distribution of key resources across all targeted habitats. Consistent with optimal foraging models, people should be more mobile across more patches when regional resource productivity is high than when productivity is low because this allows them to continuously pursue the dietary resources that are the highest ranked, human population pressures notwithstanding. Within this structure, people must also maximize foraging efficiency within their own groups and their sexual division of labor, always reconciling discrepancies in men’s and women’s subsistence interests.

These relationships are the ties that bind wetland habitat use by humans across Great Basin prehistory and provide the basis for examining the differences. Current research on Paleoindian land use turn on what subsistence goals drove mobility decisions. For Paleoindian groups, the productivity of the numerous regional wetlands may have warranted rapid and far-ranging movement among basins to take advantage of abundant large game animals. In a rich landscape, the decision to move may be based on high-payoff, male-oriented subsistence interests even while other wetland resources gathered primarily by women provided the stable dietary requirements (Elston and Zeanah 2002). This division of labor is consistent with ethnographic record of hunter-gatherers.

Alternately, the climate may have fluctuated so extremely over short intervals that it was difficult to predict that large game animals would always be present when moving into an area. As Pinson (1999) points out, people living under these circumstances would tend to maximize the various plants, small mammals, fish, birds, etc. of the wetlands to maintain subsistence reliability. This is more consistent with the trend through prehistory, where regardless of the fact that hunters continued to logistically exploit areas surrounding wetland residences, the decision to move usually rested on foraging payoffs from the near-residence resource base and thereby women's subsistence interests (Kelly 2001; Zeanah 2004).

Direct subsistence data are required to most effectively evaluate these models, but indirect data, such as lithic artifacts, can provide additional lines of evidence pertaining to how people moved across the landscape and how their movements changed according to ecological conditions. A technological model aimed at making this connection is developed in the next two chapters.

CHAPTER 4

A MODEL FOR GREAT BASIN PALEOINDIAN LITHIC ECONOMY, I: DESIGN

In 1979, Goodyear published an often-cited paper on the preference for high-quality cryptocrystalline silicate (CCS) stone (i.e., chert) by North American Paleoindian toolmakers (also see Goodyear 1989). He reasoned that this would be the best toolstone for a highly mobile lifestyle because its plasticity and fine-grained texture offer a superior balance of strength and flaking control. These qualities would be especially important for the technically-sophisticated bifacial tools seen in early assemblages. People could minimize breakage while maximizing their ability to modify tools as necessary while also generating usable flakes from bifacial cores. This would be a particularly beneficial strategy for people specializing in hunting migratory game (or migrating to hunt game), who might find themselves at some distance from toolstone sources. Kelly and Todd (1988) use the same logic to argue that this method of lithic resource use is evidence of the residentially mobile strategy with which people rapidly colonized the Americas.

This has been a serviceable generalization, but more recent studies reveal that Paleoindian technology did deviate, perhaps in relatively quick order as people settled into specific regions (cf. Meltzer 2002). This may be no truer than in the Great Basin where early assemblage patterns sometimes run in direct contradiction to the model. It is easy to infer what lithic technology should look like if key constraints are loosened. For example, as residential movements become less frequent, tool transportability should decrease in importance; as diet breadth increases, hunting-related tools should lose formality; as particular places are increasingly relied upon, informal tools and local toolstone should be more common. This is the stuff of rudimentary lithic analysis by today's training. The challenge in a regional analysis is to break from cataloging such variations as mundane twists on overarching themes to better explaining them on their own terms.

This chapter details lithic technology according to its various microeconomic terms. My intent is to provide an optimality model that predicts Paleoindian technological response to ecological conditions and toolstone characteristics in the Great Basin. I begin with a discussion of the physical constraints of lithic reduction with regard to three key artifact classes: bifaces, flake blanks, and cores. Different toolkit designs are then considered according to their potential risks and limitations, particularly in terms of the qualities and availability of lithic resources. This provides a baseline for predicting how the utility of stone tools would be monitored and manipulated by people under local circumstances.

Design Factors

Flaked stone technology is viewed here as a traditional design within which people manage functional requirements against the physical absolutes of lithic resources. They do this recognizing the costs and benefits of their preference relative to alternatives. While technological behavior can be well-described by examining the tradeoffs between these costs and benefits under certain constraints, modeling from these alone may not indicate singularly decisive factors. People must also estimate the risks and implications of their choices if they are to make timely modifications or outright design changes. This provides a more robust framework for understanding technological decisions as they play out according to toolmaker expectations of toolstone availability and tool use requirements.

Physical Rules

Archaeologists have established that bifaces were important to Paleoindian peoples throughout North America, but mathematical workups suggest that it is small flake tools, not bifaces or cores, that provide the most edge utility by weight (Kuhn 1994; Surovell 2009). If the single goal is the transport efficiency of tool-ready working edges, then mobile people should select flake blanks over cores because there is no wasted stone; the flakes are already removed and ready to use without unneeded mass. If people do wish to transport cores, then they should carry the largest ones they can to maximize usable mass. Similar logic follows for bifaces because flakes must be removed to realize their full utility, resulting in at least some wasted material in the process (Prasciunas 2007). Prasciunas (2007) argues that bifaces as cores would always be a less efficient option than amorphous cores when transport is important; therefore, a biface must have some functional purpose as a tool to warrant its manufacture in a mobile toolkit.

As noted above, the doubling of bifaces as both cores and tools has long been the implicit reason for their presumed value to Paleoindian toolmakers (Amick 1999; Goodyear 1979; Kelly 1988; Kelly and Todd 1988; Parry and Kelly 1987; Prasciunas 2007). Surovell (2009) clarifies the utility of bifacial core tools mathematically and finds that much depends on length and flaking efficiency as to how these should take shape. His model is detailed in Figure 17. For the greatest transport efficiency, bifaces should be as long and thin as possible (within practical limits) because this maximizes the working edge relative to other removable stone; in effect, there is no need to take on the flaking waste associated with acquiring usable edge from removing flakes. However, if there are limits on manufactured

1. Is a bifacial tool needed?

No........make flake blanks $$e_c \le e_k \equiv \frac{n(l_t - m_t)}{nfl_t^3 + w_c} \le \frac{n(l_t - m_t)}{nfl_t^3} \quad (1)$$

Yes.......go to 2

The transport efficiency of a core (i.e., utility divided by transport cost) can be compared to that of a set of flake blanks by adding waste to the transport of blanks. Where n is the number of flake blanks, l_t is blank length, m_t is the minimum usable portion (the "slug"), f is the ratio of thickness to length (usually between 0.1 and 0.25 [Kuhn 1994]), and w_c is flaking waste from the removal of usable flakes, the transport efficiency of flake blanks (e_k) will always be greater than that of a core (e_c) because there is no waste (Eq. 1).

2. Will biface reduction flakes be needed as tool blanks during transport?

No.......make thin bifacial tools $$e_{bt} \ge e_{bc} = \frac{l^2 - m_t^{\ 2}}{l^2 t} \ge \frac{x(l^2 t - m_c^2 t_m)}{l^2 t} \quad (2)$$

Yes......go to 3

If there is no need for a bifacial tool to function as a core then transport efficiency (e_{bt}) would be maximized by making it as thin (i.e., lightweight) as possible to remove unusable mass at the midsection. Where m_c is minimum usable core length, t is thickness, t_m is thickness after useful as a core, and x is reduction efficiency (see discussion below), the transport efficiency of a bifacial core (e_{bc}) will always be less than that of a bifacial tool because of added thickness (Eq. 2).

3. Is flaking efficiency high? $$e_{bct} = \frac{l^2 - m_t^2 + x(l^2 t - m_c^2 t_m)}{l^2 t} \quad (3)$$

No.......make thinner bifacial core tools $$l > \sqrt{x m_c^2 t_m + m_t^2} \quad (4)$$

Yes......make thicker bifacial core tools $$l < \sqrt{x m_c^2 t_m + m_t^2} \quad (5)$$

The efficiency of a bifacial core tool (e_{bct}) combines the efficiency models for bifacial tools and bifacial cores (Eq. 3). When there is no limit on manufactured biface size, large, thin core tools are preferable, with the existing margin serving more efficiently as tool edge than removed flake blanks, which entail flaking waste (Eq. 4). High reduction efficiency, however, can offset this by reducing this waste. With smaller bifaces especially, greater thickness would provide additional usable tool edge to supplement the diminished biface margin (Eq. 5).

Figure 17. Mathematical relationships among different tool reduction options. The key represents mathematically discrete choices among bifaces, flake blanks, and cores based on transport efficiency at their time of manufacture following Surovell (2009).

biface length, then a more efficient option may be to make a thick bifacial core because tool utility can be extracted at minimal expense to the tool margin. At this point, the efficiency of flaking, whether by skill or material quality or otherwise, determines exactly when a bifacial core should be made thick or thin. If flaking efficiency is high, a biface should be as thick as possible relative to its minimum usable length because utility can be extracted from the extra mass with minimal waste.

This last point seems counterintuitive because reduction efficiency is usually associated with biface thinning, not proportionate thickening. This bears on a few assumptions of the Surovell (2009) model, which is based solely on the effective removal of usable tool edge. Foremost is that all tool edges are considered equal. Such equality is not always the case because bifaces may serve different functional needs—as choppers, knives, or otherwise (see Kuhn 1994, 1996; Morrow 1996)—that impinge on pure toolstone utility. Biface edges are not as sharp as flake edges, and their cutting efficiency should diminish as proportionate biface thickness increases. This would only further discourage emphasis on the "core" side of a bifacial core tool. Moreover, Surovell's (2009) assumption that the minimum usable bifacial core size is larger than the minimum usable bifacial tool size means that a bifacial core tool should only be thick if just larger than the minimum usable core size then thin when smaller because its only value lies in being used as a tool. This is impractical and complicates reduction at the transition where wasted stone would be incurred as people try to make the tool more operable. These factors all further suggest that a thin bifacial core tool from start to finish would be the most efficient option.

Paleoindian peoples certainly fostered reduction efficiency and applied it toward biface thinning. Surovell (2009) finds this in Folsom toolkits—which are among the most toolstone efficient and transportable known prehistorically—alongside infrequent use of biface thinning flakes as tool blanks (core-struck flakes being favored). Clovis caches further attest to this priority in manufacture (Bamforth 2009; Kilby 2008). This reiterates the point that these physical relationships only serve as design constraints and the starting points from which to assess real-world technological decision-making. It would be shortsighted for prehistoric people to approach lithic resources in the way processed in Figure 17; rather, they would have known the limitations and strategized accordingly. For example, qualities which can only be measured relative to functional needs, such as durability and sharpness, would be factored in. Also, if people needed long, thin bifaces, they would go to sources where they could make them rather than restrict themselves to the thick-biface option described above. These decisions center on negotiating the costs and benefits of different approaches according to their probabilities of success and failure; i.e., their perceived risks.

Risk Minimization

Risks, like costs and benefits, are implied throughout the lithic technology literature. Risk studies in ecological research have burgeoned in the last 20 years, drawing from longstanding concepts in economic theory. Most researchers distinguish between *risk* and *uncertainty* as different types of unpredictability, the former manageable and the latter unanticipated (e.g., Cancian 1980; Cashdan 1990; Knight 1921; Stephens 1987, 1989; Winterhalder et al. 1999). Organisms react to risk out of a natural and, especially in the case of humans, experience-based understanding of a particular strategy in terms of its probability for success in meeting specific requirements. Uncertainty refers to unforeseen developments, whether potentially detrimental or beneficial, that require a response of unknown consequences, such as an environmental crash or a new technology. Uncertainty can be mitigated to some extent by information gathering.

People would always minimize technological risk through design, and this reaches into all of the socioeconomic factors involved in procuring and reducing lithic materials. Risk analysis is about understanding how strategies are chosen to minimize the potential for critical shortfall. The following discussion treats risk as a discrete design factor, recognizing that all the tools in a toolkit are unlikely to be produced together and that the reality of their production and use centers on fluid replacement as dictated by fluctuating conditions (cf. Winterhalder et al. 1999). This suits the purpose of this chapter, which is to provide a baseline for examining how risk interacts with these conditions according to the cost and benefit factors that structure routine technological decisions.

We know from the mathematics above that there is no reason to carry a biface unless it has value as a tool, thus, the decision criteria are clear when a choice must be made between one and the other. However, this relates only to toolstone utility, not functional utility in the ability to perform a task, in which case there should be some overlap. Leaving aside for now exactly what these tasks might include, it suffices to say that a biface is a somewhat specialized design whereas flake blanks may be used as is or modified (even into bifaces) as necessary. Using transport efficiency as a currency, it is possible to examine the implications of choosing one method over the other even with specific functions being unknown. A useful measure of transport efficiency is bifacial edge per tool thickness.

(Anything that relates the tool edge to some unit of transportability, e.g., weight or edge angle, could serve as a measure, but thickness has straightforward archaeological implications and can commonly be measured as complete.) From this, less variance should be expected in the functional utility of a biface than of a flake blank, and this variance should get even lower with added refinement, especially thinning, to biface production.

Figure 18 shows hypothetical probability distributions for three variations on the yield of bifacial edge per tool thickness: thinned bifaces, roughout bifaces, and flake blanks. Each possesses a mean or expected return at its center, but this average is not so important to assessing risk as is the variance—a strategy with a higher mean return may not be preferred if unreliable. Flake blanks possess the greatest variance because they would only occasionally be made into bifaces (and likely crude ones at that). Thinned bifaces should have the least variance because they are specifically designed to maximize toolstone.

Which option should people choose? This depends on the context and costs involved. A brief review of some critical aspects of risk modeling is useful before returning to bifaces and flake blanks. A good technological design should minimize risk and offset constraints better than alternatives. Strictly defined, it should keep people from experiencing critical shortfalls (see Stephens 1990). This is a fundamentally situational problem, but one that can be scaled out to represent whatever people see as their "usual" situation. When people are sensitive to risk, they should employ strategies that minimize the chance for critical shortfalls; i.e., *risk averse* strategies. However, people may choose a risky, or *risk prone*, strategy in dire situations because even if the potential for success is

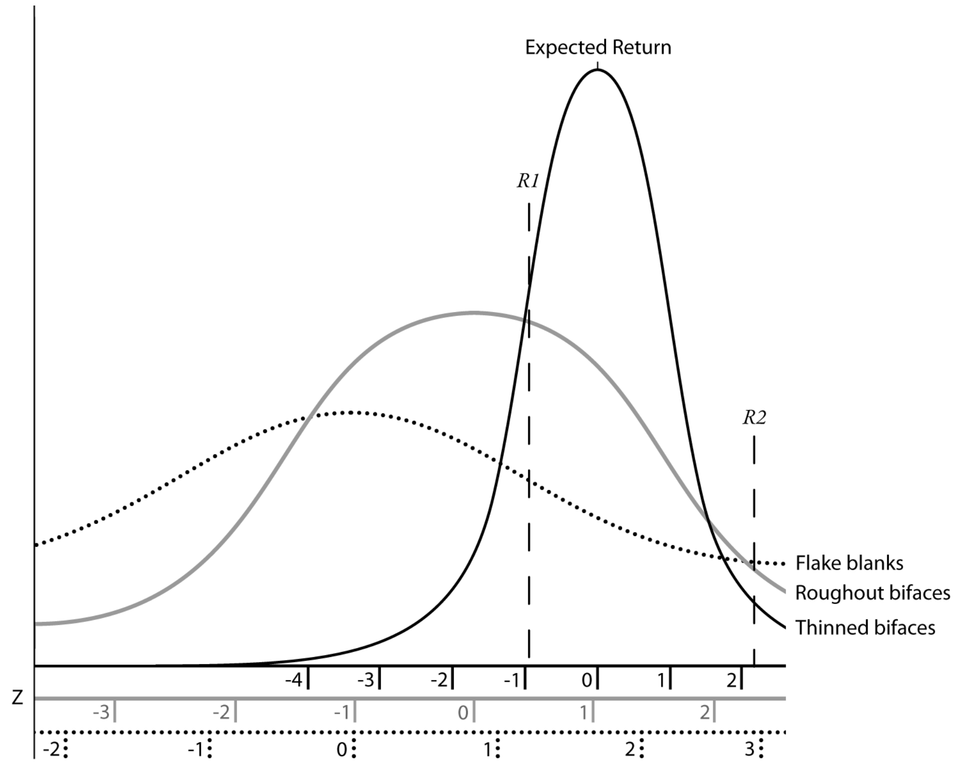


Figure 18. Normal probability distributions for three stone tool types. Each tool type has different variance and mean return for functional edge utility. R1 and R2 represent different requirements for the utility yield. People should select the tool option with the lowest variance as long as the requirement does not exceed the highest expected return (R1). If the requirement exceeds the expected return for the lowest variance option (R2), then the highest variance option should be chosen because it retains the highest probability for meeting the requirement. Z-scores are shown at the bottom of the graph for comparison using the Z-score model. The lowest score at a required minimum is the least risky option.

small, a chance remains that a required minimum need will be met. These concepts are borrowed from animal ecology research, where foraging strategies can be observed according to controlled food access. Experiments by Caraco et al. (1980; also see Stephens 1990) on the feeding habits of birds indicated that the choice between two food stations was a function of the variability in the amount of food present and the likelihood that it would meet energy budget requirements. If the birds had minimal food requirements, they preferred the less variable (i.e., more reliable) choice because there are numerous opportunities to avoid starvation; however, they would be risk prone if their energy requirements were above the expected return because a sufficient meal is more likely where there is greater variability, the rule being: if the required return is less than the mean return, then choose the less risky (i.e., low variance) alternative and vice-versa (Stephens 1981). The only exception to this rule occurs when energy budgets are secure because food availability never drops below what is needed to survive. In such circumstances organisms are said to be risk indifferent, and they may engage in effectively risk-prone behavior to maximize high payoffs where the implications of failure are negligible or non-existent.

Unlike birds, people improve probabilities and minimize risk in food-getting through technology. By definition, technology is indicative of a risk sensitive situation because it purpose is to improve reliability. Returning to Figure 18, hypothetical normal distributions for the yield of bifacial tool edge per thickness for flake blanks, roughout bifaces, and thinned bifaces are shown. If *R1* represents the required minimum, then thinned bifaces would provide the most reliable expected outcome, followed by roughouts, then flake blanks. However, if the requirement exceeds the expected return, as indicated by *R2*, then the probability of a successful outcome is best provided by choosing the high variance option, flake blanks in this case, because there are more opportunities for success.

In such cases where any combination of variance and mean return is possible, ecologists often use Z-score to assess different behaviors (Stephens and Charnov 1982; also see Bettinger 1991; Winterhalder et al. 1999). The Z-score represents deviations of an observation from the mean of a distribution measured in units of standard deviation, and it is derived by subtracting the mean from the raw score and dividing by the standard deviation. This is useful for distributions that do not share the same mean returns, such as those in Figure 18. The approximate Z-values for each distribution in Figure 18 are presented at the bottom of the graph. People generally seek to minimize the Z, and this is clear when *R1* and *R2* are compared to the scale; the lowest Z is provided by the low variance option to the left of the expected returns and by the high variance option to the right.

Another graphical way to view these relationships is by plotting mean return against standard deviation, as shown in Figure 19 (Stephens and Charnov 1982; Winterhalder 1986). For a risk averse situation, the optimal mean-standard deviation combination among any number of options is the one from which the highest sloping line can be connected to the minimum return as plotted on the y-axis. This is the combination that minimizes Z. If *R1* equals the minimum required bifacial tool edge per unit thickness, then the line would connect to the thinned bifaces design option.

In the real world, people choose among options against particular demands because these demands are always in flux. In terms of a mobile toolkit, a better view is that the required minimum represents the generally accepted parameters within which people see fit to design their technology. Thinned bifaces, roughout bifaces, and flake blanks are all options people would choose from according to whatever combination they believed was best suited for the immediate situation according to external factors (e.g., trip distance, occupation duration, raw material availability).

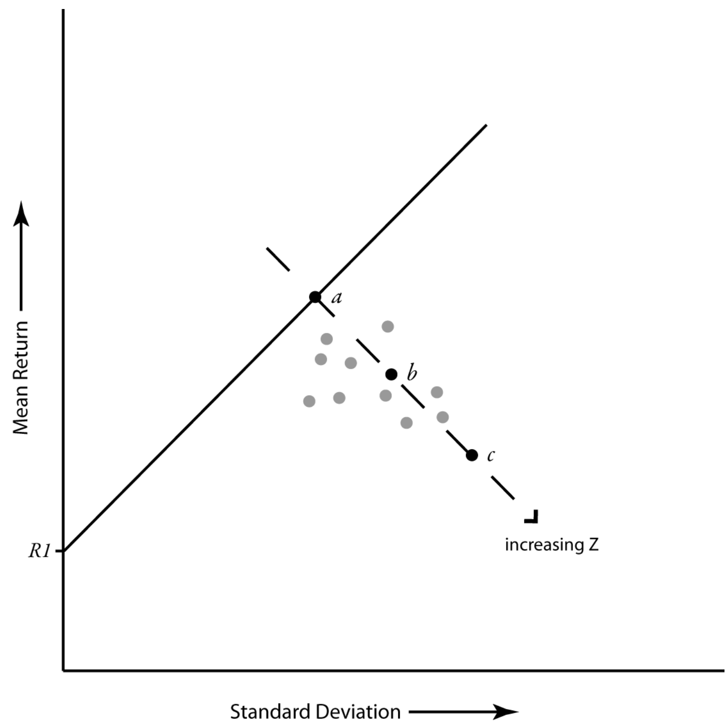


Figure 19. Graphical model for Z-score minimization. Various mean-standard deviation combinations represent alternative technological options. The optimal choice minimizes Z against the required minimum return (i.e., where the highest sloping line can be drawn). Among three highlighted options—a, b, and c—option a represents the optimal choice for the required minimum return R1.

The plot in Figure 19 shows three toolkit options assuming a range in which both bifacial tools and flake tools are anticipated as necessary for a particular trip. A linear pattern should be expected when there are several possible tool combinations, as the addition and subtraction of one over the other would equate to a regular change in the mean-standard deviation combination. As discussed above, where transportable bifacial tools are the sole requirement, then *a* represents, say, two thinned bifaces, while *b* represents one thinned biface and one flake tool, and *c* represents two flake tools. Alternately, if flake tools are necessary, we can simply exchange the tool combinations for *a*, *b*, and *c* in recognition that the desired outcome is different. In each case, *c* represents the high variance option to be considered only under critical or otherwise unique circumstances in which risk-prone behavior is necessary.

Risk Analysis in Lithic Studies

The above view of risk is not wholly consistent with previous applications in lithic studies, which are more focused on the more general ways risk can be reduced using stone tools (e.g., Bamforth and Bleed 1997; Bleed 2002; Bousman 1993; Hiscock 1994; Nelson 1996; Tainter 1996; Torrence 1989, 2001). In this sense, risk is more loosely discussed simply as a thing to be avoided, with most studies lacking any formal modeling (but see Elston 1992; Elston and Brantingham 2002).

In their review, Bamforth and Bleed (1997; also see Nelson 1996; Torrence 1989) see the prevailing definition of risk in lithic studies to be the "probability of loss," equating with the potential loss of food resources upon tool failure. They distinguish this from the "costs of loss," which are not directly related to the probabilities but do contribute to its extent and to how much investment should be placed in technology to avoid it. From this, they provide a heuristic model cross-tabulating production and application costs in terms of their potential for failure as a means of predicting risk reduction strategies; for example, extended manufacturing at quarries, caching, and careful design all represent high investments and thus entail high failure costs. This generalizing method has the drawback of working from informal arguments that are difficult to apply explicitly to specific cases, but the distinction of cost from probabilities is an important one because people also negotiate resource procurement costs using non-technological strategies, such as mobility, scheduling, and food sharing (see Grove 2010; Winterhalder et al. 1999); these all affect the level of investment in stone tools.

The definition used in this study—the probability of tool shortfall—implies that loss would be incurred if there are not sufficient tool forms in a mobile toolkit, and as discussed in the previous section, can be modeled in a manner more akin to ecological studies. Specific conditions, constraints, and options can be organized and related. This obviates the need to rely on loaded conventions common to organization-of-technology studies, such as reliability, maintainability, versatility, flexibility, etc., in favor of specific assessments of options relative to microeconomic factors. For example, Nelson (1996:136; also see Bamforth and Bleed 1997:115) argues that in situations where people specialize on a narrow set of resources, we should expect tools designed for "multiple use and portability." Nelson is referring to reliability in the Bleed (1986) sense, where tools are designed with significant upfront investment toward performance. "Reliability," as it is used in this study, refers to any number of strategies people use to minimize variance. Lithic technology varies by manipulation of a medium, not improvement upon a sharp edge; thus, a toolkit may contain tools that are generally expedient in terms of production costs but nevertheless perform their functions reliably, i.e., at low variance.

By contrast, Elston and Brantingham (2002) examine the risk implications of different microblade core strategies in northern Asia according to local environmental conditions and technological constraints. Comparing two core subtypes—wedge-shaped and boat-shaped—using the Z-score model, they see differences in their capacity to produce useable microblades and relate them to risk factors associated with exploiting the regional landscape.

Wedge-shaped cores are made from bifacial blanks and maximize toolstone, but they are also highly standardized and require initial pieces of material large enough to be worked into the optimal shape to generate microblades for use as insets in organic projectile points. Boat-shaped cores can be made more quickly by splitting sporadically encountered pebbles, but they are rounder in shape, which makes microblade removal less efficient; thus, while they maximize available material, this is at some loss of stone to core preparation and maintenance. Elston and Brantingham hypothesize that by supplementing wedge-shaped cores with boat-shaped cores, people could minimize risk on the post-Late Glacial Maximum landscape where microblades are a technology suited to hunting by mobile foragers in arctic/near-arctic environments. With a formal relationship defined, their model can be used in the region regardless of the ultimate answer to this hypothesis.

Summary

Returning to Great Basin Paleoindian technology, the risk factors discussed in this chapter provide a behavioral framework to examine the costs and benefits of different lithic resource use strategies. Thinned bifaces, roughout bifaces, and flake blanks are offered as three principal components of the technological system, each carrying with it different production efficiencies, functional capabilities, and transport requirements. How people managed these characteristics in particular circumstances is not only telling of general land use priorities, but it can also inform us on what situations entailed greater risk and to what extent people may have encountered resource stress, at least in a relative sense. A comprehensive understanding of the costs and benefits under local conditions (e.g., toolstone quality, distance, and distribution) is needed to identify when technology gets expensive. This is the subject of the next chapter.

CHAPTER 5

A MODEL FOR GREAT BASIN PALEOINDIAN LITHIC ECONOMY, II: COSTS, BENEFITS, AND THE RELATIVE EXPENSE OF STONE TOOLS

People prefer design options that are cost-effective, and they can be expected to change designs that become too expensive. Extraction, production, and transport of raw materials are crucial cost factors to ensure that a given technology is worth employing. Following from the previous chapter, the primary risk in Paleoindian lithic technology lies in what may be lost by failure to function properly, or simply by not having adequate supplies on hand. Toolkit designs should be flexible enough to accommodate these unknowns while also staying cost-effective. In other words, a good design should provide sufficient tolerances so that even at times when the risks and costs are relatively higher, there should still be an energetically advantageous margin. When this is no longer the case, we can expect the introduction of new tool forms, or complete technological overhauls (cf. Bettinger et al. 2006; Ugan et al. 2003).

This chapter focuses on how to measure aspects of Great Basin Paleoindian lithic technology in everyday use. This can be accomplished by comparing the relative costs and constraints of lithic resource use such that it is possible to understand how tradeoffs were manipulated according to changing conditions. I begin with descriptions of the available toolstones and their qualities, followed by a discussion of production and transport issues. Finally, expectations for how toolkits should vary according to these factors are offered, both generally and with respect to the distal ORB.

Toolstone Options and Characteristics

There are three primary toolstone varieties considered here: obsidian, fine-grained volcanics (FGV), and chert. These dominate Great Basin lithic assemblages throughout prehistory to varying degrees, with FGV being the most distinctive to Paleoindian times.

Obsidian

Obsidian is well known as a preferred material for flintknapping. Its glassy nature is conducive to refined percussion and pressure techniques, and this is apparent not only in the prehistoric record but from the showcase items created by modern flintknapping artisans. Correspondingly, flaked edges can be exceedingly sharp. Thin obsidian flakes can possess edges only three nanometers thick, or about three hundred-thousandths (0.00003) the thickness of a human hair (Buck 1982). Obsidian does vary in its quality but only to near negligible amounts in most cases, with some varieties having a somewhat sugary texture and others possessing extensive spherulites or bands of bubbly glass or pumice.

People usually gathered obsidian from surface or near-surface deposits in both primary and secondary contexts. Cobble size represents the most distinctive limiting factor on obsidian selection. It can range from no larger than a marble at some sources where it originated as volcanic ejecta, to automobile-size at others where massive flows occurred; however, fist- to cantaloupe-size cobbles conducive to most flintknapping needs can be found at the primary sources.

For archaeologists, one of the most valuable characteristics of obsidian is that it can be chemically traced to specific geologic sources. Figure 20 shows the primary sources of

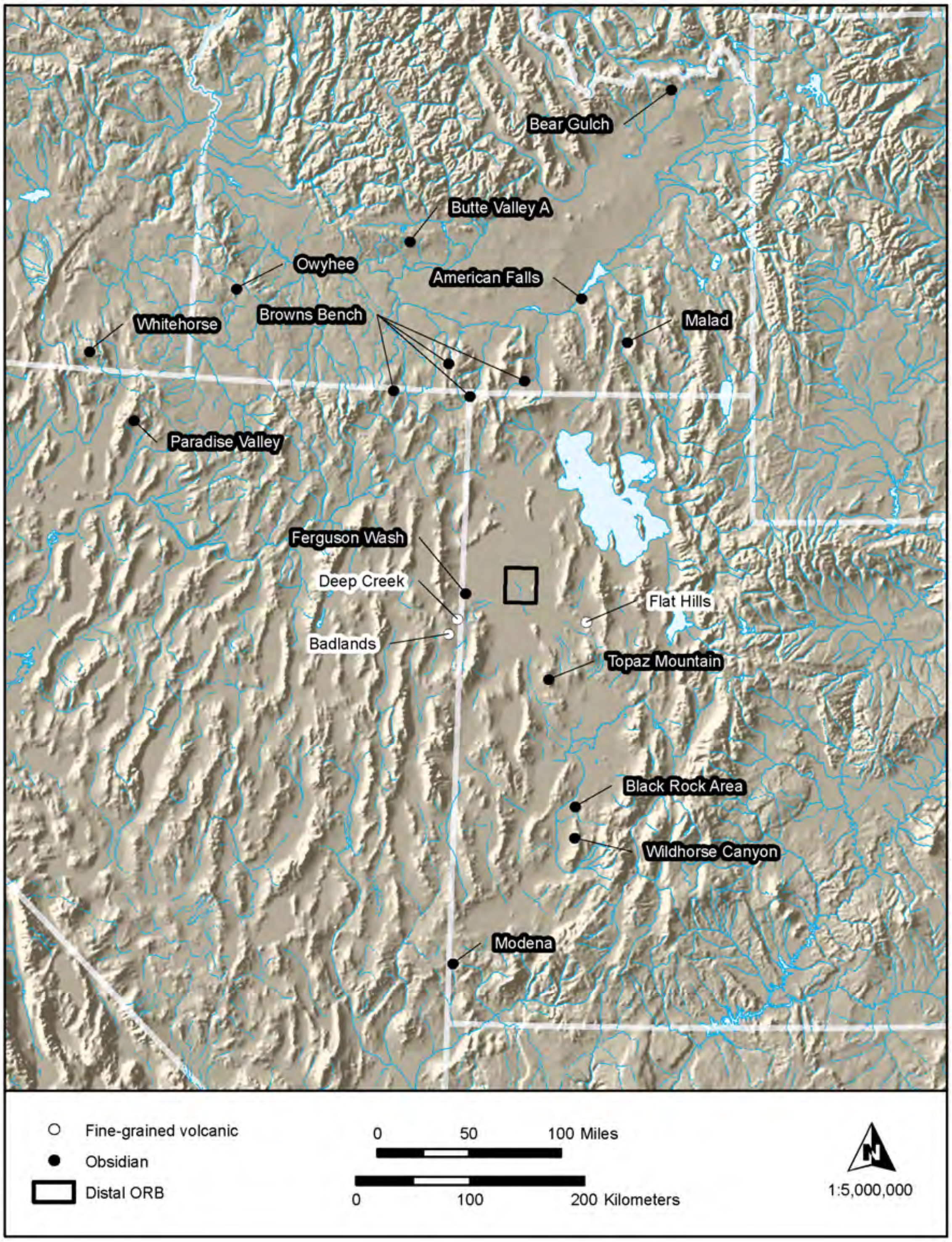


Figure 20. Geochemical sources of obsidian and FGV found on the distal ORB.

obsidian in the eastern Great Basin. Sourcing studies have taken place intensively since the 1980s to provide a nearly complete view of obsidian distribution throughout the western United States and can be viewed online at the Northwest Research Obsidian Studies Laboratory website (http://www.obsidianlab.com/). The distinctive pattern that has emerged from these studies is that obsidian largely surrounds the central Great Basin, where it is nearly absent. Obsidian is ubiquitous in Oregon and nearby parts of Nevada and California then scattered along the Sierra Nevada into the Mojave Desert through southern Nevada and back north through western Utah and into the southern Idaho.

Chert

Various cherts can be found throughout the Great Basin, but rarely in massive forms or traceable primary sources. Unlike the lithic terrane east of the Rocky Mountains, where bedded cherts of marine origin can sometimes extend for many, even hundreds, of miles (e.g., Knife River, Edwards Plateau, Flint Hills, Alibates, Burlington), the Great Basin contains numerous localized volcanic and sedimentary rock precipitates that might be labeled under any number of related names, such as chalcedony, jasper, opalite, or sinter (cf. Luedtke 1992). These materials originate in the various veins and joints of different rock types, with those from the volcanic rocks such as rhyolite containing the highest silica. Where sedimentary geology dominates in the mountain ranges, the valley alluvium can contain sporadic to abundant chert availability stretching for miles. These are of highly variable quality, however, and are usually only found in small nodules.

Qualitatively, these materials do not all share the flakeability and plasticity usually ascribed to chert. Depending on weathering and silica content, some chert varieties can be brittle to crumbly, around more cohesive, unweathered portions. The fact that these materials rarely occur in large outcrops or as large nodules constitutes a significant limiting factor for its reliability as a source for large stone tools. There are exceptions, such as the extensive Tosawihi opalite in north-central Nevada (Elston 1992), but archaeological sites usually contain a mix of chert from diverse sources (based on color) or from immediately available sources. This is to say that chert is common enough that for highly mobile people there is usually no telling where it originated, and people using small territories simply relied on what was nearby. In most cases, there would be little investment in finding and accessing these materials, as they could easily be gathered on an encounter basis.

Fine-Grained Volcanics

As has become accepted in Great Basin lithic studies, the term fine-grained volcanics (FGV) is used here to refer to the assortment of non-glassy volcanic rocks commonly used by people for stone tools (see Jones et al. 1997). This is analogous to what the archaeological literature often refers to generically as "basalt," but this term now appears inaccurate based on geochemical analysis.

I had whole-rock geochemical analysis conducted on several notable varieties of FGV in the Great Basin, and these are indicated according to their specific rock types in Figure 21. Badlands A and Deep Creek A occur near each other south of Wendover, Utah, in the Deep Creek-Whitehorse Flat vicinity on the west side of the Bonneville basin, and Flat Hills A and D can be found on the opposite side of the basin near Dugway, Utah. These are the primary sources for FGV stone tools on the ORB delta, especially Flat Hills D (Page 2008). Alder Hill, Gold Lake, and Watson Creek occur in the north-central Sierra Nevada.

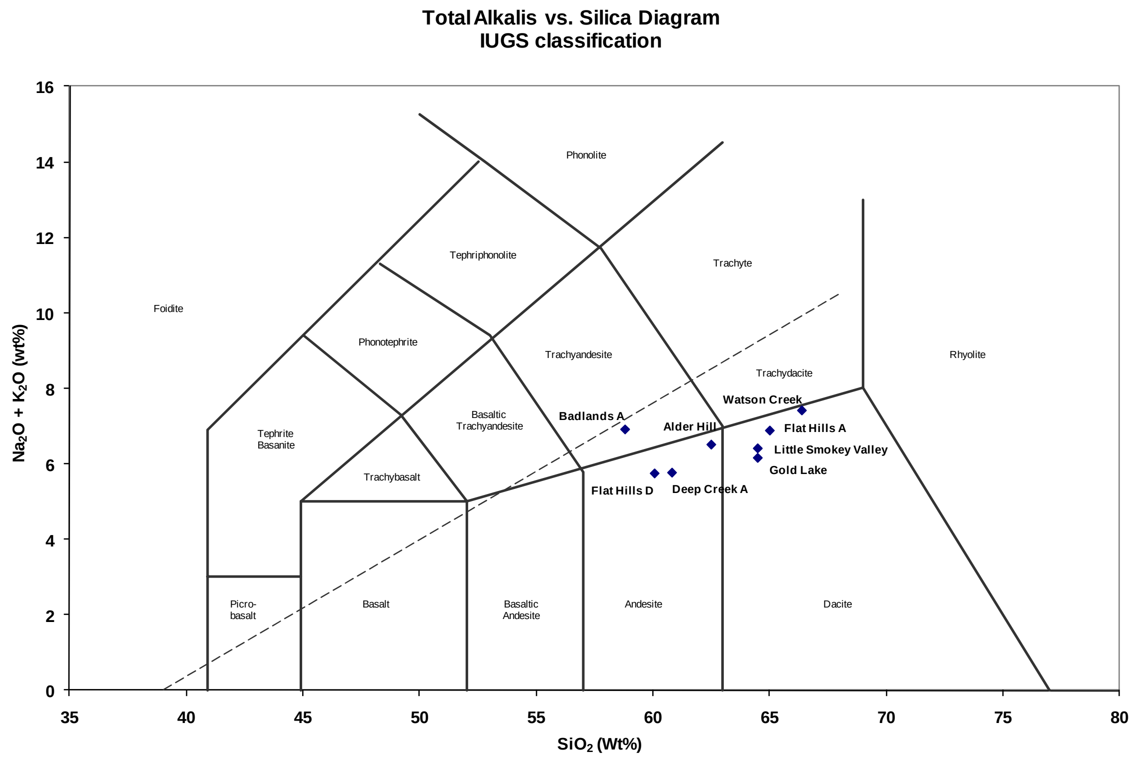


Figure 21. International Union of Geological Sciences (IUGS) classification of fine-grained volcanic rock types for several noted Great Basin sources. Chart from online source (http://www.neiu.edu/~kbartels/Petrology04.html). The data are single samples from individual rocks.

between Lake Tahoe and Sierra Valley. These sources were used extensively well into the Middle Archaic (Duke 1998). The Little Smokey Valley source refers to the valley of the same name in east-central Nevada and was commonly used by Paleoindian toolmakers (Beck et al. 2002).

By IUGS classification (Figure 21), these sources represent dacites and andesites, but from an archaeological perspective, true basalt is better thought of as the varnished material people preferred for petroglyphic rock art than as a viable toolstone. Additional sources for which only silica content has been determined, such as Goldstone 1 from the Mojave Desert as I discuss below, indicate that FGV toolstones usually exceed 60 percent SiO_2 by weight.

The term "fine-grained volcanic" is somewhat counter-intuitive from an archaeological perspective because, relative to obsidian and chert, FGV represents the coarse-grained end of the spectrum. It is in the purely geological sense that it seems most appropriate as a gross separator of volcanic (extrusive) versus plutonic (intrusive) igneous rocks, such as granite. It is obvious from FGV artifact assemblages that texture is a significant limiting factor because coarse stone was usually used for crude, expedient tool forms; occasional refined tools of this material are found but are more the exception than the rule (e.g., Basgall 2000; Davis et al. 1969; Duke and Young 2007; Jones and Beck 1999; Tuohy 1970).

The primary limitations of FGV appear to be brittleness and granularity, with even slight increases in granularity exponentially exacerbating the problem of brittleness. Increased granularity requires greater force to detach flakes from a matrix of cohesive and interlocking grains, which creates broader flakes with larger bulbs of percussion as a result. Applying greater force also adds error and failure risk during reduction simply by making the athletic movement of flaking more forceful and less accurate.

My own experience examining FGV assemblages in the Great Basin suggests that there may be a textural threshold where certain varieties are sufficiently fine-grained and flakeable that refined reduction techniques, especially biface thinning, can be applied to them systematically. Thin-section analysis was conducted on several of the FGV varieties

Figure 22. Microscopic and macroscopic images of several regional FGV sources. Microphotographs taken at 100x magnification.

presented above in an effort to tie microscopic textural features to associated technological patterns. Figure 22 shows thin sections for Little Smokey Valley, Flat Hills, Alder Hill, and Cedar Mountains materials, in general textural order from finest to coarsest grain. In each, elongate plagioclase and quartz crystals can be seen stalled in flow bands.

The primary distinction made among the thin sections is that the first, from Little Smokey Valley, is clearly distinct from the rest with a fine, velvety matrix. The next three—Flat Hills D, Flat Hills A, and Alder Hill—represent a second textual tier and are similar in their fundamental matrix. (The large phenocrysts are less common than implied by these microphotographs and are not considered important.) The fifth thin section is from the south margins of the Cedar Mountains east of the study area, and is included to represent a largely unused FGV variety; in fact, it is closer to the area than the Flat Hills or Deep Creek/Badlands sources. In hand, it is typical of the various low-grade FGV bordering on porphorytic that people only used opportunistically when better-quality reserves were low. Cedar Mountains FGV possesses a matrix not unlike the second tier sources, but it contains enough small phenocrysts that they become limiting factors.

While procurement areas from these sources (except Cedar Mountains) exhibit large-scale core and bifacial core reduction, in my experience visiting various FGV sources, there is relatively little in the way of targeted biface thinning indicated for any but the finest-grained source I have seen, Little Smokey Valley. Reduction of this material is discussed thoroughly by Beck et al. (2002). The common presence of bifacially thinned Western Stemmed point performs (see Figure 24) at this source is unique compared to those described above.

Figure 23. Production stemmed point and thinned biface fragments from the Little Smokey FGV quarry.

These interpretations remain tenuous, but provide a basis for clarifying the various factors governing FGV use. As it is, this material represents the grainy extent of what people would want, so we might expect these limitations to be manifested. If FGV textures are essentially identical for functional purposes, reduction differences between them may only be incidental to local land use demands; however, if they are texturally distinctive, then maybe the quarries were used differently for this reason. An important implication is that if textural differences were meaningful, then people who needed thin bifaces may have simply used the suitable rock and would not have utilized more intractable sources. In the Sierra Nevada, Middle Archaic people made roughout bifaces according to the same standards from both Alder Hill and Gold Lake FGV (Duke 1998; also Duke and Haynes 2009). While the artifacts indicate that people effectively got more use life out of finer-grained Gold Lake bifaces, the difference was apparently not sufficient to warrant changing the reduction approach to thinning. For current purposes, I assume that, more than obsidian or chert, the textural limitations of FGV would require greater investment time in the production of thinned bifaces or any other flaking-intensive tool product.

Moving and Replenishing Lithic Resources

Everyday lithic resource use is best addressed in terms of costs and benefits according to two primary constraints: the proximity and physical qualities of necessary materials. The manner in which people negotiate these constraints relative to functional requirements, settlement priorities, and scheduling conflicts is important to understanding the interactive nature of routine lithic reduction and toolstone procurement. These factors enter into a use context that is under continuous surveillance by people who are seeking to ensure that their needs are met without wasted effort.

People should address the costs of lithic technology by first considering the risks perceived for particular circumstances, and that the more variable these potential circumstances the more variable the technological system designed to cope with them. As I discuss in the previous chapter, greater risks entail greater costs to ensure reliability, and with stone tools, this comes through manipulations in the level of effort required to procure, process and transport material, as improvement on a sharp edge has long-since passed. Within the system defined here, where anything between flake blanks and carefully thinned bifaces can be produced, it is possible to identify the primary risk

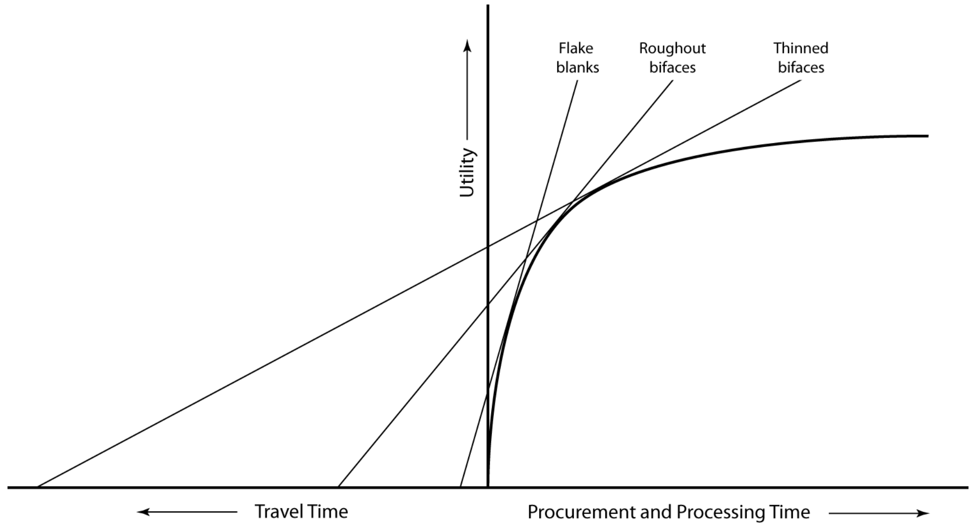


Figure 24. Transport model (following Metcalfe and Barlow 1992) showing utility relationships for flake blanks, roughout bifaces, and thinned bifaces.

concerns of Paleoindian foragers by examining how energetic investments are transferred between the artifacts themselves and the people producing them.

A transport model is presented in Figure 24 representing the different utility relationships for flake blanks, roughout bifaces, and thinned bifaces (cf. Metcalfe and Barlow 1992; C. Beck et al. 2002; R. Beck 2008; Elston 1992; Kelly 2001). Toolmaking time can be split between the quarry and a residence or an off-quarry camp according to different travel times which, for the purposes of this study, is best represented by the distance between quarries and the sites where tools are needed. There is eventually a point of diminishing returns in lithic reduction, as represented by the fall-off curve in Figure 24.

If utility is assumed to be usable bifacial tool edge per unit mass tool thickness, as discussed in the previous chapter, then utility should increase rapidly as people initiate reduction with the first flake blanks (procurement time should be minimal at known sources). A steep curve is expected because the processing investments for flake blanks are so limited but falling off significantly with biface reduction. Even roughout bifaces should not require exceptional processing times, but once thinning is commenced, processing could extend considerably relative to the earlier stages, with minimal gains in utility for the time spent. Experimental flintknapping studies have made this abundantly clear.

Understanding these tradeoffs clarifies what to expect from general reduction patterns on and off toolstone quarries. For example, C. Beck et al. (2002) find Paleoindian reduction at primary FGV sources and what they consider to be residential bases in their vicinity to support the transport model with early stage bifaces at the quarries and later stage items at residences; more importantly they find that the proportions change in step with the prediction that the most distant residences should be restricted to the latest stage bifaces. R. Beck (2008) finds similar patterns in the debitage among sites in southern Utah without regard to time period. This represents a formal model for "distance decay" that has been implicit to lithic studies for decades.

But what if people were not making thinned bifaces? Beyond the obvious fact that we should not find them anywhere, the model predicts that the earliest stages of reduction would barely change according to transport distance because they require such little processing cost; thus, if people rely only on flake blanks or even crude bifacial tools, there is little to differentiate their distribution. Simple decreases in size with distance should be expected, but even this may not be highly distinguishing if people need the same flake tools 10 km from the source as at 50 km away; the 50 km central place must have sufficient occupation length to warrant the greater costs of implementing the same technology as the one within 10 km of the source. This understanding is crucial to identifying variability in reduction strategies between on- and off-quarry sites. Throughout North American prehistory people reduced bifaces to varying extents, or "stages" (sensu Callahan 1979), and large-scale studies will always suppress variability under the maximum range of reduction that took place.

It is important to remember that stone tools are not hand-to-mouth resources like food items, and as conditions change so too do design factors and the rules of transport. As discussed above, mobility should be the critical design factor, constrained primarily by raw material limitations. The breadth of the North American record supports this, with a distinct shift from the biface-oriented technologies of Archaic peoples to simple core-flake reduction patterns among later sedentary groups (Parry and Kelly 1987; cf. Binford 1977; Kelly and Todd 1988; Shott 1986). Parry and Kelly (1987) find that the availability of raw material or other specific advancements (i.e., arrow vs. dart, hunting and gathering vs. agriculture) cannot be isolated as inherently necessitating these changes. They argue that sedentism, however arrived at, turns over the fundamental cost structure of using lithic technology. Instead of investing in the high manufacture costs of formal tools that solved problems of scheduling, transport, and multifunctionality, people living at permanent or near-permanent locations were better suited to take on added stone transport costs (usually embedded in other procurement activities) for the benefit of being able to use retouched flakes for specific tasks as necessary at single locations where they were well aware of their needs. The costlier alternative would be to directly procure stone as needed. Parry and Kelly (1987) observe this pattern among mobile peoples where toolstone is abundant.

Toolstone Supply and Planning

The above discussion is typical of lithic studies where the strong impression comes across that the prehistoric people's survival rested on the edge of a stone tool and all of its technical and morphological nuances. This most certainly was not the case under usual circumstances, although how much any of the particular variables archaeologists are concerned with (e.g., weight, production costs, distance to stone) were truly burdensome to people is difficult to say. While technology entails costs, it should represent an enhancement to survival rather than a limitation. Thus, as far away as any desired stone may be from a given location of its use, the working technological system should always provide sufficient supply on hand.

Surovell (2009) provides a formal model for how surplus toolstone should be generated. According to Surovell (2009:113), a surplus, or stockpile, represents the difference between the amount of stone procured and consumed, the size of the surplus changing as a function of time. In general, his model expresses a relationship between the costs involved in acquiring required toolstone and the costs incurred if caught short. These costs change with the duration of occupation at a site, which follows directly from patterns of residential mobility. From a mathematical standpoint, the question is: what is the optimum surplus size (S_{opt}) in a given context (Surovell 2009:118)? This is expressed as:

$$S_{opt} = \sqrt{\frac{d}{e}xkt} - k \tag{1}$$

where $d$and e are the costs of direct and embedded procurement, respectively, x is the amount of stone acquired after a shortfall, t is the occupation span, and k is a proportionality constant representing predictability in the rate of toolstone consumption (between 0 and 1, a larger value represents greater unpredictability). The model predicts that the optimum size of the surplus will increase as a function of the square root of the occupation span. As occupation span lengthens, the relative costs of accumulating surplus go down per unit time; i.e., while procurement of toolstone entails an absolute cost, this cost could be reduced to negligible over an extended period. At the same time, optimum surplus size should increase alongside greater difference between cost of embedded (e) and direct procurement (d) because the accumulated surplus reduces or eliminates the amount of stone needed after a shortfall (x). The constant k represents variability in consumption expectations, and if this variability is high, then the optimum surplus should decrease reflecting the wasted effort in accumulating extra material that cannot be safely estimated to prevent shortfalls. The more cost-effective alternative in such cases is to directly procure toolstone as needed. Because a surplus exists as a buffer against shortfalls in a site-specific context, people should abandon whatever remains when they leave a site. Finally, Surovell (2009:120) further finds that while the size of the surplus should increase with longer occupations, the percentage of surplus to consumed stone should decrease as the optimum size is met and procurement slows down.

How can toolstone surplus be measured archaeologically? Some distinction between used and unused material must be made for comparison among sites. All things being equal (e.g., distance to toolstone, raw material variability), relatively greater amounts of unused toolstone in assemblages should positively relate to other evidence of occupation span. Surovell (2009:102) uses ratios in of local to non-local material among tools and debitage to tool counts as occupation span indicators, which he combines into a single measure he calls the “occupation span index” (OSI). With data from excavations at Puntutjarpa Rockshelter, Australia, Surovell (2009:121-123) uses Gould’s (1977) original analytical categories to distinguish between used and unused material. Large cores, flake tools, and adzes are distinguished from smaller versions by Gould (1977) to separate items with use-potential. There are over 75,000 artifacts in the Puntutjarpa collection, spread over 21 stratigraphic levels. As predicted by the model, the proportion of surplus to consumed toolstone declines alongside greater OSI values. The Puntutjarpa case represents a single site where toolstone proximity can be controlled and comparisons are made through time.

Surovell (2009:123-127) uses five Folsom-age sites from the western Great Plains to test his model under varying levels of toolstone availability. In these cases, he uses tool mass to distinguish surplus from consumed stone. The distinction—artifacts greater or less than five centimeters—is an arbitrary one that asserts the relative nature of the model’s assumptions, as we are unlikely to ever know the true amount of stone considered surplus prehistorically. Surovell’s use of mass remains categorical, his analysis relying on proportions of artifacts between the two size classes. Again, the predicted negative relationship between percent surplus and OSI bears out, with only one site—Barger Gulch in north-central Colorado—deviating substantially with a markedly higher amount of surplus. Barger Gulch is situated in the immediate vicinity of Troublesome Formation chert, and Surovell interprets this to reflect another model expectation that procurement costs become inconsequential at such proximity to stone.

The definition of surplus as material that should be abandoned when people depart a site distinguishes it from the unused supply of stone that might be moved between sites.

The distinction is critical when considering mobile hunter-gatherers for whom some level of transportable supply should be available. This is a situational problem related to the location of a site relative to toolstone and occupation span. Surovell's (2009) Folsom cases exemplify this as it is well-established that these groups were highly residentially mobile. While his separation between surplus and non-surplus based on artifact size is arbitrary, even the portable supply component of a mobile toolkit would be discarded at times according to the model predictions. People carrying transport-efficient tools may discard them to eliminate the transport costs altogether if their next move falls into an area where they can readily make new tools. Because toolkits were designed with the model variables reasonably estimated, it seems unlikely that people would switch from one side of the surplus threshold to the other very often, but the potential for this adds a dynamic element to how we examine assemblages in different contexts.

Archaeological Expectations

The economic variables I have discussed up to this point center on commonly recognized decision factors in lithic resource use—mobility, toolstone distribution, toolstone qualities—with emphasis on how these factors are engaged by people in the overall process of designing and employing a technological strategy. This section provides specific predictions for Great Basin Paleoindian lithic technology and how these should be manifest on the distal ORB. The discussion references detailed expectations presented in Table 5. These follow from the models presented in the last two chapters, and serve as the basis for artifact comparisons in the next two analytical chapters. The expectations are relative in nature and therefore are best suited for comparative analyses of temporal and/or spatial data.

Table 5. Archaeological Expectations for Great Basin Paleoindian Lithic Technology Based on Duration of Occupation.

Technological Aspect	Duration of Occupation	
	Short	Long
Toolkit design	Multipurpose tools made in advance of use combining reliable performance with transport efficiency (e.g., thinned bifaces); high manufacture costs and standardization	Blank-based tools made for immediate use, to serve as necessary from a surplus; low manufacture costs and minimal adherence to form
Toolstone selection	High-grade raw materials, such as obsidian, chert, and high-grade FGV	Any suitable toolstone variety that is close, including low-grade raw materials such as FGV, quartzite, and various metamorphic rocks
Toolstone acquisition	Residential moves in the vicinity of toolstone sources	Logistically-based as needed; embedded into routine foraging activities or directly procured
Quarry reduction	Extended; late-stage work evident (e.g., biface thinning) to make a working tool	Minimal; flake blanks produced for transport and later reduction into various tool types
Toolkit diversity	Low; multipurpose tools in a standardized type set	High; functionally discrete tools made as needed from flake blanks
Artifact reworking	High; tools systematically refurbished through a planned sequence to conserve stone	Low for local surplus, but high to extreme for non-local stone (if better-quality than the local stone)
Artifact replacement	Tools from high-grade stone replaced with similar stone when encountered; finely flaked tools replaced with similar forms	Tools from high-grade stone replaced with nearest stone, even if low-grade; finely flaked tools uncommon and subject to replacement with cruder forms
Artifact size	Larger size range; tools capable of being resharpened and/or redesigned to accommodate unpredictable use requirements	Smaller size range, with tools made to limited-use specifications and according to predictable use requirements
Toolstone surplus	No obvious surplus; tools may be discarded with utility remaining if further transport is cost-inefficient	Surplus of local stone should occur most visibly as cores and flake blanks abandoned at residential site
Archaeological visibility	Low; smaller sites for shorter stays; toolkit designed for transport efficiency economizes toolstone	High; larger sites for longer stays; toolkit designed for expediency is wasteful of toolstone

A key assumption in this study is that basin wetlands represent the primary centers of residential activity for Great Basin Paleoindian groups. The distribution of these habitats would be patchy, but geographically predictable, with the spaces between them representing logistically utilized uplands and/or non-exploitable terrain to be crossed when moving between basins. While this is surely an oversimplification of Paleoindian behavior, it is a practical starting point from which to examine lithic economy. When people were occupying a particular basin, they would be subject to similar raw material constraints regardless of their mobility within that basin. When in-place for extended periods, people could lean heavily on local, poorer-quality stone, disassembling a small set of multipurpose generalized tools into various expedient forms as transport efficiency decreased in importance. This variability could have taken place at any temporal scale from annual fluctuations in wetland productivity to the long-term decline of Late Pleistocene-Early Holocene environment. The relative influence of occupation span structures the predictions for various toolkit aspects presented in Table 5.

It is clear from the geochemical sourcing of obsidian tools that Paleoindian groups could have moved routinely through home ranges spanning hundreds of kilometers (Jones et al 2003; Smith 2010), but little is known about how mobility varied within this space (Duke and Young 2007). The relationships proposed here presume nothing about the size of foraging territories beyond the likelihood that, most of the time, any given basin wetland should have been one among several options. In fact, these relationships are designed to be sensitive to the variability in land use that should be expected in the volatile climate of the times, an aspect I have emphasized elsewhere (Duke and Young 2007). Keeping in mind, however, that the responses detailed in Table 5 would have been considered in advance of movements, it is unlikely that people would drop in and out of technological poses with regularity. Regardless, short stays should result from high residential mobility, and long stays should entail greater logistical mobility, although there may well be cases where certain individuals practiced extended logistical mobility sufficient to warrant highly transportable toolkits. Hunting or otherwise task-oriented parties that leave the group residence for long periods should leave assemblages that reflect short stays. It is assumed that trade is not a major factor in toolstone movement in Paleoindian times.

Predictions for the Distal Old River Bed

The distal ORB offers an expansive Paleoindian record that can be divided into at least two chronological units: an earlier one beginning near the end of the Younger Dryas at roughly 12,100 cal BP and continuing to approximately 11,200 cal BP, and a later one extending from 11,200 cal BP to about 9900 cal BP when the area finally became desiccated. These date ranges correspond with the west and east sides of the study area, respectively. The distal ORB record is therefore well-suited for comparative analysis drawing from the expectations in Table 5. The hypothesis being addressed in this study is that shorter stays should correspond with earlier occupations and longer stays with later occupations. If the long-term trajectory of the post-Younger Dryas environment was one of decline, such patterning would provide one line of indirect evidence that people intensified their use of the distal ORB as they lost other basin wetland options.

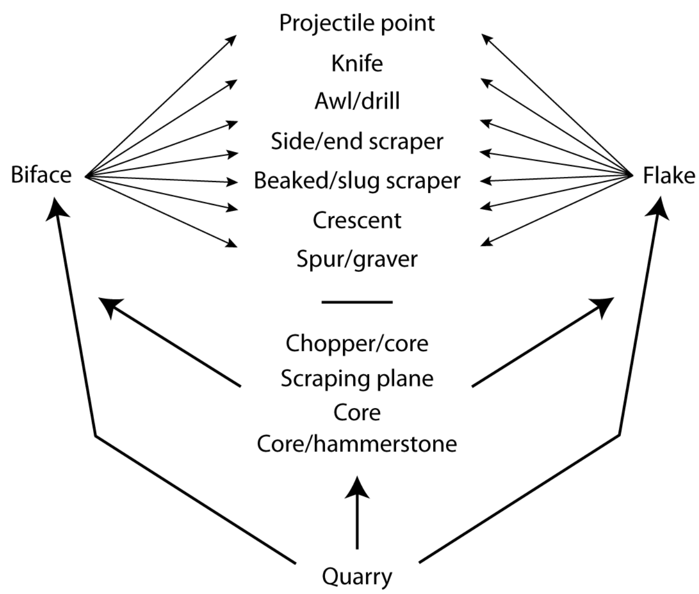


Figure 25. Possible reduction relationships for primary Paleoindian stone tool types. All toolstone emanates from the quarry/procurement area as a finished tools or as generic bifaces and flake blanks. Large arrows represent the items most likely to be made at the quarry prior to transport. These usually represent the largest tools, or otherwise those that require the greatest investment in minimizing waste and risk prior to transport. The small arrows indicate tools that could reasonably be produced after transport to a location of use. As transport efficiency increases, tools requiring the greatest production investments, especially bifaces, should increasingly be manufactured at the quarry (also see Figure 24).

For this study, the key difference in recognizing shorter versus longer stays archaeologically is in identifying differential emphasis on transport efficiency. The flake blank-rough biface-thinned biface distinctions discussed previously provide the basis for tracking this emphasis through tool types on the distal ORB. A model for reduction relationships is provided in Figure 25, centered on the initial design choice between a biface or flake blank. At the quarry/procurement area, people would make the decision to generate tools from flake blanks or bifaces. As discussed in the previous chapter, unless a biface has utility as a tool it should not be made solely as a core; thus, flake blanks should always be the most transport-efficient option under such circumstances. If bifaces do have tool utility, there should be a direct relationship between the importance of transport efficiency and the use of biface thinning to reduce unneeded toolstone mass. Bifaces can otherwise simply be roughed out, with edge angle being controlled more by the thickness of the original blank as tools are resharpened bifacially. Rather than take on the risks entailed by using a thinning sequence to provide tools, people could choose flake blanks of various size and thickness at the quarry and use and reduce them independently (Duke and Haynes 2009; Duke and Young 2007). This effectively generates a thinness-graded set of bifacial tools that serves the same purpose as a single thinned biface worked through a sequence (Duke and Young 2007), but with the added advantage of being able to limit on-quarry production investments to only what is necessary to reduce the risks of future loss, especially through breakage.

Archaeologically, where transport efficiency was not a priority, we should expect little at quarries beyond core reduction and large, roughed out bifaces because breakage risks would be eliminated quickly; transported flake blanks could easily be worked into various tools as necessary at residential and/or other task-specific sites. The greater the emphasis on transport efficiency, however, the more investment should be placed at the quarry, which should be evidenced by biface thinning and individual tool production (e.g., projectile points, knives, crescents). This is consistent with the transport model described earlier in this chapter (see Figure 24). Returning to Figure 25, certain large items—like choppers, core tools, and cores—should always be manufactured at the toolstone source, with pure cores only being transported away when people are in the position of acquiring surplus. If surplus occurs on the distal ORB, it should be more common on the east side of the study area in the Wildcat Mountain vicinity where longer residential stays are hypothesized.

The predictions in Table 5 follow from this model, and the end products shown in Figure 25 should reflect varying investments in the reduction of bifaces and flake blanks. Shorter occupations relate directly to emphasis on toolkit transport efficiency while this emphasis should decline alongside longer stays. It is expected that the older assemblages from the west side of the study area should reflect these shorter occupations through more streamlined toolkits than those seen on the east side. West-subarea toolkits should exhibit the greatest use of high-grade materials, especially obsidian; they should be less diverse owing to greater multifunctionality in some tools; and individual tool sizes should be larger to ensure that adequate toolstone supply is available when needed. By contrast, east-subarea toolkits should contain greater amounts of FGV; greater toolkit diversity owing to the expedient use of flake blanks to manufacture functionally-distinct tool types as needed; and tool sizes should be smaller because individual items are meant to serve single purposes.

The expectation that tool sizes should be greater in shorter-stay toolkits superficially seems at odds with the prediction that people would constantly be looking to use toolstone efficiently. This relates back to the surplus issue discussed in the previous section. Transport-efficient toolkits should not only reduce unneeded weight, but they should also buffer against the uncertainty that comes with a mobile lifestyle that may not place people near desired material at ideal times. All things being equal, greater discord between tool use requirements and expected encounters with suitable material creates greater unpredictability and increases the optimal size of toolstone reserves, as expressed above in Equation 1. Highly mobile people should accommodate this need through bigger tools that can be reduced and used in a sequence. While this is not a straightforward representation of surplus as defined by Surovell (2009)—i.e., material that is accumulated at a site then abandoned upon departure—we should expect that highly mobile people would operate on a bigger toolstone budget than those who are less mobile because the potentiality for unforeseen need is greater. Viewed another way, they would not be inclined to let toolstone reserves dwindle to near the minimum required when direct procurement trips are not justified. Where stays are long enough to warrant procurement of additional stone, people can work near their required minimum because there is predictability in the acquisition of new supply. Thus, we should not only expect more highly mobile people to use larger stone tools, but we should expect that they will discard larger tools as well.

There is no local toolstone available from the distal ORB; therefore, people would always be in a situation where procurement entails direct costs. The primary FGV sources are no closer than 60 km to the center of the study area (although additional outcrops could lie as close as 30 km), and it is 90 km to Topaz Mountain obsidian. Surovell (2009:78) suggests a maximum distance of 20 km for a toolstone source to be considered local, but even this is a generous distance to extend people from their residence in an average foraging radius. Ethnographic data indicate that foraging areas extending farther than 10 km one way are the exception rather than the rule for hunter-gatherers (Binford 2001:238; Kelly 1995:133). Regardless of which cutoff is more appropriate the distal ORB sits farther from toolstone than either, and thus we should not expect people here to accumulate surplus through routine embedded procurement. Tools should always represent items common to the toolkit, and there should be few cores.

However, the great distance to raw material from the study area should generate a high degree of variability in the reduction investment put into tools. Mobile groups moving quickly through the area would maintain a transport-efficient toolkit that should look much like elsewhere, but when people had to directly procure stone, they would tend to return only with what they anticipated as necessary, possibly with little intention of transporting it out upon leaving the basin. In the latter case, tools should take on an expedient character in the service of immediate needs. Thus, contra a standard "distance decay" model (cf. Beck et al. 2002), many such artifacts should look like they were reduced at quarry immediately nearby. This should especially be the case for FGV, which is less amenable to controlled flaking than obsidian and was usually used for larger tools. Minor differences in occupation span on the distal ORB could therefore entail marked shifts in toolstone procurement and reduction strategy decisions. This could have occurred at any time alongside fluctuations in wetland productivity. The focus of this study is on long-term regional wetland decline and, again, an east-west distinction with transport efficiency being better represented in earlier, west-subarea assemblages is expected.

Finally, when the distal ORB was routinely visited, people may have cached, scavenged, or otherwise used previously discarded material rather than make costly direct trips to geologic sources. There is certainly no reason to believe people would not have been opportunistic about this, but a dependent technological strategy is unlikely. Caching in particular would seem prudent in a remote area, but the distance and isolation of the distal

ORB is sufficient to be a limiting factor. Because raw material is located farther away than normal foraging activities, developing a cache would be impractical according to the model described above; tool use requirements alone should have been the focus of provisioning. It is worth considering, however, that the proposed larger tools discarded by the most mobile people passing through could have served as a bank of stone for later groups who had reason to exploit remaining tool utility. In this scenario, earlier residents would have effectively surplused the distal ORB for those who came later, stretching the toolstone sources out toward the area over time. Later people would then be scavengers of leftover stone—in a sense, scavengers of their own discarded tool types—but this again is unlikely as a driving toolstone provisioning strategy. Scavenging as an important means of toolstone acquisition would increase risk the farther one gets into the basin because the costs of resupplying escalate. Each of these strategies assumes that people could find caches or see abandoned tools in a wetland stream network that likely looked somewhat different from one year to the next—the distal ORB was not the deflated playa it is today.

For all of these reasons, caching and scavenging behavior are not expected to be significant aspects of technology in the study area. From an opportunism standpoint, however, later groups would have more cause to scavenge because they would have operated nearer the minimum required tool size than earlier—i.e., shorter-stay—occupants. This would be difficult to measure archaeologically because situational procurement decisions are unknown, and there is no easy way to tell if a highly reduced tool was actually scavenged and not simply reduced from an existing toolkit component. Looking at individual artifacts, differential weathering and or double obsidian hydration rinds may be able to address the issue, but these are not data that are readily or consistently available.

Summary

This chapter focuses on the various cost-benefit tradeoffs made by toolmakers under different constraints. Three primary aspects are discussed: toolstone characteristics, proximity to toolstone, and duration of occupation. These are all important to consider when comparing the relative investment in transport efficiency of stone tools in different circumstances. Following from design parameters discussed in the previous chapter, and functional requirements, all technological aspects will be in flux depending on the situation.

Three raw material types—obsidian, FGV, and chert—are described according to their physical qualities relative to flintknapping requirements and functional needs. Obsidian and FGV are the key toolstones in the distal ORB study area. These materials are very different in their characteristics, with obsidian being the best for controlled flaking and sharp tools and FGV being relatively non-compliant for flaking and not nearly as sharp as obsidian, but a good choice for durable, heavy duty tools. Depending on how people see the importance of given stone to particular functions, they can be expected to make tradeoffs in choosing between materials according to its proximity to the location of use and the duration of residence at that location. People should also make tradeoffs in terms of tool form according to toolstone proximity and occupation span.

A transport model is described that formally relates these factors in terms of energetic cost savings and tool utility. The differential use of bifaces and flake blanks is argued to be the key design aspect (described in the previous chapter) with which

Paleoindian toolmakers flexibly manipulated transport efficiency along these lines. In general, it is predicted that bifaces, especially thinned bifaces made from high-grade material such as obsidian, would be preferred when people are moving quickly through the distal ORB wetlands because this maximizes tool utility while minimizing the cost of transporting unusable mass. When occupations were of sufficient duration to justify direct procurement costs, the use of flake blanks from the closest stone—FGV, in this case—should increase in cost-effectiveness because as tool use requirements become more predictable, production investments previously put into creating transport efficiency can be transferred to the transport of adequate toolstone supply. A full list of predictions owing to these factors is provided in Table 5.

Finally, the fact that there is no local toolstone around distal ORB is important. With known FGV sources 60 km from the center of the study area, people would rarely be in a situation to embed lithic procurement into routine foraging activities, which are usually conducted within 10 to 20 km of residences. Thus, when they visited the area, they had to reasonably gauge tool-use requirements in advance, possibly more so than in any other basin wetland in the Great Basin. A formal model for managing toolstone supply is provided following Surovell (2009) which predicts that people on the distal ORB would always be in a situation of direct procurement unless their intended stay did not extend beyond existing supply. Caching should be infrequent because there were few circumstances in which extra material would be brought home. Groups moving through quickly integrate their supply into transport-efficient toolkits via large tools that can be reduced and reworked for several functions, while those staying longer should bring only what they need, followed by direct procurement trips as needed, which would also return the minimum required. Tools would be smaller because of the limited need to accommodate unforeseen use. While the discard of larger tools by groups staying for shorter periods could serve as a source of remaining tool utility for people staying longer, scavenging behavior is not expected to be an important means of toolstone procurement because greater distance from toolstone sources entails greater risks of shortfall if sufficient material cannot be found.

Returning to the chronological model for the distal ORB, shorter occupations and more transport-efficient toolkits are expected to be early, and longer occupations and less transport-efficient toolkits are expected later within the 12,100 to 9900 cal BP timeframe. The different patterns should correspond to assemblages on the earlier, west study area distributary branches and the later east side study area distributary branches, respectively. Opportunistic scavenging likely took place to greater extents over time if people stayed for longer episodes as other basin wetlands in the region dried up; thus, there should be greater evidence of this on the east side of the study area.

CHAPTER 6

METHODS AND MATERIALS

This chapter details data sources and how the lithic analysis was performed. The data are drawn from collections associated with numerous projects conducted in the study area, including my own surveys and excavations. Fieldwork, sample selection, artifact classification, special studies, and statistical methods are described.

Fieldwork

This study draws from artifact collections taken on various projects on Air Force lands in the Great Salt Lake Desert. Most of these projects were surveys with limited excavations, including those at the Cache and Com sites described in Chapter 2. The extent of survey acreage is shown in Figure 26 and detailed in Table 6. As calculated by GIS, the total acreage of surveys shown in Figure 26 is 30,003 acres, from which 95 Paleoindian archaeological sites and 3,156 artifacts are used in this study.

This amounts to 15 percent of the 200,000-acre study area and is considered largely representative of the distal ORB delta, especially south of Knolls Dunes. As described in Chapter 2, Wild Isle and Wildcat dunes are anchored to the variable topography of the ancient distributary system; thus, the spaces in between them lack substantial archaeology. I have made several informal transects between the dune fields and west of Wild Isle that confirm this, although additional material can be found where the channels come into the study area from the south.

Figure 26. Archaeological surveys conducted in the study area since 1998.

My work largely comes from contract archaeological surveys, usually through Far Western, conducted over a 10-year period since 2001. Additionally, I have served as the lithic analyst on several of the projects run by Jim Carter through Historical Research Associates, the only exceptions being the Wild Isle, or "TS-5," surveys in 1998 and 2000 (Table 6). Excavations at the Cache and Com sites in 2007 took place under UNR's Sundance Archaeological Research Fund (SARF).

I have divided previous work into pre- and post-1998 projects (Table 6), with only the post-1998 work that I am most familiar represented on Figure 26. Efforts from 1991 through 1997 were directed by Dr. Brooke Arkush, Weber State

Table 6. Detail of Archaeological Projects Conducted in the Study Area.

Project Name	Type	Year	Principal Investigator	Acres	No. of Artifacts in Study	Description
TS-5 Inventory	Survey	1998	J. Carter	9,755	393	Primary Wild Isle survey encompassing north, south, east, and west portions
TS-5 Central Area	Survey	2000	J. Carter	3,900	42	Central area of Wild Isle
South Route Inventory	Survey	2001	D. Duke	920	32	Road survey from along south study area boundary to west Wild Isle
Wild Isle 22-Site Testing	Excavation	2003	J. Carter	-	55	Test excavations at 22 sites on Wild Isle Dunes
Wildcat 04 Inventory	Survey	2004	J. Carter	5,037	8	Survey in eastern Wildcat Dunes and on Wildcat Mountain
Wildcat 05 Inventory	Survey	2005	D. Duke & D. Craig Young	2,880	1,052	Survey on western margins of Wildcat Dunes and at Lone Dunes
Wildcat 06 Inventory	Survey	2006	D. Duke & D. Craig Young	3,260	863	Survey on western margins of Wildcat Dunes and at Lone Dunes
Cache and Com Sites	Excavation	2007	D. Duke	-	25	SARF-funded excavations at the Cache and Com Sites
Knolls 08 Inventory	Survey	2008	D. Duke	1,437	295	Survey in northwestern Knolls Dunes
Knolls 10 Inventory	Survey	2010	D. Duke	2,563	157	Survey in northern Knolls Dunes
Other Post-1998 Projects	Survey	n/a	n/a	251	40	Various small-scale compliance surveys and other collections
Various Previous Projects	Survey	1991-1997	B. Arkush	-	194	Survey by Weber State University in the 1990s

University (WSU), as large-scale sample surveys. These were the first surveys in the area, and were aimed at identifying the basic archaeological patterns on UTTR; thus, they were necessarily cursory and covered large tracts of land. This is evident where post- and pre-1998 surveys overlap, with notably higher site counts from the later surveys. However, the early surveys were sufficient to reveal a unique Paleoindian record, as described in a published account by Arkush and Pitblado (2000). Collections from the WSU projects are largely limited to projectile points or otherwise distinctive tools whereas 100 percent of recorded flaked-stone tools have been collected on surveys since 2001, and most of the tools found on the Wild Isle surveys in 1998 and 2000 were collected. All post-1998 surveys were conducted using 30-m transect intervals.

Sample Selection and the Potential for Mixed Temporal Components

The total dataset for this study consists of 3,156 flaked stone artifacts, composed of 1,209 projectile points or otherwise time-diagnostic artifacts, and 1,947 other flaked stone tools. Ninety-five sites account for 86 percent of the total artifacts (n=2,721),[3] with the remaining artifacts—all projectile points—coming from isolated finds (n=177) and 87 other sites (n=258). My analysis utilizes all of the projectile points available to me, which likely represents better than 95 percent of all those that have been found in the study area since 1991 and identified as GBS or Pinto. The other-tool dataset is less comprehensive, and only represents sites I am confident contain effectively single-component Paleoindian assemblages with five or more tools (including projectile points). These assemblages also represent collections at or near 100 percent of the artifacts observed at the site when recorded. There other sites, especially in the Wild Isle Dunes vicinity, that contain substantial assemblages but are not used in this study.

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[3] This count is reflects five more items than the 2,716 stated in Chapter 8 as the total used in the technological analysis of the 95 sites. These are projectile points that were unavailable for the analysis, but their styles are known, and they are included as part of the site assemblages and used in the typological analysis in Chapter 7. They represent single artifacts from separate sites, so the effect of their absence on the technological analysis is considered negligible.

Later-period archaeology exists in the study area and is largely restricted to the dunes or blowout areas where the material has deflated to the playa. These deflationary zones are where the potential for mixed components is highest (see Chapter 3 for discussion). Currently, 368 total archaeological sites have been recorded within the study area boundaries through various cultural resource management projects. Of these, 182 are incorporated in this study as containing, at a minimum, GBS or Pinto projectile points. From these, 95 are selected as single-component or nearly single-component Paleoindian sites that qualify for full analysis with greater than five tools and complete surface artifact collection. There are certainly other Paleoindian sites on the distal ORB delta, many of which are single-component but contain limited assemblages. Some others are mixed but contain Paleoindian projectile points that could be used in this study; these are the other 87 sites mentioned previously. This leaves 186 sites, and many of these also contain mixed assemblages that include non-diagnostic Paleoindian artifacts, as indicated by artifact weathering and/or technological similarity. It is difficult to say how many of these are post-Paleoindian, but single-component late-period sites are almost exclusively limited to the dunes, especially Wildcat Dunes and eastern Knolls Dunes.

The issue of temporal mixing for the purposes of this study relates to the integrity of the 95 sites that are used for full technological analysis on non-diagnostic artifacts. From these sites, there are 109 additional flaked stone tools that were not included in the analysis. Forty-nine of these represent items that were either unavailable, fragmentary, non-diagnostic of Paleoindian technology, or simply looked like they may represent later-period tools. Weathering often served as a reliable separator of Paleoindian versus post-Paleoindian

Table 7. Post-Paleoindian Projectile Point Types from the 95 Sites Selected for Technological Analysis.

Dune Field	Projectile Point Type					TOTAL
	Humboldt	Gatecliff Cont. Stem	Elko	Rosegate	Indet.	
Wildcat Dunes	4	1	9	1	5	20
Lone Dunes	7	-	4	4	5	20
Knolls Dunes	1	-	11	1	2	15
Wild Isle	2	-	1	-	-	3
TOTAL	14	1	25	6	12	58

artifacts, but this was not always the case, and several of these 49 items exhibit no clear affinity for either time period. Almost 30 percent (n=14) of these are made from chert, and represent the mid-size biface fragments typical of those seen on the dunes in middle-to-late Archaic sites.

The remaining 60 artifacts are projectile points. Two of these are noted as "Western Stemmed" in old catalogs, but could not be accessed for review. However, the others represent post-Paleoindian styles. These are detailed in Table 7, and largely represent middle or late Archaic items at sites near dune-playa interfaces. This seems like a disproportionately high number of projectile points to the other artifacts just mentioned, but late-period projectile points can be found as isolates throughout the dune areas so their occurrence on the playa overlaying Paleoindian sites with no associated assemblage is not surprising. Looking at their dune associations, the majority of these points come from the east side of the study area where the active dune fields exist (Table 7); only three items come from Wild Isle Dunes.

Also, most of those sites with some late-period artifacts exhibit relatively clear spatial separation such that late components do not present ambiguous mixing problems. For example, four of the post-Paleoindian projectile points and 10 of the other artifacts mentioned above come from 42To922/923, but these items are largely found in a spatially discrete area at one end of the site. The remaining site area contains an expansive and weathered Paleoindian component that contributes 145 artifacts to the technological analysis. The Cache Site (42To2622)—targeted for excavations of the early component (see Chapter 3)—represents the most temporally mixed site in the study, and even here the Paleoindian tools can be confidently separated from later artifacts. The site is prototypical of a dune-playa interface context along the west margin of Wildcat Dunes where later assemblages sometimes found deflating onto weathered Paleoindian components. The artifact cache the site is named for contains five of the non-diagnostic artifacts (obsidian flake blanks) counted above alongside one large Elko projectile point (and a pumice shaft straightener). Obsidian hydration dating indicates that all of the cache artifacts are post-Paleoindian (Young et al. 2006).

Outside of these exceptions, both the non-diagnostic tools and the post-Paleoindian projectile points are widely scattered across the 95 analyzed assemblages. Chert and FGV are generally good temporal separators, chert being later and FGV earlier as described in Chapter 3. Obsidian was used across time periods, but the presence or absence of weathering is usually adequate to make distinctions (this is less the case for flakes than tools, but debitage is not a focus of this study). Even without these qualifications, the Paleoindian toolkit is markedly dissimilar from that of later periods. Nonetheless, there is some potential for post-Paleoindian non-diagnostic tools—such as bifaces, flake tools, etc.— in the final technological analysis sample. Overall, however, this should not present a meaningful bias in the analysis.

Analysis Methods

This section focuses on attributes and methods used in the analysis. Various standard measurements and attributes have been recorded for all of the artifacts as presented in the relevant contract reports, many taken by me or under my direction. I have drawn these data from these sources—e.g., length, width, thickness, weight, artifact class, material type—but all were subject to my review and adjustment during the course of the specialized analysis presented here. Thus, there is not a one-to-one correspondence between the current data and what has been previously reported.

Technological Attributes

The primary analytical objective of this study is to identify technologically meaningful patterning following from the physical and ecological factors discussed in the previous chapters. Conventional tool classes—e.g., biface, uniface, projectile point—are used to this end, but they are each defined based on a specific set of attributes estimated to represent actual technological approach. For example, the distinction between a uniface and a biface, which is particularly important to this study, can be simply based on whether the artifact is flaked on one or two faces, but these are not necessarily sensitive to the vagaries of tool use in a given context. Scrapers, for example, are often flaked on a flat side as people modify the working margin. There are many such items on the distal ORB, and thus bifaces must reflect a continuous focus on maintaining a bifacial edge to be classified as such.

Artifacts may have been many things before they were discarded, but they are classified in this study based on what they were during their last use. Their relationship to reduction strategies is ascertained through diagnostic attributes. Tools were analyzed along two lines in this regard. The primary variables are linear measurements, tool type, material type, and breakage. In addition, evidence of remnant flake blank characteristics coupled with assignment to different reduction trajectories are used to situate these variables in the technological strategies governing tool use.

Flaked stone tools were classified into 17 primary categories as described in Table 8. Select items are shown in figures 27 through 34. These represent my best attempt to monitor technological aspects while staying as close to conventional categories as possible. My previous experience with the aforementioned projects provided initial direction, and primary literature on Paleoindian lithic technology was consulted, especially Gramly (2000) and Beck and Jones (2009). The distal ORB assemblages are generally crude in nature, so it was impossible to make the categories mutually exclusive. Expecting overlap, I chose to analyze the entire dataset instead of sampling. Finally, weathering on the artifacts from sandblasting is common, so only obvious distinctions can be made. This is not an issue for most of the tool classes, but minimally used or retouched items are likely underrepresented (e.g., utilized flakes).

Two types of data were generated to directly examine reduction trajectories and the differential use of flake blanks versus extended bifacial reduction. Remnant blank evidence was recorded as present if a tool exhibited one or more of the following attributes: remnant detachment scar, plano-convex cross-section, or longitudinal curvature. Additionally,

Table 8. Artifact Classes Used in the Technological Analysis.

Tool Type	Description	Figure No.
Bifacial Tools		
Projectile points	Projectile points possess a hafting element/base oriented proximally opposite a generally pointed distal tip. To be included in this class, the artifact must not exhibit evidence of use as any other tool type in the analysis.	35-41
Expedient bifaces	Expedient bifaces generally exhibit rough percussion flaking and minimal attention to form. Margins are uneven and overall shape is variable. Flaking rarely extends over the middle of either face, indicating that thinning was not the preferred reduction strategy.	n/a
Thinned bifaces	Thinned bifaces exhibit evidence that reduction was conducted with the intent to reduce the proportionate thickness of the item. Percussion or pressure flaking scars extending over the middle of either or both faces must be present.	28
Narrow bifaces	Narrow bifaces are generally similar to expedient bifaces, but they are elongate in form.	29
Jots	Jots are small biface fragments which usually possess multiple breaks. They are often non-orientable and exhibit evidence of bipolar reduction from expended bifaces, mostly small pressure-flaked items which were probably projectile points. This definition is not as restrictive as that given in Duke and Young (2007) but is still meant to capture items resulting from this process.	30
Choppers	Choppers are large bifacial to partially unifacial artifacts that exhibit battered and/or otherwise dulled margins.	27
Bifacially utilized flakes	Bifacially utilized flakes show evidence of formal or use-related bifacial flaking along at least one margin of a flake. Functionally, they may represent cutting tools.	n/a
Unifacial Tools		
Side scrapers	Side scrapers are generally unifacial along a steep margin. Flaking on the opposite face may be present that contributes to a bifacial margin, but this only reflects modifications made to create and maintain the used face. Scrapers are distinguished from simple unifaces by evidence that they were used specifically for scraping. They exhibit uniform edges with prominences removed through use. They may be straight, concave, or convex, and there may be multiple used edges on a single item. Sometimes, straight margins are convergent to a point that may or may not have been used.	31
Beaked scrapers	Beaked scrapers exhibit a steep convergence of two worked edges to form a "beak." Their implied use is as a graver, but they vary in form between subtle to prominent and pointed to rounded precluding an exact functional assignment.	32

Scraping planes	Scraping planes can be similar to the side scrapers describe above, but they are distinctively larger in size and possess prominent, steep margins.	31
Unifaces	Unifaces represent those artifacts that are unifacially flaked but are otherwise not functionally distinctive. Their edges exhibit no evidence of scraping.	n/a
Perforators		
Awls/drills	Awls represent artifacts with an elongate bit. These resemble what would otherwise be called "drills," but the bit is flat and bifacial indicating that their primary function was as a awl or heavy-duty punch. Tips are generally rounded in planview rather than sharply pointed.	33
Spurs/gravers	Spurs are small projections flaked along the margins of an artifact. These are commonly small and delicate, suggesting poking/punching function, but some are more robust and could have been used as gravers. The artifacts classified as spurs/gravers in this study indicate no other function, but these projections can often be found on other artifacts, especially scrapers.	34
Chisels	Chisels or "chisel-tip" projectile points are described by Tuohy (1969) and Beck and Jones (2009). A square distal end appears to be produced by alternate beveling, usually of Lake Mojave stemmed tools. They may represent a perforating tool.	36
Cores	Cores are polyhedral masses of stone from which flake blanks for other stone tools are derived. Flake removals from single or multiple platforms are evident.	n/a
Core/hammerstones	Core/hammerstones are effectively core tools which exhibit intensive battering on one or a few edges. These may have been used to flake other stone tools, or as pounding tools themselves.	n/a
Multipurpose	Multipurpose tools are items that show evidence of use as two or more of the above categories.	n/a
Miscellaneous		
Slug scrapers	Slug scrapers are unifacial with steep edge angles and a high exterior side. They are generally round to oval in planview, with unifacial edges around virtually all of the margins.	n/a
Great Basin crescents	Great Basin crescents are crescent-shaped tools that are usually bifacial. A distinction is made here between those items that are typologically consistent with the hallmark crescents of the Great Basin and the generally "crescentic" shaped tools that are common to the scraper assemblage (usually convergent/beaked scrapers on one end).	n/a
Irregular bifacial tools	Irregular bifacial tools are usually made from the reduced remnants of larger bifaces and projectile points. They often possess alternating unifacial and bifacial edges that were created as-needed for specific functions. They are often similar to jots, but may be larger and exhibit clear evidence of modification.	30

Figure 27a. Choppers from the distal ORB.

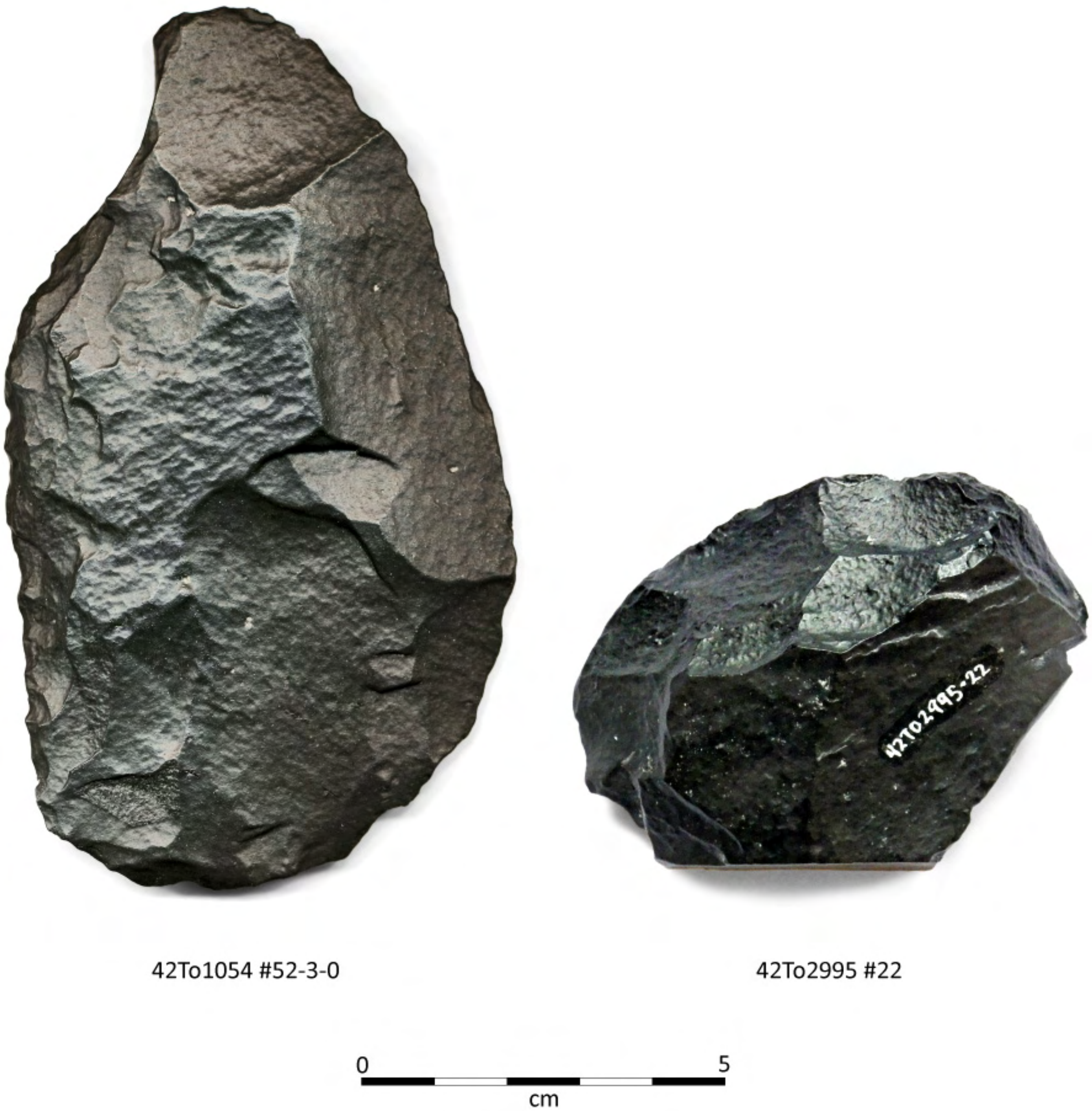

Figure 27b. Choppers from the distal ORB.

Figure 28a. Thinned bifaces from the distal ORB.

Figure 28b. Thinned bifaces from the distal ORB.

Figure 28c. Thinned bifaces from the distal ORB.

Figure 28d. Thinned bifaces from the distal ORB.

Figure 29a. Narrow bifaces from the distal ORB.

Figure 29b. Narrow bifaces from the distal ORB.

Figure 30. Jots and irregular bifacial tools from the distal ORB.

42To922-923 #12

42To1006 #4-17-0

42To1868 #6-3-0

0 5
cm

Figure 31a. Scrapers from the distal ORB.

Figure 31b. Scrapers from the distal ORB.

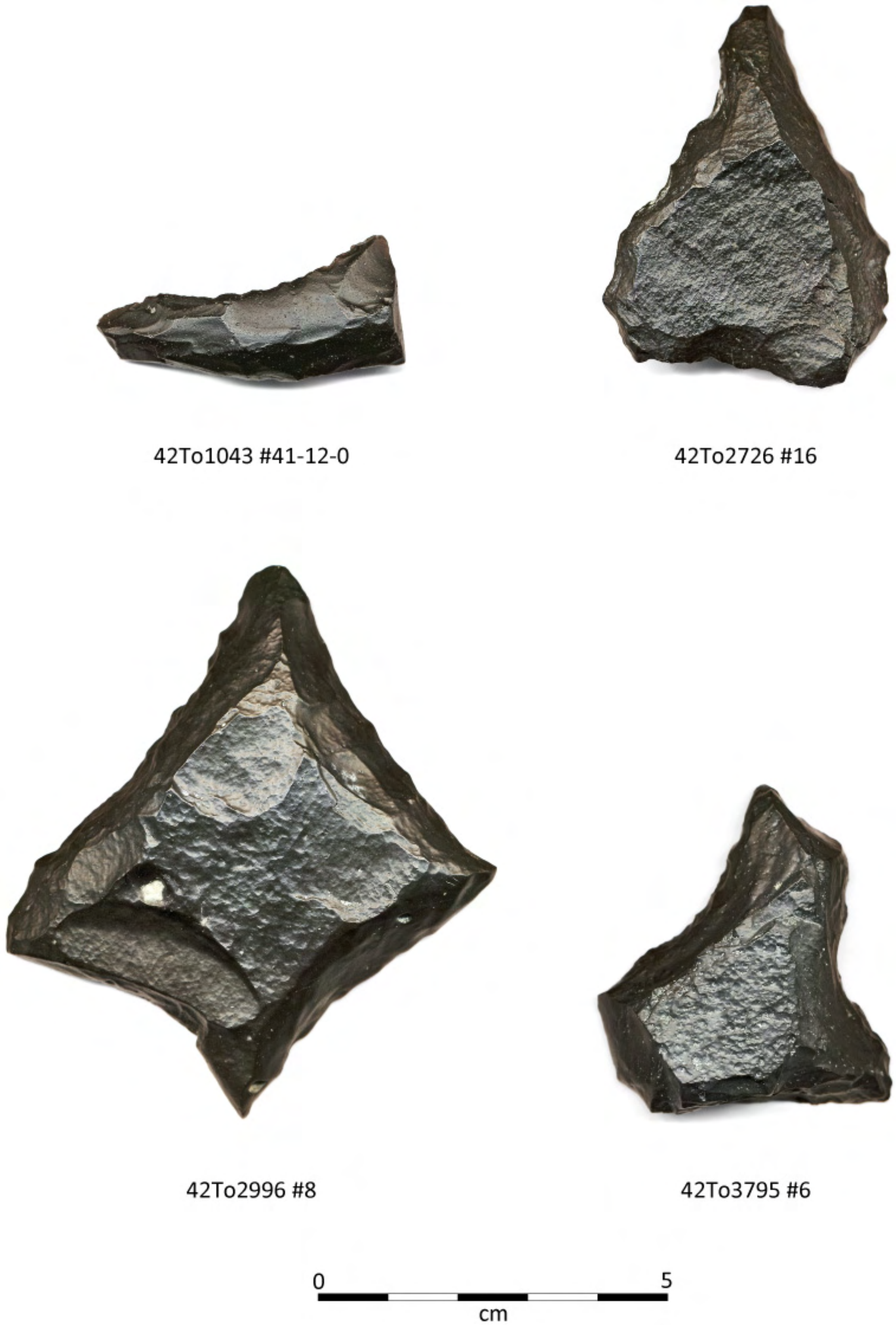

Figure 32. Beaked scrapers from the distal ORB.

Figure 33. Awls/drills from the distal ORB.

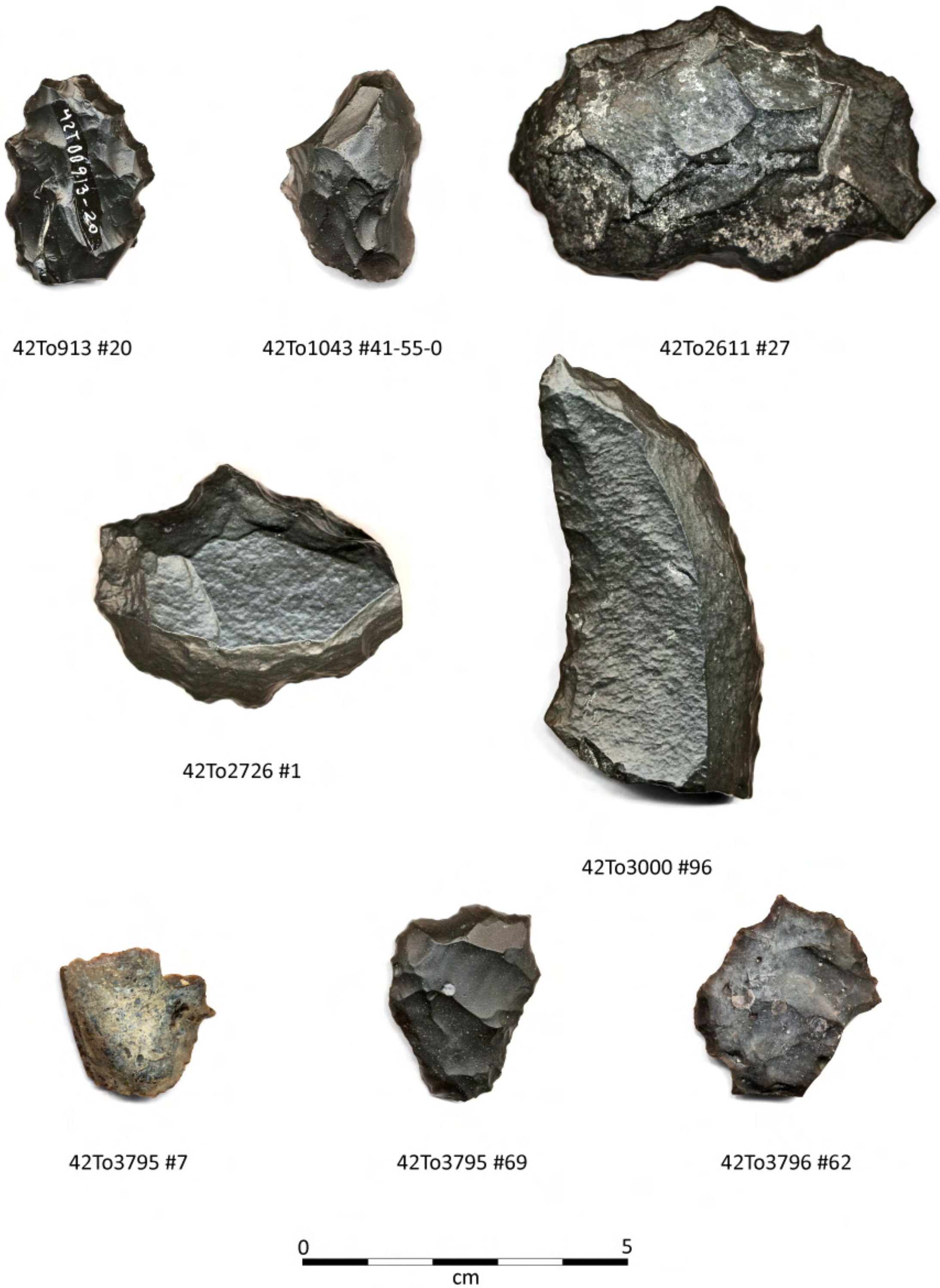

Figure 34. Spur/gravers from the distal ORB.

Table 9. Definitions for Reduction Trajectories.

Trajectory	Description
A	This represents artifacts that were transported from the quarry at a large size scale. They would not have been removed from a separate transported tool. Must be >12 mm thick. These can be any tool class, including bifaces and unifaces.
B	Artifacts that bear no clear indication of their original size. They could have been removed from a larger transported tool (i.e., one >12 mm thick) or made from a smaller flake blank. These can be any tool class, including bifaces and unifaces.
C	Tools that are clearly made from flake blanks, either transported straight from the quarry or reduced from larger transported tools on site. Must be <12 mm thick and exhibit remnant flake blank evidence. These can be any tool class, including bifaces and unifaces.
D	"Thinned" bifaces, as evidenced by flake scars indicative of an intention to decrease proportionate thickness by flaking through the midpoint of either tool face. Must be >12 mm thick.
E	Miscellaneous fragments that would otherwise be categorized as Trajectory B, but which are small and indicative of toolstone economization or the breakage of small tools/projectile points. Must be >12 mm thick. These can be any tool class, including bifaces and unifaces.

artifacts were assigned to a working trajectory based on these attributes and their estimated size when reduction began. Reduction trajectories A through E are described in Table 9.

These distinctions are used as an independent means of comparing the various attribute data described previously. The use of 12-mm-thickness to distinguish trajectories A and C is arbitrary, but in my experience, both experimentally and archaeologically, serves as a good break point between large-blank production and tool reduction. This pertains particularly to FGV. Figures 27 and 28 show two of the largest bifacial artifacts found on the distal ORB, and they are 14-mm and 18-mm thick, respectively. It would be difficult to remove a flake over half these thicknesses from either. Twelve millimeters is used as a liberal maximum at which a flake-based tool could be generated from a transported bifacial core, with thicknesses of 8-12 mm likely also representing items produced at a quarry.

Stylistic Classification of Great Basin Stemmed and Pinto Artifacts

Temporally-diagnostic artifacts constitute over a third of the assemblage, and with only a few exceptions, can be classified as GBS or Pinto. These are conventionally referred to as projectile points but could also have served as other tools; in this study, they are subjected both to the technological analysis described above as well as stylistic classification. Pinto artifacts are readily distinguished by their split/indented bases, but GBS typology is complex and regionally variable. Examples of each style are presented in figures 35 through 40.

Great Basin Stemmed. The following discussion details my methods for classifying the various types within the GBS series. Six types are used here: Cougar Mountain (Figure 35; includes Haskett varieties), Lake Mojave (Figure 36), Parman (Figure 37), Silver Lake (Figure 38), Stubby (Figure 39), and Bonneville (Figure 40). The commonly used point types are well known, and I rely on the interested reader to consult the primary literature for further detail (e.g., Amsden 1937; Butler 1965; Daugherty 1956; Hester 1973; Layton 1970, 1972b; Pendleton 1979; Rice 1972; Tuohy 1968; Tuohy and Layton 1977); an excellent recent review is provided by Beck and Jones (2009).

Table 10 provides the classification system used for GBS artifacts. It is oriented toward salient morphological attributes, most of which are widely recognized. All types are allowed to vary in size. This system is not mutually exclusive, although it is designed to

Figure 35a. Cougar Mountain projectile point from the distal ORB.

Figure 35b. Cougar Mountain projectile points from the distal ORB.

Figure 35c. Cougar Mountain projectile points from the distal ORB.

Figure 36a. Lake Mojave projectile points from the distal ORB.

Figure 36b. Lake Mojave projectile points from the distal ORB.

Figure 37a. Parman projectile points from the distal ORB.

Figure 37b. Parman projectile points from the distal ORB.

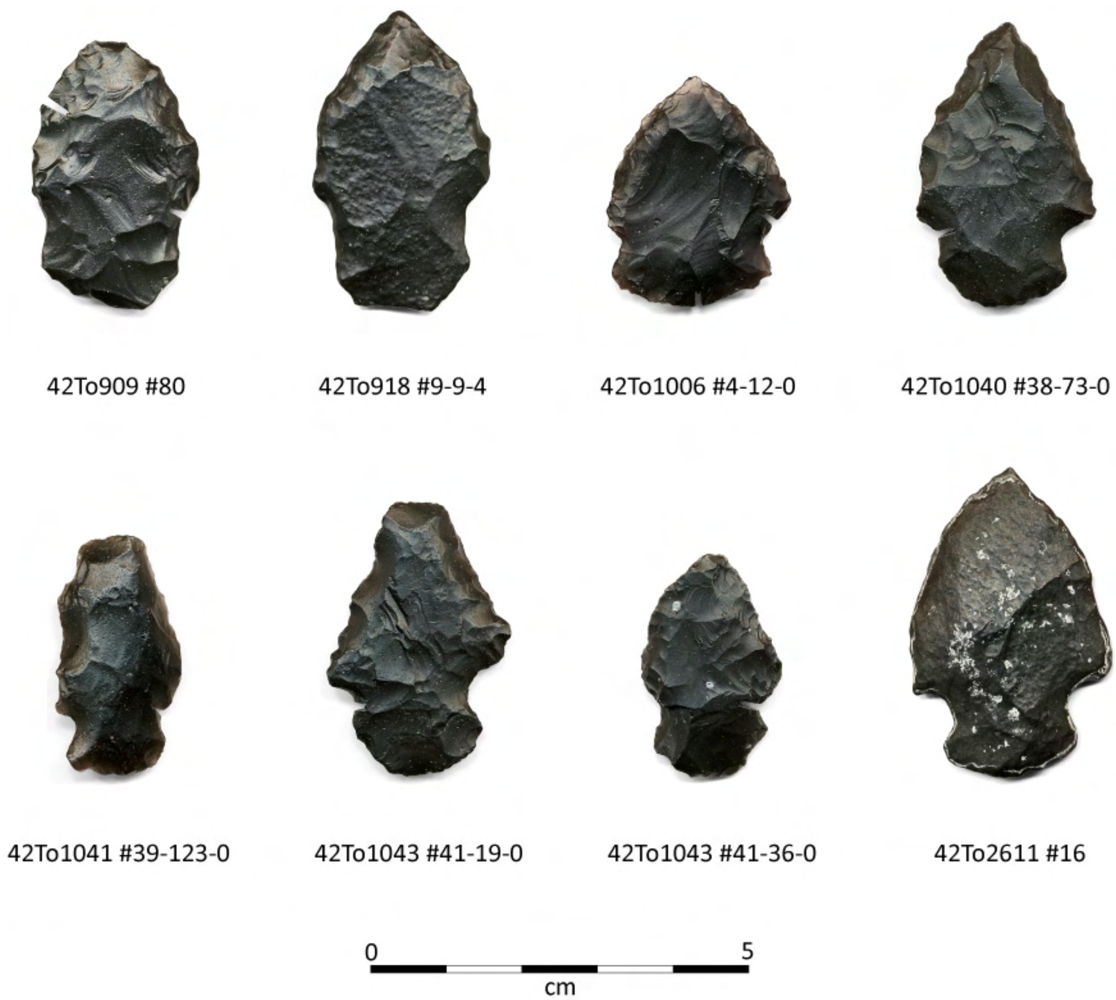

Figure 38a. Silver Lake projectile points from the distal ORB.

Figure 38b. Silver Lake projectile points from the distal ORB.

Figure 39. Stubby projectile points from the distal ORB.

Figure 40a. Bonneville projectile points from the distal ORB.

Figure 40b. Bonneville projectile points from the distal ORB.

Figure 41a. Pinto projectile points from the distal ORB.

Figure 41b. Pinto projectile points from the distal ORB.

Table 10. Great Basin Stemmed Type Definitions.

GBS Type	Stem Margins	Stem Length	Blade Length	Blade Shape	Further Considerations
Cougar Mountain	Contracting	Longer than width	n/a	n/a	Lack of distinctive shouldering separates this type from Lake Mojave, which has pronounced shoulders. Includes Haskett.
Parman	Parallel or expanding	Longer than width	n/a	n/a	Distinctive 180-degree shoulder angles and "tongue"-shaped stems are classified as Parman even if stem is not longer than it is wide.
Lake Mojave	Contracting	Longer than width	n/a	n/a	n/a
Silver Lake	Parallel or expanding	Less than or even with width	n/a	n/a	Stem margins are usually expanding to nearly notched in some cases.
Bonneville	Any	Less than or even with width	Long relative to stem	n/a	n/a
Stubby	Any	n/a	n/a	short relative to width	n/a

reduce overlapping categories as much as possible. After playing with different attributes and statistical relationships, this was the most suitable way I found to keep the analysis simple and avoid typological missteps owing to vagaries of artifact reworking and toolstone differences.

Two unique point types are distinguished here: "Stubby" and "Bonneville." Stubby, or "Dugway Stubby," is a type offered by colleagues working on the proximal portions of the ORB delta immediately to the south (Jones et al. 2002; Schmitt et al. 2007). The defining characteristic of the Stubby type is a short, often not even pointed, blade relative to maximum width of the item at the shoulders. This usually results from extensive reworking.

Thus, any of the other point types have the capability of being “stubby,” but keeping them separate was convenient for the distal ORB collections. Silver Lake, with its expanding base, is the type they most resemble, but stems for Stubby vary widely from contracting to expanding to square to different from one margin to the other, which suggests that reworking was not limited to the blade. In essence, while potential overlap exists, this never presented a problem in the current analysis.

The Bonneville type is assigned to the most common category of stemmed artifact on the distal ORB, and for much of the analysis were classed as “untypeable stemmed.” Their chief distinctiveness is that they possess long blades relative to their stems. Like the Stubby type, they exhibit a wide array of informal stem morphologies, but they are most akin to Silver Lake types from the Mojave Desert, which themselves are generally crude and variable in form. Bonneville points are similar in their lack of careful adherence to a specific template.

Like the other types, Bonneville and Stubby artifacts should not be restricted to the ORB, but ought to be found elsewhere in the Great Basin. The value in calling them out is that they are relevant to Paleoindian lithic economy in this particular case. Every point type used in this analysis, with the sole exception of Parman, is pictured in Amsden’s (1937) early descriptions of the Lake Mojave assemblages. In fact, the Mojave Desert record superficially bears more resemblance to that of the distal ORB than anywhere in the Great Basin. If the ORB typology truly stands out, it should produce different typological results when applied elsewhere.

I was able to test the typology on actual collections from the Mojave Desert through a contract archaeology project for the U.S. Army National Training Center at Fort Irwin (Duke 2010a). The Fort Irwin and the neighboring China Lake military installations cover a combined 1.7 million acres and are home to an extensive Paleoindian-Early Archaic record. Contract archaeology projects account for much of the data generated from these installations, but several published summaries exist (e.g., Basgall 2000; Davis 1975; Sutton et al. 2007; Vaughan and Warren 1987; Warren 1984; also see Basgall 1993). My task was to clarify early period FGV use on the base through XRF sourcing. Drawing from six prominent sites—Goldstone (CA-SBR-2348), Nelson Lake (CA-SBR-2355), Awl (CA-SBR-4562), Henwood (CA-SBR-4966), Rogers Ridge (CA-SBR-5250), and CA-SBR-12108 (unnamed)—I selected 104 complete or nearly complete GBS (n=55) and Pinto (n=49) points representing approximately 50 percent of the total FGV assemblages. The sample is not random, but it is considered generally representative. The bias toward FGV should not be a major factor since this material accounts for two-thirds of the total assemblages.

The results of the comparative analysis are presented in Table 11, keeping in mind that the aim of this exercise was not to question or otherwise reclassify point specimens from other areas, but simply to gauge the discriminating power of the current typology. As might be expected, near the type locales for Lake Mojave and Silver Lake points, these styles dominate, with only two items being classified as Bonneville.

I also examined images in the published literature to make comparisons to other areas (Table 11). These are not ideal comparisons since the specimens were likely selected for illustration with some bias, but I expected Bonneville and Stubby types to be captured

Table 11. Typeable GBS Projectile Points from Various Great Basin Locales.

Location	Projectile Point Type						TOTAL
	Cougar Mountain	Parman	Lake Mojave	Silver Lake	Bonneville	Stubby	
Eastern Great Basin							
Distal ORB	18	125	109	210	382	100	944
Sunshine/ENCC[1]	105	15	25	14	-	7	166
Mojave Desert							
Fort Irwin[2]	-	-	30	23	2	-	55
Lake Mojave[3]	2	-	5	4	2	1	14
NW Great Basin							
Parman Localities[4]	9	20	-	2	3	3	52

[1]Beck and Jones (2009); [2]Duke (2010a); [3]Amsden (1937); [4]Layton (1970)

within the established categories. The only exception to this is for Beck and Jones (2009) where the total count of 166 represents the number of points shown in figures for the respective types. Also, the numbers presented in Table 11 do not represent one-to-one accounting of what is pictured in the studies reviewed because some items were not classifiable or were otherwise considered nondescript. I simply typed those that I could.

There are few differences between my classifications and the originals. Projectile points shown in Amsden's (1937) figures are much like those from Fort Irwin, and perusal through illustrations in the Fort Irwin-China Lake gray literature shows that these are representative of assemblages throughout the Mojave Desert. Points from the Parman localities (Layton 1970) generally stay true to form as well, although many of the more square-based styles Layton calls "Parman #2" are uncharacteristic of those seen on the distal ORB ("Parman #1" is more typical).

Beck and Jones (2009) provide illustrations for most of their points from the Sunshine Locality and neighboring areas of eastern Nevada (i.e., Butte, Long, and Jakes valleys), which they refer to as the "Eastern Nevada Comparative Collection." These are considered together in Table 11. Cougar Mountain and related long-stem forms, uncommon in both the distal ORB and the Mojave Desert, dominate these collections, especially at the Sunshine Locality. Beck and Jones (2009:170) also call out "Ovate" as a separate type that is similar to Cougar Mountain and Haskett (cf. Butler 1965), but which lacks any clear point of shouldering; combined, Beck and Jones' Cougar Mountain and Ovate points comprise over two-thirds of the typeable points at the Sunshine Locality. My classification of those pictured did nothing to change this distinction; in fact, nine of their Lake Mojave points would be Cougar Mountain by my classification because they lack distinctive shoulders, but this is a hazy zone of overlap and not considered very meaningful. I did not analyze the distal ORB assemblages for Ovate points, and I noticed only a few pressure-flaked bifaces that could qualify. This rarity should be expected if they coincide with Cougar Mountain, which themselves are uncommon in the dataset. Otherwise, seven of the items Beck and Jones (2009:Figure 6.17) identify as Silver Lake could also be called Stubby by my typology.

Pinto. The temporal placement of Pinto continues to be one of the messiest issues in Great Basin projectile point studies (Basgall and Hall 1993; 2000; Bettinger and Taylor 1974; Harrington 1957; Haynes 2004a; Hockett 1995; Holmer 1978, 1986; Jenkins and Warren 1984, 1987; Lanning 1963; Layton 1970; Meighan 1981; O'Connell 1975; Schroth 1994; Rogers 1939; Thomas 1981, 1983; Vaughan and Warren 1987; Warren 1980). Pinto points are often considered poor chronological indicators, with close attention to their morphology and distribution necessary to distinguish them from other split- and indented-base styles. Based on his efforts in the central Great Basin, Thomas (1971, 1981, 1983) actually stopped using Pinto as a label, choosing instead Gatecliff Split Stem and Elko Eared to subsume similar forms, the former he dates from ca. 5800 to 3500 cal BP and the later ca. 3500 to 1200 cal BP. The Early Holocene record at Gatecliff Shelter is minimal (Thomas 1981, 1983), and data from surrounding areas suggest that authentic Pinto points are uncommon in the central Great Basin. This separates the distal ORB from the Mojave Desert of southern California where Pinto is most markedly expressed and where research continues to be focused; in fact, the type locality lies 750 km to the southwest in the Pinto basin.

As they were originally defined by Amsden (1935), Pinto points are thicker than the Middle Archaic styles at Gatecliff Shelter and typically possess a more footed base and upward sloping shoulders. In California, Bettinger and Taylor (1974) also distinguish these robust forms from the long, thin, pressure-flaked varieties of the Little Lake series, which they date between approximately 6100 and 3200 cal BP. Examples from the distal ORB are shown in Figure 41. Amsden (1935) describes the Pinto basin points as averaging 40 mm long, 18.8 mm wide, and 8.8 mm thick (also see Basgall and Hall 2000:238). The Pinto items from the distal ORB are similar in size at 37.9 (n=141) x 20.0 (n=134) x 6.4 (n=164), with maximum thickness being the most notable deviation.

Two classification keys have been proposed to distinguish the early Pinto variety (Basgall and Hall 2000; Vaughan and Warren 1987), both of which were utilized in this study, with the more recent Basgall and Hall (2000) key providing most of the type calls. A total of 171 of the 186 Pinto items in this study were subjected to the keys, the results provided in

Table 12. Pinto Typology as Determined by Various Classification Keys.

Classification Key	Projectile Point Type					
	Pinto	Gatecliff/ Elko	Gatecliff Split Stem	Elko*	Humboldt	Ind./out of key
Basgall & Hall (2000)	137	10	-	-	-	24
Vaughan and Warren (1987)	65	30	-	-	-	76
Thomas (1981)	-	-	80	58	2	31

*Thomas distinguishes between Elko Eared and Elko Corner-notched based on basal indention ratio, with 31 from the distal ORB being Elko Eared, 24 Elko Corner-notched, and three indistinguishable Elko series.

Table 12. It is important to note that neither Basgall and Hall (2000) nor Vaughan and Warren (1987) differentiate between Elko and Gatecliff, concerning themselves only with distinguishing Pinto. The Vaughan and Warren key is designed to be mutually exclusive, building from the Thomas (1981) key, and is sensitive to variability in Pinto morphology away from the Awl site, where it was originally evaluated. Less than half of the distal ORB sample is classified as Pinto by this key; the others were excluded for being too thin (< 6.4 mm; exactly the mean of the distal ORB sample) or shoulderless. Basgall and Hall (2000) note this fussiness in the Vaughan and Warren key and base their primary distinction from Elko/Gatecliff on notch opening angle (>80 degrees). Basgall and Hall's aim is to distinguish essentially known Pinto artifacts from later Archaic types; thus, there is some presumption of Pinto by the practitioner prior to using the key. Results from processing the sample through the Thomas key are also presented in Table 12 for comparison.

The entire distal ORB sample is assumed here to be a regional variant of the Pinto style. Variable patterning from the Mojave Desert is not surprising, so no great significance is attributed to this. More importantly, the distal ORB sample is found in the same geoarchaeological contexts (i.e., paleochannels, underneath dunes) as GBS artifacts, and exhibits similar technological associations as GBS artifacts, as discussed in the next two chapters. Pinto points are also weathered to the same extent, and otherwise show no characteristics that warrant further scrutiny for the purposes of this study. As I discuss in Chapter 2, obsidian hydration indicates that GBS and Pinto date similarly, and, in fact, when comparing hydration data from specimens called Pinto versus non-Pinto in the Basgall and Hall key, there is essentially no difference between small samples from the two groups. For Topaz Mountain obsidian, those classified as Pinto average 8.9 microns (n=10, SD=1.1) compared to 8.7 microns (n=8, SD=1.4) for non-Pinto. A t-test indicates that these samples are not statistically significantly different ($t=-.31$, $df=12$, $p=.76$).

Along with the classification keys comes the argument, similar to that made here, that Pinto points should be old based on ancient lake-margin and distributary-system archaeological contexts and similarities with stemmed-point technology. Pinto and GBS points can often be found together in Mojave Desert sites, but they can also be found separately, with strong associations with ground stone in the case of Pinto. This suggests that while they may overlap, Pinto persisted well into the Early Holocene.

Haynes (2004a) argues that overlap, rather than replacement or temporal hiatus, is supported by both the radiocarbon record and obsidian hydration data in the Mojave Desert. Radiocarbon dates are few, but several seem representative when considered in context. At the Awl site, two depositional strata were originally identified by Basgall and Hall (1993), with a rock feature located at the top of the lower stratum. Two charcoal samples from this feature date ca. 10,700 cal BP. Comparing GBS to Pinto proportions between the two strata, Basgall and Hall (1993) find 80 percent of Pinto points occur in the upper stratum and 89 percent of GBS occur in the lower stratum. These data suggest that Pinto was present at the Awl site prior to 10,700 cal BP then became significantly more common shortly thereafter. At Rogers Ridge, both stemmed and Pinto points were found in the vicinity of a series of four radiocarbon dates between ca. 9000 and 9400 cal BP (Jenkins 1987). Over 30 Pinto points were collected at the Flood Pond site alongside fire-cracked rock features, ground stone, and *Anodonta* shell fragments (Hall 1993); no GBS points were observed. A date of 7500 cal BP was acquired from charcoal in an ash-pit feature that appears to be representative of the site assemblage.

Haynes (2004a) believes these three sites are key to identifying Pinto chronology, with the style being in place in the Mojave Desert prior to 10,700 cal BP, becoming more common at the expense of the stemmed series until sometime after 9000 to 9500 cal BP, then enduring through 7500 cal BP, at which time GBS points are no longer present. There remains much to be desired from the radiocarbon record for Pinto, but this chronology is completely consistent with that proposed for the distal ORB (i.e., pre-9900 cal BP). Finally, Haynes (2004a) provides obsidian hydration data from his own study area in the Yucca Mountain vicinity of southern Nevada that further indicates this overlap. From items made primarily of the Shoshone Mountain obsidian source, GBS points have a mean rim thickness of 7.5 (n=59) and Pinto points 5.3 (n=51). The means are significantly different statistically, but the range of readings overlap comfortably. No overlap is apparent in the distal ORB collections (see Chapter 2), and data from other parts of the Mojave Desert indicate that at some localities the point styles co-occur (Basgall 1995; Gilreath and Hildebrandt 1997; Rosenthal and Eerkens 2004). Variable temperature histories may be affecting these results, as asserted in Chapter 2, but overall, the data support a GBS-Pinto association for some period of time.

Evidence on the timing of Pinto in the eastern Great Basin is sparse, but generally supports Haynes' (2004a) chronological model. Holmer (1978, 1986) suggests that Pinto forms resembling those from the Mojave Desert date between ca. 9300 and 7100 cal BP based on date ranges from Danger Cave, Hogup Cave, Sudden Shelter, and Cowboy Cave, the first two of which are located in the Great Salt Lake Desert area. He uses a discriminant analysis to morphologically separate these from items that could be classified as Gatecliff or Elko, which can be observed at other sites, such as Swallow Shelter and O'Malley Shelter, to post-date ca. 7400 cal BP.

There is little else from the eastern Great Basin that can help refine this sequence. Beck and Jones (1994:71) provide obsidian hydration data for a few Pinto points that again suggest some overlapping contemporaneity in the Butte Valley area of eastern Nevada. Beck and Jones (2009) also report a limited Pinto at the Sunshine Locality just to the west of Butte Valley in Long Valley, that appears to be part of an extensive Paleoindian record they estimate dates as late as approximately 10,100 cal BP. Pinto is similarly found in low frequencies alongside GBS assemblages in nearby Jakes Valley (Estes 2009). Two Pinto points are dated at Bonneville Estates Rockshelter to between 5600 and 5100 cal BP (Goebel, personal communication 2011).

Statistics

Several statistical tests are used in this analysis, often in an exploratory manner. These are described as necessary in the analytical chapters, but a few parameters are described here to keep from having to repeat standard practices. Most commonly, chi-square is used to compare categorical proportions and two-sample t-tests are used for quantified data. These are always conducted at a five percent significance level. The results of these tests are only reported when they are vital to the discussion, but otherwise should be assumed when mention is made of differences being “statistically significant.” Sample size is discussed where applicable, and tests were always designed to maximize sample size as much as possible. For chi-square tests, care was taken not to generate too many cells or include data categories totaling less than five items, unless otherwise stated.

CHAPTER 7

PROJECTILE POINTS AND OTHER STEMMED ARTIFACTS

Projectile points are an obvious lead-in to the broader technological study because of their potential as cultural and temporal markers. There is particular analytical value within the GBS series because this typological group possesses such great variety in form. As discussed in this chapter, projectile points carry telling information about both how people used flaking strategies to manage and manipulate lithic resources and how these strategies changed through time.

The term "projectile point" is a convenient category, but some of these artifacts may not have been points at all. The possibility that they actually represent various knives and/or scrapers is one that has gained acceptance in the recent literature (e.g., Beck and Jones 2009), but no definitive use wear or experimental data exist sufficient to clarify how often this should be the case (see Lafayette 2006). This is directly addressed later in this chapter, and, in fact, there are specimens from the assemblage here that clearly have alternate uses by way of their similarity to other tool types. Nevertheless, most still appear to be projectile points and so the term will be used here out of convention alongside more generic reference to "stemmed artifacts" where applicable. The initial concern of this chapter is with chronology, and for this, functional aspects are irrelevant as long as a stylistically diagnostic stem type is present.

The total sample of early point types from the study area is 1,209, consisting of 1,021 GBS, 186 Pinto, one Folsom, and one Scottsbluff. A total of 944 GBS points are typeable, the others being aberrant or too fragmentary for a designation. There are 1,032 points from 176 sites, and 47 of these sites contain five or more typeable GBS and/or Pinto specimens. Isolated finds account for 177 items. Examples of GBS and Pinto artifacts from the distal ORB are presented in figures 26 through 41 in the previous chapter.

The Folsom and Scottsbluff points are not dealt with in detail in this study but are worth brief mention (Figure 42). Occasional Folsom points are known in Utah and into areas of Idaho and Nevada surrounding the Bonneville Basin (Beck and Jones 2009; Copeland and Fike 1988; Justice 2002), so the fact that only one has been found on the distal ORB suggests that there is a timing discrepancy between the use of Folsom and distal ORB access. The latest accepted date for Folsom is argued by Haynes (1992, 1993; Haynes et al. 1992) and Holliday (1997) to be between 12,100 and 11,900 cal BP. This corresponds with the earliest wetland dates on the distal ORB.

The accepted date range for Scottsbluff—a stemmed style associated with the Cody complex of the High Plains—is approximately 10,600 to 9,600 cal BP (Knell 2007; Holliday 2000) and corresponds well with the latter half of the proposed range for the distal ORB. Its rarity in the study area is noteworthy, marking archaeological, and presumably cultural, distinctiveness between the Great Basin and the neighboring Plains. There are other points in the sample with Cody complex affinities, but not so distinctively and not without Great Basin lithic resource use patterns (i.e., obsidian and FGV). Both the Folsom and Scottsbluff points are made from exotic varieties of chert not seen in the rest of the assemblage. The distal ORB is therefore rightfully comparable as a Great Basin archaeological record.

Figure 42. Folsom (two views) and Scottsbluff projectile points from the distal ORB.

The Distribution of Stemmed and Pinto Artifacts

There are no direct temporal data on stemmed artifacts on the distal ORB, but the black mat dates and overlapping distributary paleochannel relationships I describe in Chapter 2 provide a basis for broad chronological relationships. The west and east distributary channel groups are used to divide the study area into earlier and later subareas, respectively, as described previously. Are there proportionate differences in GBS and Pinto artifact types between these subareas? This appears to be the case, providing the first indication of temporally meaningful assemblage differences in the study area.

Cluster analysis was employed to address the question, drawing the sample from 47 sites with five or more typeable artifacts (Figure 43). This sample contains 709 of the total 1,207 GBS and Pinto specimens. Six categories are used: Lake Mojave, Parman, Silver Lake, Bonneville, Stubby, and Pinto (there are too few Cougar Mountain for statistical comparison). The cluster analysis was completed in Minitab 16, using McQuitty linkage and squared Euclidean distance. Exploratory two-, three-, and four-way analyses were conducted. The two-way results are the most robust, separating 39 sites from eight others based especially on the presence of Pinto and Bonneville types in the former, hereafter referred to as "Cluster P1," as opposed to Parman and Lake Mojave in the latter, or "Cluster P2"; in fact, there is only one Pinto point in Cluster P2. A four-way analysis distinguishes two additional sites from the two-way clusters: 42To926, with a high proportion of Lake Mojave, and 42To1006, which is over 80 percent Silver Lake. These are not considered meaningful distinctions, and the two-way clusters are used here.

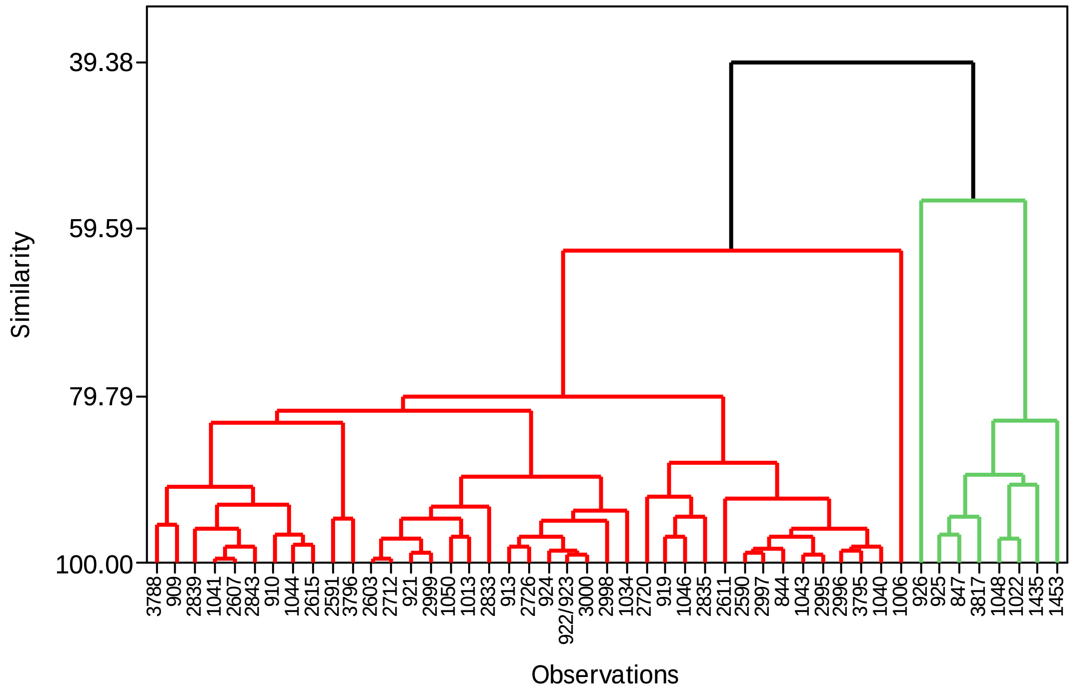

Figure 43. GBS/Pinto assemblage clusters for the distal ORB. Cluster P1 is shown in red and Cluster P2 in green.

A seriation provides a visual display of the data. This was done using WinBasp 5.43 freeware. As seen in Figure 44, all the sites in Cluster P2 group at one end of a seriation beginning with Parman and continuing with Lake Mojave, Silver Lake, Bonneville, Stubby, and finally Pinto.

The entire typeable sample of 1,130 items was used to examine the spatial distribution of types across the study area. Using the paleochannel groups described in Chapter 2 as a guide, the study area was divided into east and west subareas at a UTM (WGS84) easting of 295000 m (see Figure 7, Chapter 2). The west subarea contains Wild Isle and west Knolls dunes, while Wildcat and east Knolls dunes are in the east subarea; mostly mudflats define the space in between these dune fields, where there is little archaeology.

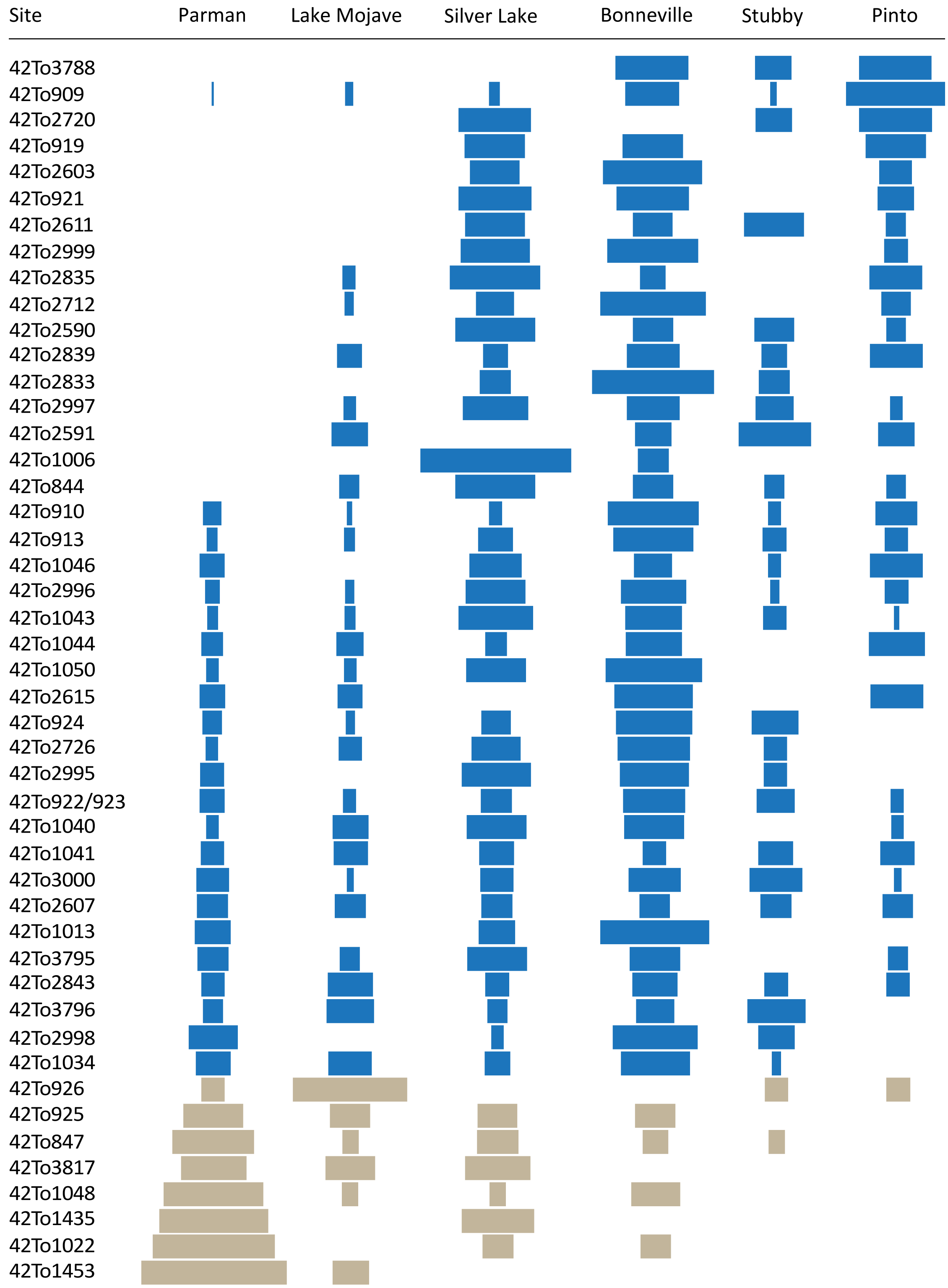

Figure 44. Seriation of GBS and Pinto artifacts from the distal ORB delta. Cluster P1 is shown in blue, Cluster P2 in tan.

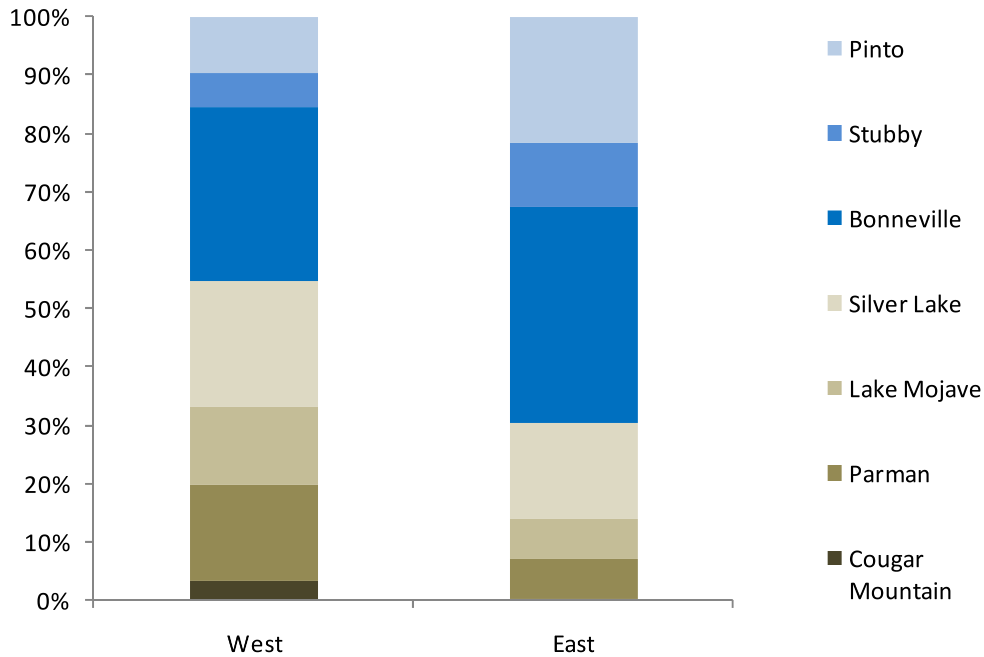

Figure 45. Relative percentages of GBS and Pinto artifacts by subarea.

Proportionate differences are presented in Figure 45, inclusive of Cougar Mountain, and show a distinct difference between the two subareas with Cougar Mountain, Parman, Lake Mojave, and Silver Lake more common in the west subarea and Bonneville, Stubby, and Pinto more common in the east subarea. The difference between the two type groups by subarea is statistically significant (χ^2=68.561, *df*=1, *p*<.01).

A few other patterns within this distribution are important for later discussion. For the whole study area, Bonneville, Silver Lake, Stubby, and Pinto account for 78 percent (n=878) of the typeable assemblage, while Cougar Mountain, Parman, and Lake Mojave contribute only 22 percent (n=252). Of these last three types, 65 percent (n=163) are found in the west subarea. Seventy-eight percent (n=128) of these are found on Wild Isle Dunes, with 60 percent (n=75) located in the southern half of this dune field at the divergence of what appear to be the oldest distributary channels in the study area (<UTM 4479000 E; see Figure 7). Moreover, Cougar Mountain, Lake Mojave, and Parman artifacts represent 44 percent (n=75 of 171) of all the typeable artifacts in this area. This combines with a near lack of Pinto artifacts from here, reinforcing the association of Pinto artifacts with the later part of the chronology.

Not only are Cougar Mountain, Parman, and Lake Mojave artifacts spatially restricted and less common than the other types, but they are also found in smaller assemblages. Referring back to the cluster analysis, Cluster P2, which is defined by high proportions of Parman and Lake Mojave artifacts, accounts for only 14 percent (n=98) of the total sample versus 86 percent (n=611) for Cluster P1. Thus, while there are temporal distinctions, the technological mode defined by Cluster P1 largely defines the study area as a whole, although it is more distinctive in the east subarea. The eight sites represented in Cluster P2 contain 11 typeable artifacts per site, while Cluster P1 sites contain 16 typeable artifacts per site. This further suggests that Cluster P1 and east-subarea assemblages represent longer site occupations and/or less transport efficiency than those from Cluster P2 and the western subarea, in line with model expectations.

Technological Aspects

Toolstone Selection and Geochemical Source Use

The unique aspect of the distal ORB is that it is so remote from toolstone sources. Currently, 60 km (from the center of the study area) represents the closest known sources of FGV at Flat Hills, to the east near Dugway, and Deep Creek, in the opposite direction, south of Wendover near the Utah-Nevada border. The two closest primary sources of obsidian are

Topaz Mountain, 90 km to the south, and Browns Bench, 175 km to the north. Ferguson Wash obsidian is 50 km away on the west margin of the basin, but only comes in small pebbles rarely used by in Paleoindian times.

The longer people stayed on the distal ORB, the more local the toolstone profile should become. With regard to the primary toolstone classes, as residential stays lengthened, FGV should increase in use over obsidian. At a small scale, this could come via normal replacement of tools made from more exotic materials, but per the model presented in this study, people should have reasonably anticipated their length of stay and oriented their toolstone usage accordingly. This would be especially important so far removed from stone sources.

Obsidian and FGV greatly dominate the assemblage at 97 percent, with obsidian accounting for 63 percent of these. Only three percent (n=42) of the assemblage is made from chert or quartzite, and are not considered further. The summary data for all 1,207 GBS and Pinto artifacts are presented by toolstone type in Table 13, with obsidian and FGV proportions specified in Table 14 and shown graphically in Figure 46. Comparing obsidian and FGV proportions between the east and west sides of the study area, a chi-square test shows that a greater than expected amount of obsidian occurs on the west side (χ^2=5.46, df=1, p=.02), where 67 percent of artifacts are obsidian compared to 60 percent on the east side.

As can be seen in Figure 46, Pinto and Stubby are the types most dominated by one material or the other, with Pinto being the only type predominantly made from FGV (58%). Cougar Mountain is an exception to this pattern but there are only 18 specimens. Stubby is defined by resharpening, so it is not surprising that this type exhibits an extreme association

Table 13. Toolstone Selection for GBS and Pinto Artifacts by Subarea.

Subarea	Material Type				TOTAL
	Obsidian	FGV	Chert	Quartzite	
East	388	260	14	7	669
West	344	173	15	6	538
TOTAL	732	433	29	13	1,207

Table 14. Obsidian and FGV Counts for GBS and Pinto Artifacts by Subarea.

Type	East		West		TOTAL
	OBS	FGV	OBS	FGV	
Cougar Mountain	2	-	7	9	18
Parman	27	16	49	29	121
Lake Mojave	34	10	53	12	109
Silver Lake	54	45	74	24	197
Bonneville	135	94	84	58	371
Stubby	64	6	26	3	99
Pinto	55	76	19	26	176
Other/Ind.	17	13	32	12	74
TOTAL	388	260	344	173	1,165

with obsidian. What is more intriguing about this type is that there are proportionately more of them in the east subarea than the west, where obsidian prevails; thus, the differences between obsidian and FGV use from one side to the other are more distinctive when Stubby is excluded from the statistics. Bonneville is the only other stylistic type that increases in frequency on the east side, and these are made from FGV more often than the other primary point types (although the differences are minimal), as seen in Figure 46.

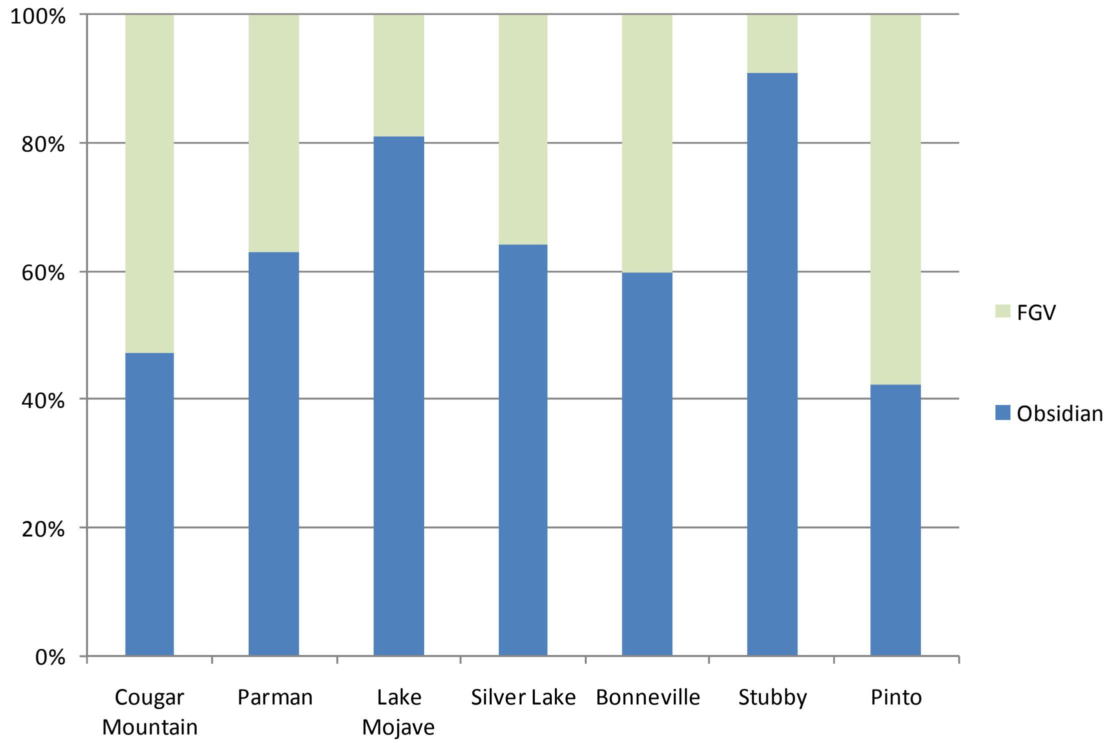

Figure 46. Relative percentages of obsidian and FGV by GBS and Pinto type.

Specific source utilization should follow the trends in the primary toolstone classes. A large-scale effort was made to identify the geochemical sources of obsidian and FGV artifacts in this study. Craig Skinner, at the Northwest Research Obsidian Studies Laboratory, conducted all XRF analysis, which was done alongside various contract archaeology work for Hill Air Force Base and additional SARF-funded efforts. Obsidian sources were largely known prior to this study, but FGV sources had to be identified. This required searching the hills surrounding the basin whenever possible, a task that benefited from the collaborative legwork of David Page, who details these findings in a separate study (Page 2008). Over 85 percent of FGV artifacts that have been subjected to XRF analysis can

Table 15. Geochemical FGV Source by GBS and Pinto Type.

FGV Source	Projectile Point Type							TOTAL
	Cougar Mountain	Parman	Lake Mojave	Silver Lake	Bonneville	Stubby	Pinto	
Flat Hills D	2	2	-	6	10	-	6	26
Flat Hills A	-	2	3	4	8	3	1	21
Flat Hills C	-	1	-	-	2	-	-	3
Deep Creek A	-	1	-	-	5	-	6	12
Badlands A	-	1	2	-	3	-	-	6
Smith Valley	-	-	-	-	-	-	1	1
Unknown	-	-	1	1	4	-	4	10
TOTAL	2	7	6	11	32	3	18	79

Table 16. Geochemical Obsidian Source by GBS and Pinto Type.

Obsidian Source	Projectile Point Type							TOTAL
	Cougar Mountain	Parman	Lake Mojave	Silver Lake	Bonneville	Stubby	Pinto	
Topaz Mountain	3	26	39	57	76	27	34	262
Browns Bench	1	26	20	27	37	19	9	139
Black Rock Area	-	2	4	6	9	2	3	26
Malad	-	1	3	-	10	3	2	19
Wild Horse Cany.	4	-	1	-	4	1	2	12
Paradise Valley	-	3	-	1	3	1	-	8
Modena	-	-	1	2	1	1	1	6
Ferguson Wash	-	-	-	3	-	-	1	4
Bear Gulch	-	-	-	-	1	-	-	1
American Falls	-	-	-	-	-	1	-	1
Unknown	-	1	3	1	2	1	-	8
TOTAL	8	59	71	97	143	56	52	486

now be assigned to a geochemical source (Table 15), alongside over 97 percent of obsidian (Table 16). These sources are shown in Figure 20 in Chapter 5.

Tables 15 and 16 provide the obsidian and FGV sourcing data for the different projectile point types. Of the total GBS and Pinto assemblage, 71 percent of obsidian (n=486

Table 17. Major Obsidian Sources by Dune Field.

Obsidian Source	West subarea		East subarea		TOTAL
	Wild Isle	Knolls Dunes	Wildcat Dunes	Lone Dunes	
Topaz Mountain	115	21	67	58	261
Browns Bench	50	31	38	20	139
Other/Unknown	34	6	28	16	84
TOTAL	199	58	133	94	484

of 683) and 19 percent (n=79 of 408) of FGV have been sourced. A wide array of sources is apparent in the obsidian, from every direction but east. Topaz Mountain and Browns Bench dominate the assemblage at 83 percent, with Topaz Mountain being the closest and most common at 53 percent of the total (Table 16).

An east-west comparison between these points reveals no statistically significant difference in the proportions of Topaz Mountain, Browns Bench, and grouped "other" sources (χ^2=2.356, *df*=2, *p*=.31). This is an unexpected result, and it may be more of a reflection of the non-local nature of all the toolstone than it is the technological aspects being examined. Topaz Mountain and Browns Bench dominate the assemblage and are found in opposite directions south and north, respectively. The bulk of the artifacts are on a roughly east-west line in the study area (i.e., Wild Isle-Wildcat), thus controlling for distance to these two sources within the sample. The only exception to this is Knolls Dunes, which cuts the distance of 175 km to Browns Bench (which was measured from the study area center) down to at least 160 km, and increases it to Topaz Mountain to 100 km. The counts for different obsidian sources by dune field are presented in Table 17 (excluding two artifacts that are not associated with dunes), and a series of chi-square tests shows no differences between any

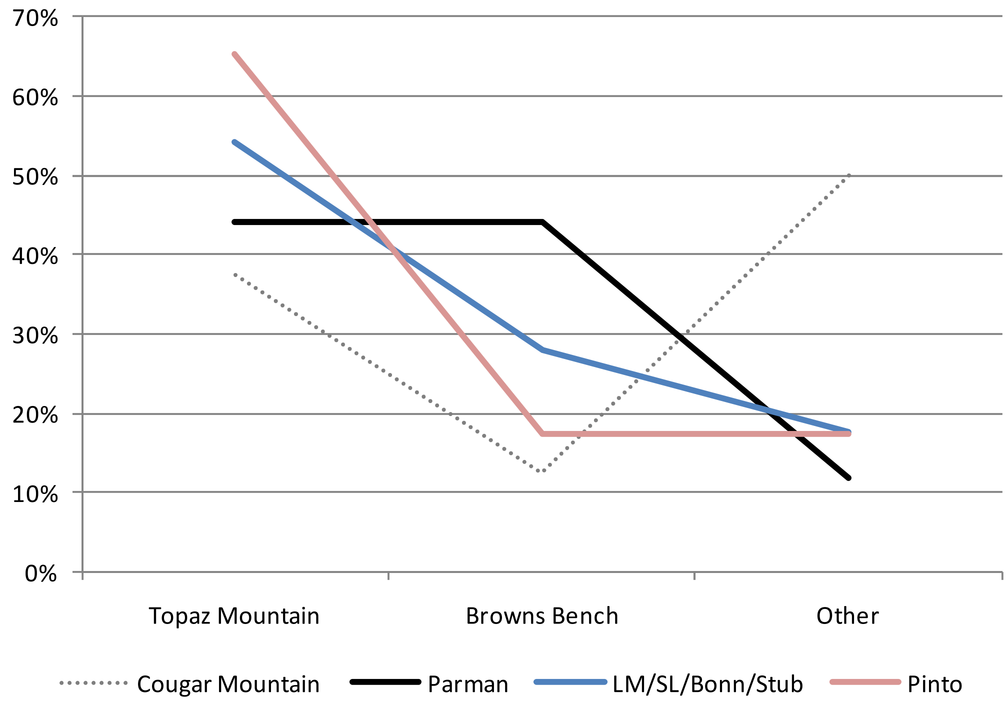

Figure 47. Obsidian source distribution for GBS and Pinto artifact type groups.

pairing of Wild Isle, Wildcat, or Lone Dunes; however, the Knolls Dunes assemblage is significantly different from each, owing to higher counts of Browns Bench obsidian.

The distribution of obsidian sources among projectile point types is more telling, although similarity remains high for most of the point types (Figure 47). Chi-square comparisons of just Topaz Mountain, Browns Bench, and other varieties show no statistically significant difference in source use between Lake Mojave, Silver Lake, Bonneville, and Stubby (Figure 47). Cougar Mountain stands out with a high proportion of "other" sources, but only eight artifacts were sourced (although the fact that four are Wild Horse Canyon, out of the total 12 for the 486 typeable points sourced, is worth noting). The most telling distinction, and one that might be expected, is between Parman and Pinto types (χ^2=9.169, *df*=2, *p*=<.01). Parman possesses the highest proportion of Browns Bench of any GBS type, at equal levels to Topaz Mountain, while Pinto exhibits the highest proportion of Topaz Mountain. Source proportions for Parman are also significantly different from those of the Lake Mojave-Silver Lake-Bonneville-Stubby group (χ^2=6.319, *df*=2, *p*=.04). Pinto source proportions are markedly different from those of Parman (Figure 47), but less so from the Lake Mojave-Silver Lake-Bonneville-Stubby group. They do not differ statistically from this latter group (χ^2=2.996, *df*=2, *p*=.22), but the higher rate of Topaz Mountain within Pinto does follow expectations.

There are too few sourced FGV specimens to make any strong comparisons between dunes or point types, but the gross data alone are important for understanding toolstone use in the study area. As shown in Table 16, the assemblage is dominated by material from opposite sides of the basin—Deep Creek/Badlands to the west and Flat Hills to the east. These findings are consistent with those of Page (2008) for sites immediately south on the proximal ORB delta. It is important to note that items sourced as Badlands A carry a chemical signature that is as-yet indistinguishable from FGV sampled from Wildcat Mountain, located within the study area; however, Wildcat Mountain material is coarse-grained and generally not toolstone-quality whereas Badlands A is high-quality for FGV, so specimens with this signature are assumed in this study to come from the Badlands area rather than Wildcat Mountain. The Flat Hills variants A, C, and D have all come from samples found in the same general area about 60 km from the study area (Page 2008). The potential remains that there are closer collection areas of Flat Hills material between the

Table 18. Descriptive Statistics for GBS and Pinto Weight (g) by Toolstone Type.

Stylistic Type	N	Mean	SD	Min	Max
Obsidian					
Cougar Mountain	4	11.82	13.04	3.8	31.1
Parman	39	7.03	3.84	3.0	18.4
Lake Mojave	36	6.08	3.41	1.9	20.3
Silver Lake	75	5.54	3.22	1.0	19.3
Bonneville	91	4.19	2.66	0.6	18.9
Stubby	42	3.60	1.51	1.4	7.7
Pinto	36	2.82	1.63	0.9	8.5
ALL	323	4.92	3.43	0.6	31.1
FGV					
Cougar Mountain	4	10.15	5.19	5.6	16.3
Parman	20	8.51	3.35	3.8	18.8
Lake Mojave	11	7.91	3.30	3.9	15.0
Silver Lake	46	6.82	2.67	2.9	15.9
Bonneville	68	6.57	2.96	2.2	15.4
Stubby	5	3.32	0.41	2.8	3.7
Pinto	55	4.57	1.94	1.2	9.9
ALL	209	6.34	3.04	1.2	18.8

eastern basin margin and Dugway, 30 and 60 km away, but we have not been able to find any during the course of extensive searching.

To summarize, XRF sourcing information provides a toolstone selection profile that is largely consistent across projectile point types. For both obsidian and FGV, the closest sources dominate, but it is apparent that people drew from additional sources in all directions at distances of 200 to 400 km. This suggests more of a convergence pattern on the distal ORB than any regular directional round (cf. Jones et al. 2003). While a more local obsidian profile for Pinto compared to GBS styles hints at the longer stays predicted by the model, all of the sources are so far away that resolution is minimal. Proportionate differences in the use of obsidian versus FGV in general are more robust. A sharp preference for FGV over obsidian for Pinto points, even while the obsidian source profile resembles that of the GBS types, is the best indication of this. Parman points are also distinctive in their high incidence of Browns Bench obsidian. This type has long been associated with the northern Great Basin and thus may mark a regional distinction in distal ORB occupation.

Size and Morphology

The more reliant people are on distant toolstone sources, the more transport efficiency they should try to manufacture into their tools. Obsidian comes from farther away than FGV, and therefore should reflect more of this efficiency. Obsidian can look more invested-in superficially simply because it is easier to flake, so there must be proportionate changes in the reduction of both materials to represent different technological priorities truly.

Basic weight and material type data provide the initial insights (Table 16). Of the total GBS and Pinto assemblage, 532 provide measurements. Differences in artifact size between obsidian and FGV are distinctive, but proportional, as FGV versions of each stylistic type (excluding Cougar Mountain for low sample size and Stubby for low FGV sample size) outsize their obsidian counterparts (Figure 48). Comparing the east and west subareas, the same pattern follows for each type, as indicated in Table 17.

The model predicts that bifacial toolkits designed to be transport-efficient will exhibit greater tool size than in those where this is less of a priority. Moreover, bifacial tools should be proportionately thinner, reflecting the minimization of unusable stone. This occurs between subareas, as expected, with both obsidian and FGV being proportionately thinner in the west subarea at statistically significant levels (Table 18). An interesting pattern is that FGV points are proportionately thinner than those made from obsidian despite not as-often being “thinned” during reduction, a quirk that is discussed more below.

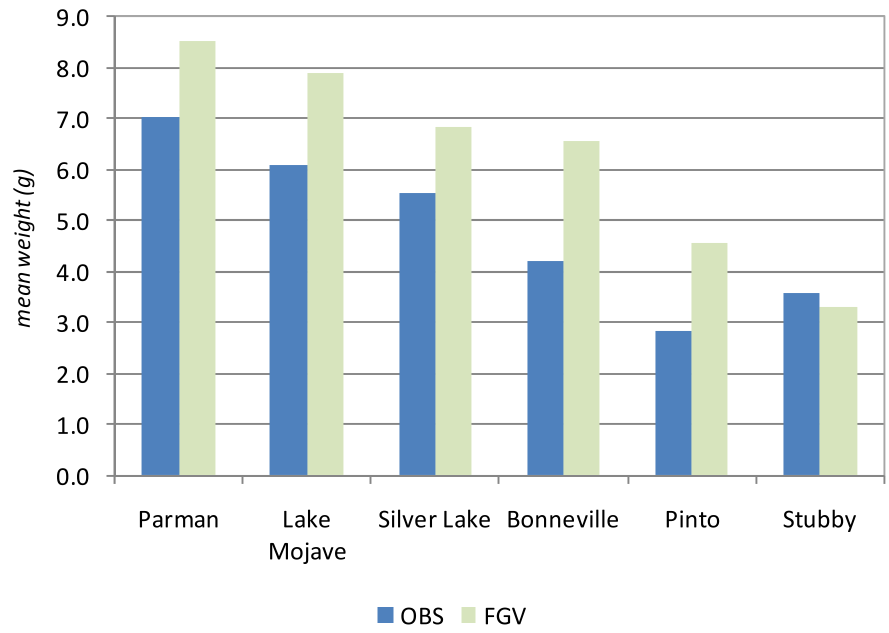

Figure 48. GBS and Pinto weight (g) by stylistic type and toolstone.

Table 19. Descriptive Statistics for GBS and Pinto Weight (g) by Subarea.

Stylistic Type	N	Mean	SD	Min	Max
West					
Cougar Mountain	8	10.99	9.23	3.8	31.1
Parman	37	8.31	4.14	3.7	18.8
Lake Mojave	30	6.68	2.93	2.8	15.0
Silver Lake	52	6.27	3.39	1.5	19.3
Bonneville	56	5.50	3.00	1.1	14.0
Stubby	17	3.95	1.45	2.0	7.3
Pinto	26	4.40	1.98	2.1	9.9
ALL	226	6.24	3.79	1.1	31.1
East					
Cougar Mountain	-	-	-	-	-
Parman	22	6.22	2.44	3.0	11.0
Lake Mojave	17	6.19	4.29	1.9	20.3
Silver Lake	69	5.84	2.83	1.0	15.9
Bonneville	103	5.05	3.04	0.6	18.9
Stubby	30	3.36	1.41	1.4	7.7
Pinto	65	3.67	2.00	0.9	9.4
ALL	306	4.92	2.87	0.6	20.3

Table 20. Descriptive Statistics for GBS and Pinto Width/Thickness Ratio by Subarea.

Toolstone	N	Mean	SD	Min	Max
West					
Obsidian	147	3.05	0.64	2.1	5.3
FGV	79	3.73	0.83	2.5	6.9
ALL	226	3.29	0.78	2.1	6.9
East					
Obsidian	176	2.84	0.61	1.7	4.8
FGV	130	3.43	0.81	1.7	6.2
ALL	306	3.09	0.76	1.7	6.2

Reduction Trajectory Evidence

The patterns that have been described suggest differences in transport efficiency in line with the model, but should also represent various expressions of the technological design that is being implemented. Is there an identifiable reduction strategy structuring these data? Evidence of reworking and the presence of remnant flake blank attributes are used here to isolate these relationships.

If some projectile points were the byproducts of an extended reduction process, then they should exhibit less in the way of remnant flake blank evidence than those that are not. This evidence is tracked in two ways. One is to identify the following attributes: remnant detachment scar, plano-convex cross-section, or longitudinal curvature; if any one of these is observable, blank evidence is marked as present. The other way is to assign the artifact to the trajectory, as discussed in the methods chapter, based on overwhelming presence of these attributes sufficient to be confident that it was made from a flake blank less than 12 mm thick (see previous chapter). This is a more restrictive and reliable method.

Variation along these lines should be expected in two ways: 1) less blank evidence on obsidian than FGV, which is less amenable to flaking and reshaping; and, 2) less blank evidence on point types that were more often resharpened. A simple comparison between FGV and obsidian satisfies the first expectation, with blank evidence present on 72 percent (n=152 of 209) of FGV and 46 percent (n= 150 of 323) of obsidian.

For the second expectation, it seems intuitive that smaller points would naturally be the ones with a lower incidence of remnant blank evidence, but this is not the case on the distal ORB. As discussed above, significantly smaller points are present in the east subarea than in the west; however, those from the east subarea exhibit substantially more blank evidence (68%, n=194 of 306) than those in the west (48%, n=108 of 226). This pattern holds for both obsidian and FGV between the subareas, although the difference between the two materials is not statistically significant in the east subarea while it is in the west. This supports the supply model I present in Chapter 6 that Paleoindian groups staying for longer periods on the distal ORB would operate at a smaller tool size owing to a reduced need for transport efficiency. This was expected in the east subarea. East subarea projectile point assemblages reflect this tradeoff, with flake blanks serving as the supply, and further suggest that scavenging was not a primary means of acquiring additional tool utility.

Functional Considerations

Artifact weathering precludes use-wear analysis on the assemblage, but it is possible to align some items with forms from the broader tool assemblage. These forms are also discussed in the next chapter, the priority here being to distinguish projectile points from non-projectile points as best as possible to see if there is any patterning.

Over 80 percent of all GBS and Pinto artifacts made from obsidian or FGV are classified as projectile points versus non-projectile point tools (n=888). There is no meaningful difference between GBS (85%, n=607 of 715) and Pinto (83%, n=143 of 173). There is variability among the different types that is worth clarifying. Parman exhibits the highest rate of projectile points to other tools at 98 percent (n=92 of 94), with only two Parman items being reworked: one side scraper and one convergent (beaked) scraper. There is a sharp decline with Lake Mojave, Bonneville, and Pinto, which sit at approximately 80 percent projectile points. Over half of the non-projectile point Lake Mojave artifacts are chisel-tip tools (n=10 of 16), which also constitute the majority of the total 15 among all the types. This is a pattern observed elsewhere, and Beck and Jones (2009; also see Tuohy 1969) identify this unique tool form exclusively on Lake Mojave forms at the Sunshine Locality. Perforators, especially drills/awls, are distinctive to Bonneville and Pinto, perhaps owing to their elongate nature relative to their bases. Silver Lake forms exhibits over 90 percent as possible projectile points, with scrapers of several sorts driving the other-tool artifacts. More non-projectile point GBS and Pinto artifacts occur in the east subarea (n=101 of 525) than the west subarea (n=37 of 363), suggesting a trend toward economizing toolstone later in time (χ^2=13.378, df=1, p<.01).

Beck and Jones (2009:235) argue that Silver Lake is the main GBS type serving as a non-projectile point tool, such as a knife. This argument cannot be demonstrated either way with the distal ORB data, and Beck and Jones (2009) present little evidence supporting this interpretation themselves (Duke 2010b), but several patterns suggest that maintaining them primarily as projectile points should not be dismissed. Impact fractures occur across GBS types, averaging a 14-percent occurrence rate, with only Stubby forms having markedly less at seven percent. More distinctive is the occurrence rate for Pinto, which is 25 percent.

Further evidence that all the GBS artifacts are usually projectile points comes from data on how previous breaks were reworked. Two attributes were tracked through the assemblage: tapered tips and reworked basal breaks. Artifact ISO-GR3 (Figure 35a) provides a good visual reference for both attributes. Tapered tips represent the reworking of breaks at the distal end of a projectile point. A new tip is made by flaking over the break, but without a complete adjustment to the existing margins of the item. Instead, minimal material is removed to create an adequate new tip, but only to a certain length where the existing margins are maintained, thereby generating a tapered look. As seen in Figure 35a, both sides of ISO-GR3 exhibit evidence of impact breakage that was repaired by this method. Tapered tips are present on eight percent (n=56 of 725) of the obsidian and FGV artifacts that classified as projectile points versus non-projectile point tools. Sixty-two percent (n=35 of 56) of these are made from obsidian and the others from FGV. Forty-one percent (n=23 of 56) of the assemblage are Pinto, which were more clearly projectile points designed to be reworked in the haft. Of the 33 GBS items, 12 are Silver lake, eight are Bonneville, five are Lake Mojave, five are Stubby, and three are Parman.

Reworked basal breaks can be found at the proximal end of GBS artifacts. Again, ISO-GR3 (Figure 35a) provides an example, with flaking present sufficient to accommodate, but not completely remove, the broken area. This attribute is present on 15 percent (n=90 of 583) of the obsidian and FGV artifacts classified as projectile points; six of these items also exhibit tapered tips. Sixty-eight percent (n=61 of 90) of these are made from obsidian. During my analysis of GBS artifacts from Fort Irwin (see Chapter 6), I noticed that basal reworking always removed direct evidence of the previous break. Sometimes this came in the form of small pressure flakes, but the break was still noticeable by way of the squarish bottom that remained. This would seem to be an interesting mark of regional differences in projectile point maintenance between people in the Mojave Desert and those on the distal ORB.

For GBS projectile points, these attributes may mark maintenance techniques used to manage breakage toward the ends of the tool. From a design perspective, a Cougar Mountain point such as ISO-GR3 is already tapered at both ends and thickest in its central region, which should have the effect of distributing breakage away from the midsection. Tapered tips presumably serve to direct breakage at the location of the taper. Remnant breaks at the bases of GBS points are less diagnostic of purpose, but there may well have been some benefit to leaving these small tags in terms of preventing breakage in the haft. The two-to-one occurrence of these attributes on obsidian versus FGV further suggests their value for improving use-life on those items on which the benefits are most likely to be realized. The higher rate of occurrence on Pinto points is also predictable because these were designed for reduction in the haft, ultimately to the extent that they become shoulderless. Stemmed points appear to be designed for ready removal from a socketed shaft, and much of GBS typological variability may be owed to periodic reduction overhauls following breakage. Beck and Jones (2009:184-192) suggest that Cougar Mountain, Parman, and Lake Mojave could represent such a sequence, but exclude Silver Lake based on inconsistent size and morphology. These issues could be explored experimentally.

CHAPTER 8

TOOL ASSEMBLAGES

The projectile point analysis indicates that morphological distinctions exhibit lithic resource use differences predicted by the technological model. Cougar Mountain, Parman, and Lake Mojave types are more transport-efficient than Pinto and Bonneville types, and these type groups correspond with earlier (west) and later (east) subareas of the study area, respectively. How does this carry into other tools? Can different toolkits be assembled from within the widely recognized technological pattern? The data provided in this chapter indicate that some separation is possible and that it falls along expected lines for change through time in Paleoindian land use priorities on the distal ORB.

A total of 2,716 flaked stone tools from 95 sites were examined for this analysis. This includes 772 projectile points and other GBS/Pinto items which were included in the analysis in Chapter 7. To maximize typological associations, much of this section focuses on tools from sites that were included in the projectile point cluster analysis, almost three-quarters of the total assemblage. The remaining tools are considered later to examine broader temporal and spatial patterning.

Cluster analysis again provides the quantitative distinctions among sites. Of the 47 sites used in the projectile point analysis, 38 could be examined in their entirety. As shown in Table 21, this totals 2,004 stone tools, including 538 of the previously discussed projectile points. For the initial clustering, the tool classes were collapsed into four primary categories that account for most of the artifacts: projectile points, expedient bifaces, thinned bifaces,

Table 21. Artifact Counts by Site and Tool Class for the 95 Sites in the Technological Analysis.

Site Number	PPT	Bifaces				Unifaces				Perforators			Bif. Util. Flk.	Chop.	Core	Core/ Ham.	Mult.	Misc.	TOTAL
		Exp.	Nar.	Thin.	Jot	Side	Conv.	Plane	Unif.	Awl	Spur	Chis.							
Seriation (in order)																			
42To3788	5	7	1	1	-	1	1	1	-	1	2	-	1	-	-	-	-	-	21
42To0909	66	77	10	11	8	29	7	1	-	21	5	-	2	-	-	-	5	10	252
42To2720	6	3	3	6	2	6	1	1	1	5	2	-	-	-	-	-	1	1	38
42To2603	8	2	-	3	2	3	3	-	-	-	-	1	-	1	-	-	-	-	23
42To2611	8	8	3	1	-	9	5	-	3	2	5	-	-	-	-	-	-	1	45
42To2999	11	1	1	4	3	5	1	1	-	1	2	-	-	-	3	-	3	1	37
42To2835	13	2	2	7	-	-	2	-	-	2	-	-	2	-	-	-	-	-	30
42To2712	18	24	10	9	5	6	11	1	2	12	9	-	-	-	-	-	5	-	112
42To2590	6	7	2	3	1	5	2	-	-	3	2	-	-	-	-	-	3	-	34
42To2839	6	6	1	1	2	2	2	-	-	1	1	-	-	-	-	-	-	-	22
42To2833	5	1	2	1	5	1	1	-	-	-	-	-	-	-	-	-	-	-	16
42To2997	13	5	2	12	-	2	-	1	-	1	-	-	-	-	-	-	-	-	36
42To2591	5	3	3	6	1	1	4	-	3	-	3	2	-	-	1	-	2	1	35
42To1006	6	-	-	-	-	1	-	-	1	-	1	-	-	-	-	-	2	-	11
42To0844	8	7	-	1	-	1	1	-	1	1	1	-	1	-	1	-	-	-	23
42To0910	27	10	8	7	3	21	7	-	2	4	3	-	2	-	1	1	1	4	101
42To0913	12	1	-	1	1	4	3	-	-	1	2	-	-	-	1	-	-	-	26
42To1046	13	7	-	2	-	1	1	-	-	-	-	-	-	-	-	-	-	-	24
42To2996	35	17	6	20	3	13	8	1	5	5	1	-	3	-	-	-	2	1	120
42To1043	30	24	3	7	1	2	8	-	1	1	4	-	-	-	1	-	3	-	85
42To1044	26	9	-	-	1	2	4	-	-	1	-	1	2	-	1	-	1	-	48
42To2615	6	5	2	1	1	4	2	1	-	1	-	-	-	-	-	-	-	-	23
42To0924	14	5	1	4	8	13	6	1	1	5	1	-	-	-	1	-	5	-	65
42To2726	11	7	2	5	3	11	8	1	-	2	8	-	-	-	-	-	4	1	63
42To2995	7	15		2	2	4	2	1	-	1	1	-	-	2	-	-	-	1	38
42To0922/923	20	15	8	8	4	39	27	9	2	-	4	1	1	-	2	2	1	2	145
42To3000	25	21	14	14	6	13	13	-	6	7	2	-	-	-	-	-	-	1	122

Table 21. Artifact Counts by Site and Tool Class for the 95 Sites in the Technological Analysis (cont'd).

Site Number	PPT	Bifaces				Unifaces				Perforators			Bif. Util. Flk.	Chop.	Core	Core/ Ham.	Mult.	Misc.	TOTAL
		Exp.	Nar.	Thin.	Jot	Side	Conv.	Plane	Unif.	Awl	Spur	Chis.							
42To2607	5	2	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	10
42To1013	8	1	-	1	2	-	2	-	-	-	-	-	1	-	-	-	2	-	17
42To3795	19	25	-	10	-	17	4	1	6	1	6	-	3	1	1	-	3	1	98
42To2843	8	4	3	1	1	3	2	-	2	-	-	-	-	-	-	-	-	1	25
42To3796	16	7	1	1	2	10	8	-	1	3	2	1	2	-	1	-	1	-	56
42To2998	15	7	8	4	3	16	2	1	-	5	1	-	-	-	-	1	1	1	65
42To0847	23	4	-	3	-	9	8	-	1	-	1	-	1	-	1	-	4	1	56
42To3817	12	2	-	5	-	5	3	-	1	-	-	-	-	1	-	-	1	-	30
42To1048	11	6	-	1	-	2	-	-	-	-	2	-	-	-	-	-	-	-	22
42To1022	6	2	-	4	-	5	1	-	-	-	-	-	-	-	1	-	-	-	19
42To1435	5	-	-	2	-	1	2	-	1	-	-	-	-	-	-	-	-	-	11
Non-seriation																			
42To0849	2	5	-	-	-	1	-	-	1	-	-	-	2	-	-	-	-	-	11
42To0850	-	9	-	-	1	2	-	-	2	1	3	-	-	-	1	-	1	-	20
42To0911	4	5	-	1	1	5	1	-	1	-	-	-	-	-	-	-	-	-	18
42To1004	4	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	7
42To1008	1	2	-	4	1	1	4	-	-	-	-	-	-	-	-	-	2	-	15
42To1016 (Com)	5	1	-	3	-	1	-	-	-	-	-	1	1	-	-	-	-	-	12
42To1021	3	-	-	-	1	1	-	-	-	-	-	1	-	-	-	1	1	-	8
42To1023	2	-	-	-	-	2	-	-	-	-	1	1	-	-	-	-	-	-	6
42To1028	3	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	7
42To1029	1	2	-	1	-	-	1	-	1	-	-	-	-	-	1	-	-	-	7
42To1030	3	-	1	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	6
42To1032	1	-	-	10	-	1	-	-	-	-	-	-	1	-	2	-	1	-	16
42To1053	3	1	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	7
42To1054	2	1	-	1	-	1	-	1	-	-	-	-	-	1	-	-	2	-	9
42To1058	1	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8

Table 21. Artifact Counts by Site and Tool Class for the 95 Sites in the Technological Analysis (cont'd).

Site Number	PPT	Bifaces				Unifaces				Perforators			Bif. Util. Flk.	Chop.	Core	Core/ Ham.	Mult.	Misc.	TOTAL
		Exp.	Nar.	Thin.	Jot	Side	Conv.	Plane	Unif.	Awl	Spur	Chis.							
42To1059	4	2	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	9
42To1455	2	-	-	-	-	1	-	-	-	-	-	-	1	-	1	-	-	-	5
42To1863	1	2	-	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	8
42To1867	-	1	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	2	7
42To2564	2	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	1	7
42To2571	1	-	-	1	-	1	-	-	-	-	1	-	1	1	-	-	1	-	7
42To2572	1	-	-	1	1	7	-	1	-	-	-	-	-	-	1	-	2	2	16
42To2580	1	-	1	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	5
42To2581	2	2	1	2	-	4	1	-	1	-	2	-	-	-	-	-	1	2	18
42To2593	-	2	-	-	2	1	-	-	-	-	5	-	-	-	-	-	-	-	10
42To2597	2	-	1	1	-	1	-	-	2	1	-	-	-	-	-	-	-	-	8
42To2604	1	-	-	2	1	3	1	-	-	-	1	-	-	-	-	-	1	-	10
42To2612	2	1	-	1	-	-	1	-	-	-	4	-	-	-	-	-	-	-	9
42To2616	1	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	1	-	6
42To2622 (Cache)	4	3	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	10
42To2718	3	-	1	-	-	-	2	1	-	-	-	-	-	-	-	-	1	-	8
42To2719	-	3	-	-	1	1	3	-	-	-	2	-	-	-	-	1	-	-	11
42To2722	3	1	-	1	-	1	1	-	-	1	1	-	-	-	-	-	-	1	10
42To2724	1	1	1	2	1	4	2	-	-	-	2	-	-	-	-	-	1	-	15
42To2727	4	2	-	3	-	3	2	-	-	1	-	-	-	-	-	-	2	-	17
42To2728	1	1	-	-	-	2	2	-	1	-	1	-	-	-	-	-	-	-	8
42To2733	2	-	1	4	1	1	1	-	-	-	-	-	-	-	-	-	-	-	10
42To2832	3	-	1	4	1	1	1	-	-	-	-	-	-	-	-	-	-	-	11
42To2836	3	1	-	2	-	-	-	-	2	1	3	-	-	-	-	-	-	-	12
42To2837	2	3	1	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	8
42To2838	2	8	2	-	2	-	3	-	1	1	-	-	-	-	-	-	-	-	19
42To2840	1	3	1	-	-	1	1	-	5	-	-	-	-	-	-	-	-	-	12
42To2842	1	5	1	-	1	3	-	-	1	-	-	-	-	-	-	-	-	-	12

Table 21. Artifact Counts by Site and Tool Class for the 95 Sites in the Technological Analysis (cont'd).

Site Number	PPT	Bifaces				Unifaces				Perforators			Bif. Util. Flk.	Chop.	Core	Core/ Ham.	Mult.	Misc.	TOTAL
		Exp.	Nar.	Thin.	Jot	Side	Conv.	Plane	Unif.	Awl	Spur	Chis.							
42To2844	3	2	3	-	2	-	3	-	-	-	-	-	-	-	-	-	-	-	13
42To2846	2	5	3	1	-	-	-	-	1	-	-	-	-	-	-	-	-	1	13
42To2984	3	1	1	-	-	3	1	-	1	1	-	-	-	-	-	-	-	-	11
42To2985	-	7	-	-	-	3	2	-	4		-	-	-	-	-	-	-	-	16
42To2986	-	3	1	-	-	1	-	-	4	2	1	-	-	-	-	-	-	-	12
42To2990	2	1	-	-	-	1	2	-	4	-	-	-	-	-	1	-	-	1	12
42To2993	2	-	1	1	-	-	-	-	4	-	-	-	-	-	-	-	-	-	8
42To2994	2	2	1	7	-	5	3	-	2	1	-	-	-	-	-	-	-	1	24
42To3789	-	10	-	-	1	3	-	-	-	-	-	-	-	-	-	-	1	-	15
42To3813	1	8	2	1	1	6	1	-	3	-	2	-	1	-	-	-	-	-	26
42To4221	3	31	3	3	-	6	1	-	2	-	-	-	4	1	3	-	1	-	58
42To4227	-	1	-	-	-	5	-	-	-	-	-	-	-	-	-	-	2	-	8
42To4228	-	1	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	6
42To4229	3	11	1	-	-	19	1	-	3	-	2	-	3	-	-	-	2	-	45

Notes: PPT=projectile points, Exp.=expedient bifaces, NAR=narrow bifaces, Thin.=thinned bifaces, Side=side scrapers, Conv.=convergent scrapers, Plane=scraping planes/heavy scrapers, Unif.=unifaces, Awl=awls/drills, Spur=spurs/gravers, Chis.=chisels, Bif. Util. Flk.=bifacial utilized flakes, Chop.=choppers, Ham.=hammerstones, Mult.=multiple use tools, Misc.=miscellaneous and unifaces; the rest were placed in “other,” which loosely reflects the relative diversity of the assemblages. The cluster analysis was performed with Minitab 16, using McQuitty linkage and squared Euclidean distance. A two-cluster solution was chosen to provide a working dichotomy. As shown in the dendrogram in Figure 49, two clusters provided a good distinction between sites. These two clusters are referred to as “Cluster T1” and “Cluster T2.” It is also important that Cluster T1 represents most of the sites (n=25 of 38) and artifacts (n=1,664 of 2,004), and its respective assemblages contain a greater average number of artifacts per site than Cluster T2. The effects of these differences are discussed further later in this chapter.

Cluster T2 is weighted toward more projectile points and bifaces than Cluster T1, which contains relatively more of every other class. This is shown in Figure 50. The only exception is if thinned and expedient bifaces are separated, where thinned bifaces are more common in Cluster T2. It is useful to refer back to the projectile point clustering to gather meaning from these differences. In the two-way clustering of those assemblages, one cluster (Cluster P2) is weighted heavily toward the presence of Parman and Lake Mojave points, biface thinning, extended reworking, and obsidian use. Five of the eight sites included in that cluster are represented in the tool analysis—42To847, -1022, -1048, -1435, and -3817—and all of them fall into Cluster T2 and are likewise associated with biface thinning and projectile points, suggesting that there is an investment in toolstone conservation not as evident in Cluster T1.

The tool patterning generally reflects that of the projectile points, providing a basis for exploring other predictions of the technological model inclusive of all the artifact types.

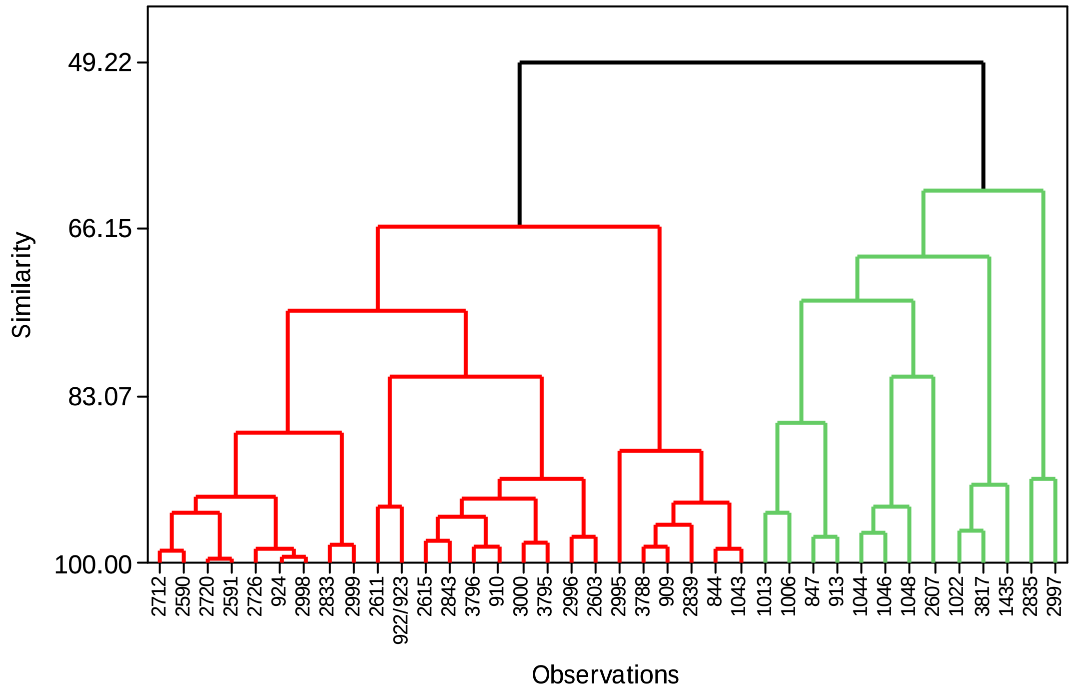

Figure 49. Tool assemblage clusters for distal ORB. Cluster T1 is shown in red and Cluster T2 in green.

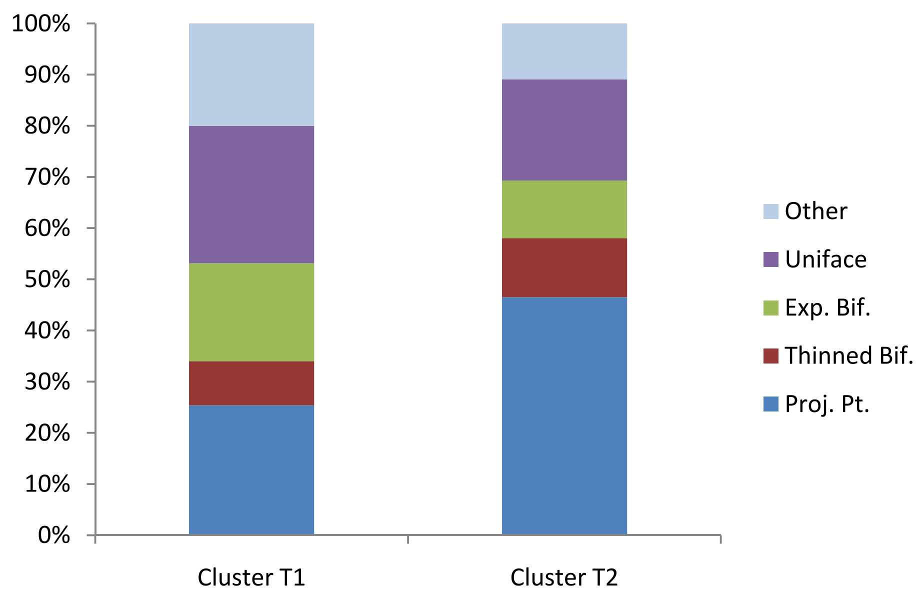

Figure 50. Percentage distribution of primary tool types by cluster.

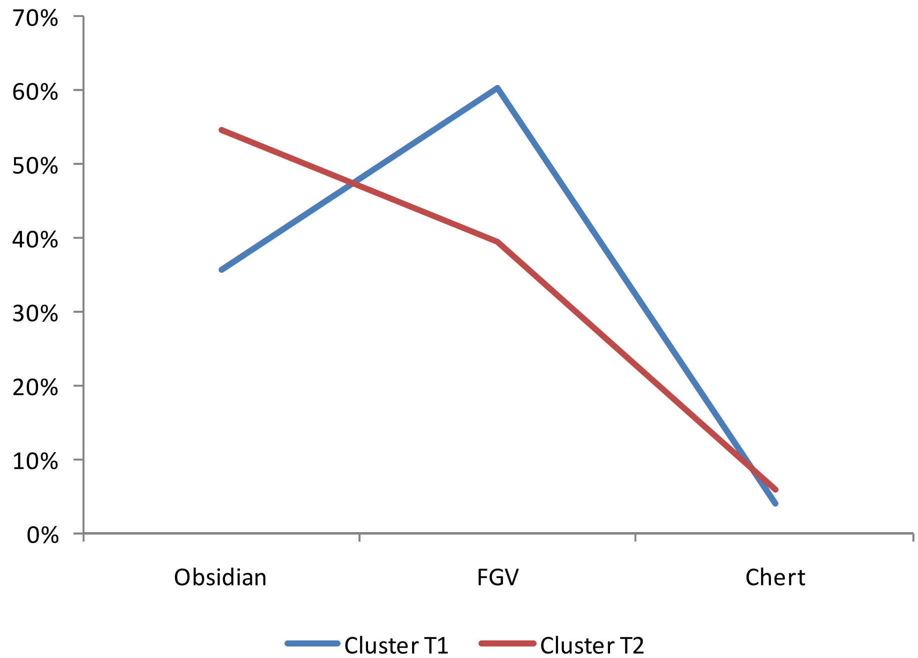

Figure 51. Proportions of primary toolstone types by tool cluster.

Four expectations stand out: if people placed greater emphasis on toolstone conservation, they should 1) prioritize high-quality stone to exert greater control over the modification of tools, 2) reduce tools through a long-range sequence rather than make tools as needed from transported flake blanks, 3) use larger tools from which they can generate these different forms, and 4) possess a generalized toolkit that maximizes multifunctionality per individual tool.

The expectation that Cluster T2 should exhibit a greater reliance on high-quality stone stands out clearly, as shown in Figure 51. Of the 2,004 artifacts in both clusters, it is FGV that characterizes the distal ORB assemblages on the whole at 57 percent (n=1,123), with obsidian representing the primary high-quality alternative (39%, n=772), alongside some chert (4%, n=85); variable other materials account for the remaining one percent of the assemblage (n=24). When split into clusters, however, we see 61 percent (n=203 of 335) of Cluster T2 is made from obsidian and chert compared to only 40 percent (n=654 of 1,645) of Cluster T1 (Figure 51). A statistical comparison of the two independent proportions indicates that this difference is significant (Z=-7.11, p<.05). The people who used tools in Cluster T2 preferred high-grade stone most of the time, while the opposite is reflected in Cluster T1 in a near exact reversal of proportion.

This pattern holds between clusters for each of the five tool categories with the exception of thinned bifaces. A series of chi-square tests shows each to be statistically significant. As might be expected, biface thinning is directed at obsidian and chert in nearly identical proportions in each cluster.

Figure 52 shows that the second prediction also emerges, albeit subtly, when the clusters are compared according to reduction trajectories (see Chapter 6). For this analysis, 1,963 of the 2,004 tools are available. The expected differences are present for each trajectory, although there is no statistically significant difference between the occurrence of A, B, and C at a five percent significance level (χ^2=.137, df=2, p=.93). The differences are significant at this level when trajectories D and E are compared (χ^2=27.6, df=1, p<.01). Thus, while the presence of thick tools (A), indeterminate-trajectory tools (B), and flake-based tools (C) is roughly similar between clusters, the proportions of thinned bifaces (D) and miscellaneous small tools (E) are distinctive. The tendency for thinned bifaces to be weighted toward Cluster T2 is known, but it is of interest that small irregular tools, which are often made as a last repurposing of thinned bifaces, are more common in Cluster T1. The sample sizes for

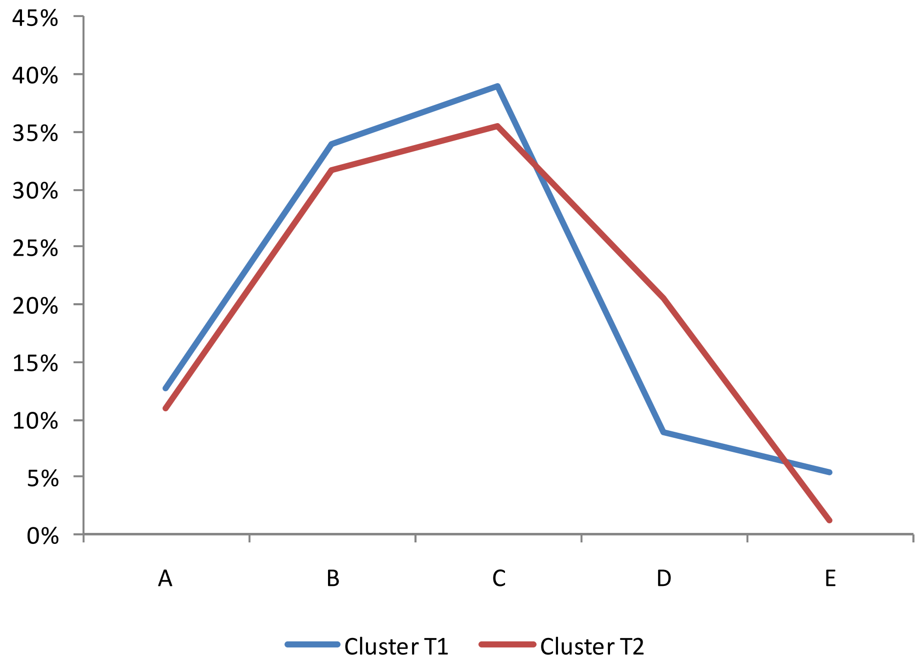

Figure 52. Reduction trajectory proportions by tool cluster.

irregular bifacial tools are low (n=88 for T1, n=4 for T2), but the pattern is worth noting for its relevance to related discussion later in this chapter.

As predicted, Cluster T2 tools are also larger, although this only applies to certain material types. Looking at just the two primary material choices—obsidian and FGV—1,968 have weight data, and the basic statistics when taken together are similar for each cluster at 10.9 g and 11.1 g, for T1 and T2, respectively (two large outliers weighing 188.2 and 143.0 g are excluded). However, we know that Cluster T1 is dominated by FGV and Cluster T2 is dominated by obsidian, and this appears to have a balancing effect as the expected pattern emerges when toolstone type is distinguished; the basic statistics are shown in Table 22. For both obsidian and FGV, Cluster T2 has heavier artifacts. The differences are significant for

Table 22. Basic Weight (g) Statistics for Obsidian and FGV Tools by Statistical Cluster.

Cluster	Obsidian					FGV				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
T1	587	4.0	2.9	0.5	31.2	990	15.1	14.4	0.7	118.3
T2	177	5.7	4.3	1.1	33.6	130	18.4	16.8	1.1	85.8

for both obsidian (t=-5.18, *df*=225, *p*<.01) and FGV (t=-2.16, *df*=154, *p*=.03). Comparing the materials, FGV tools average roughly three times the size of those made from obsidian. They are also more variable.

The fourth expectation is that if people are seeking to economize their materials, then their toolkit would be more generalized; i.e., more utility should be invested in a single item that may be flexibly designed such that it does not always take on the form of a tool made specifically for a single purpose. The concept of "richness" has been borrowed from ecological studies by other archaeologists (e.g., Grayson and Cole 1998; Jones et al. 1989; Kintigh 1984, 1989; Odell 1996b) and is used here to examine toolkit diversity among sites.

From the patterning described above, less tool richness should be expected from Cluster T2. It is defined by extended tool reduction and high-grade material preference. A quick review of Figure 50 also shows that four primary categories of tools dominate the total assemblages at a higher rate than in Cluster T1, as indicated by the category "other." The ratio is 3.7:1 for Cluster T1 (n=451 of 1,664) compared to 7.2:1 for Cluster T2 (n=47 of 340). However, the differences in assemblage size for each cluster have not been discussed. Since a greater number of types of tools should be expected with a greater number of artifacts, the ratios may simply relate to sample size.

It is expected that Cluster T2 assemblages should have fewer tool types than in Cluster T1 if reduction is more "streamlined." Conversely, the notion that technology would be streamlined is an implication of the behavioral model, which holds that people should have such a toolkit because they are moving quickly through the area, focusing on a narrow set of high-ranking resources, and creating smaller sites. Therefore, the issue is not only that people who stayed longer left more expended tools, but they also should have intensified their use of the area; i.e., broadened their diet to some extent, perhaps creating an expanded toolkit. In this case, not only should there be more types of tools in Cluster T1, there should be more types per number of artifacts—the assemblages should be "richer." It should also be the case in Cluster T1 that the distribution of these different types should be relatively common—there should be a similar "evenness" to their distribution across site assemblages.

To examine these aspects of assemblage diversity, adjustments need to be made to make sites comparable regardless of artifact counts. Cluster T1 assemblages are, in fact, larger than those in Cluster T2, averaging 66.6 tools compared to 26.2 (i.e., 2.5:1). Average site area for Cluster T1 is twice that of Cluster T2 at 98,507 to 47,249 square meters, respectively. As expected, there is a direct relationship between the number of types of artifacts (richness) and assemblage size, as shown in Figure 53.

Richness can be compared between cluster regardless of sample size by calculating the average richness values using their respective regression equations (see Grayson and Cole 1998). The results are provided in Table 23 and show that while there is greater average richness in Cluster T1 at any given assemblage size, the difference between the two

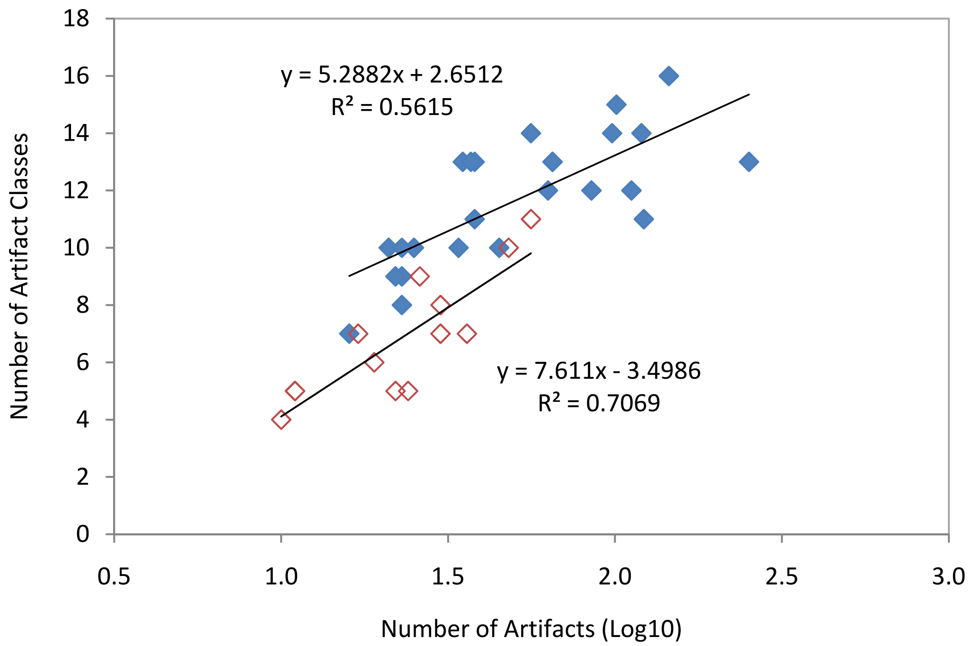

Figure 53. Regression relationship between tool richness and assemblage size for tool clusters. Blue represents Cluster T1 and white represents Cluster T2.

Table 23. Predicted Average Richness for Assemblages of 10, 25, and 50 Artifacts.

Cluster	Max. Ass. Size	Predicted Average Richness					
		10	95% CI	25	95% CI	50	95% CI
T1	56	7.9	6.4, 9.5	10.1	9.2, 10.9	11.6	11.0, 12.3
T2	252	4.1	2.7, 5.5	7.2	6.4, 7.9	9.4	8.1, 10.8
Difference	-	3.8	-	2.9	-	2.2	-

Note: CI=confidence interval

clusters barely changes with greater assemblage sizes; in fact, it even decreases, likely as maximum possible toolkit size is reached.

Spatial Patterning and Temporal Associations

The differences in richness are best attributed to a "disassembling" of the technology by way of flake blank-oriented toolmaking, as modeled, rather than any meaningful addition of tool types to the toolkit. As predicted by the model, the assemblages can be statistically divided to represent more versus less transport-efficient toolkits. Cluster T1 contrasts with Cluster T2 by containing smaller, more diversely purposed tools. These assemblages are also bigger both in surface area and assemblage size, and the tools are usually made from the nearest FGV sources. While FGV is used in an expedient manner, the obsidian that is present exhibits extensive economization; small miscellaneous biface fragments and non-distinctive utilized pieces are more common here than in Cluster T2. Cluster T2 contains larger tools representing a more reduction-efficient toolkit. Obsidian is more preferred in Cluster T2 and there is less tool type diversity.

These generally correspond with the two projectile point clusters discussed in the previous chapter, both in terms of their technology and their temporal distribution on the distal ORB. Cluster T1 is inclusive of so many sites that it is more representative of the study area as a whole than a particular area, but patterning generally characterizes the east subarea more than the west. East versus west subarea differences in tool type are shown in Figure 54 inclusive of the entire obsidian and FGV assemblage of 2,563 artifacts. The occurrence of fewer projectile points and unifaces alongside more "other" artifacts toward the east subarea is in step with patterns seen in Cluster T1 and Cluster T2, but the occurrence of thinned and expedient bifaces is reversed. The proportionate differences between these two biface classes are not statistically different at the five percent significance level used in

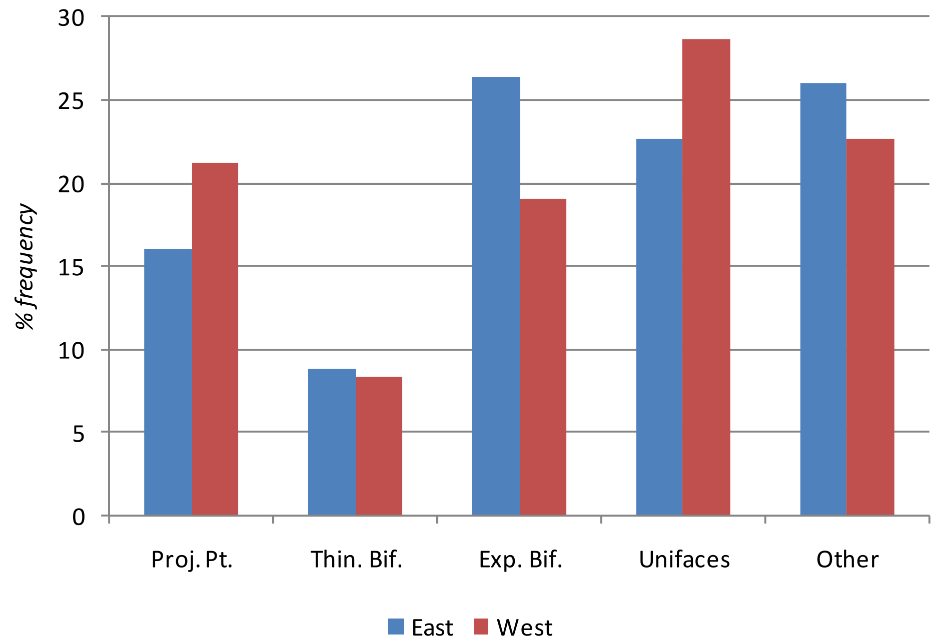

Figure 54. Primary tool type distributions by subarea.

this study (χ^2=3.597, *df*=1, *p*=.06), but a p-value of .06 on the chi-square test is so close that they are best considered dissimilar to the cluster results.

Other aspects of Cluster T1 are even more associated with the east subarea. It is useful to make these comparisons without the projectile points, which skew the data in ways described in Chapter 7. This provides a sample of 1,815 obsidian and FGV artifacts. A weight comparison (which further excludes seven outliers over 120 g and 14 items with no measurement) shows a minimal (but expected) difference in the size of FGV between east and west subareas, but there is a sharp difference in the weight of obsidian, as seen in Table 24. East-subarea obsidian non-projectile point artifacts are less than two-thirds the size of their west-subarea counterparts (t=-4.99, *df*=260, *p*<.05); the sizes are closer, although still significantly different, between clusters (see Table 22).

Table 24. Basic Statistics for Obsidian and FGV Tools by Study Subarea.

Subarea	Obsidian					FGV				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
East	314	3.7	3.3	0.3	33.6	967	17.1	14.9	0.7	118.3
West	174	5.8	4.9	0.5	43.0	339	18.3	14.1	1.6	91.4

This is reflected in the relatively common occurrence of small obsidian biface fragments and miscellaneous tools in the east subarea. These comprise 18 percent (n=85 of 472) of the "other" tools in the east and eight percent (n=12 of 148) in the west subareas. The difference is statistically significant at a five percent significance level (χ^2=8.368, *df*=1, *p*<.05). This combines with the already more common occurrence of "other" tools to the east subarea and Cluster T1. Moreover, GBS and Pinto artifacts can be seen to exhibit this kind of pattern, with 20 percent (n=99 of 502) being repurposed into non-projectile point tools on the east subarea compared to only 10 percent (n=24 of 222) in the west. A virtually identical pattern exists in the tool clusters, with 19 percent (n=89 of 461) in Cluster T1 and nine percent (n=15 of 162) in Cluster T2 being repurposed. These patterns all reflect a more local toolstone use pattern as extreme economization is placed on exotic, high-quality obsidian.

If Cluster T1 can be associated with projectile point cluster P1 and the later occupations of the distal ORB, then Cluster T2 should correspond with Cluster P2 and the presumably earlier archaeology of the west subarea. Much of the data supporting this is expressed by the contrasts above, but the actual locations of the sites in Cluster T2 provide further demonstration. Cluster T2 consists of only 13 sites compared to the 25 in Cluster T1,

Table 25. Frequency of Nearest Obsidian and FGV Sources to Other Sources by Subarea.

Subarea	Obsidian			FGV		
	N	Topaz Mountain	Other	N	Flat Hills	Other
East	13	9	4	50	30	20
West	51	28	23	108	77	31

five of which—42To847, -1022, -1048, -1435, and -3817—are located in the west subarea. This does not stand out by itself, but all of these sites are also in the projectile point cluster P2, which only consists of eight sites itself. Of the 25 sites in Cluster T1, none are from the projectile point cluster P2.

Toolstone selection patterns line up with these associations. Obsidian is more common among non-projectile point tools in the west subarea (35%, n=187 of 531) than in the east subarea (24%, n=314 of 1,284) at a statistically significant level (χ^2=21.77, *df*=1, *p*<.05), just as it is between tool clusters associated with these subareas.

Some XRF sourcing has been conducted on these tools (see Table 25). Sample size is low for obsidian, but nevertheless, the proportions are as would be expected with proportionately more Topaz Mountain (~90 km) to farther sources present in the east subarea than the west. Likewise, Flat Hills dominates the FGV to a greater extent in the east than the west, and sample sizes are adequate for comparison. Flat Hills and Deep Creek/Badlands both lie about 60 km from the center of the project area but on an east-west line, respectively. It is possible then that there is some bias toward the use of Flat Hills in the east subarea, but at a savings of only a few kilometers, this is not expected to be a significant factor in the comparison.

CHAPTER 9

DISCUSSION AND CONCLUSIONS

The distal ORB provides a view of Paleoindian people living as far into the middle of an intermontane drainage basin as is possible in the Great Basin. Significant upland food resources cannot be found for 30 km and toolstone for 60 km in the mountains that ring the Great Salt Lake Desert. This has to be a telling statistic from an ecological perspective. For people we presume to be highly mobile hunter-gatherers, what are the implications of being extended so far from other options? In this chapter, I discuss these implications and how technological change through time on the distal ORB could reflect Paleoindian responses to broader environmental decline and the loss of wetland habitats in the Great Basin.

As geographically remote as the distal ORB is, it was also part of a vast distributary wetland that could sustain human groups for longer periods than anywhere else in the eastern Great Basin. I argue that this large scale served as a buffer to people who did not always need to extract all that was available, but rather preferred to move among basin wetland patches in pursuit of the highest-ranking resources—especially large game—when these were abundant. Various basin wetlands were likely utilized similarly when times were good, but as the Late Pleistocene closed out, and warmer, drier conditions set in over the region, Paleoindian groups lost many of these options and would have had to intensify their use of those wetlands that persisted.

Lithic economy on the distal ORB supports this model with evidence of increasing occupation length through time. The availability of the distal ORB appears restricted to a largely post-Younger Dryas time frame beginning at approximately 12,100 cal BP and ending with total desiccation of the wetlands about 9900 cal BP or shortly thereafter. The study area can be divided into two parts corresponding with distributary branches that roughly correlate with early (12,100-11,200 cal BP) and late (11,300-9900 cal BP) periods within this time frame. These are deemed the west and east subareas, and their respective archaeological assemblages exhibit shifting settlement priorities within a flexible range of effectively the same technological system.

Technological differences are predicted by a model that distinguishes the relative importance of extended residential stays according to formal relationships between lithic reduction strategies, transport distance, and raw material characteristics. The concept of transport efficiency is used to relate these factors under a singular stone tool design goal that should become deemphasized with longer stays. The broader constraint affecting the importance of toolkit transport efficiency is the decline of regional basin wetland habitats. As these diminished and disappeared, people would have become less mobile among basins.

Because these wetland habitats were tied to individual drainage basins, they exhibited a patchy distribution. From the perspective of lithic resource use, each of these basins possesses a distance-defined toolstone source profile different from the other. At times when people were more mobile across basins, their toolkit should be more transport-efficient and be made from higher-grade toolstone varieties suited to this need. When people stayed in particular basins for extended periods, the more they should have traded the production and maintenance costs of transport efficiency, which requires this effort to constantly maximize tool utility per unit mass, for more cost-effective acquisition of toolstone to be used as needed according to increasingly predictable tool-use expectations. In large wetland areas, such as the distal ORB, people could move sequentially over short distances until it was cost-effective to move to another basin; thus, even while they were perhaps no less residentially mobile than anywhere else, their lithic economy would take on more logistically-mobile characteristics within the predictable resource structure of a single basin (Duke and Young 2007). These contrasting strategies are reflected in the lithic technology of the early and late distributary branches of the distal ORB, respectively.

Summary of Results

Lithic assemblage patterning follows the expectations for shorter versus longer occupations corresponding with earlier (west subarea) and later (east subarea) parts of the study area, respectively. Stone tools that are found in the west subarea, especially in the Wild Isle Dunes vicinity, tend to reflect shorter stays and greater transport efficiency than those to the east along the margins of Wildcat Dunes. Assemblages in the east subarea are interpreted to represent longer stays and less emphasis on transport efficiency. These findings are based on analysis of 3,156 artifacts—1,209 GBS and Pinto artifacts and 1,947 other flaked stone tools—the large majority of which (n=2,721) represents full tool collections from 95 Paleoindian sites (see Chapter 6).

Typologically, projectile points represent a leading distinction with Parman, Lake Mojave, and Cougar Mountain GBS types more common in the west subarea and Bonneville, Stubby, and Pinto types more common in the east subarea. These trends are indicated both by distribution and in a statistical cluster analysis. The early pattern represents a much smaller archaeological signature than the later one, with Bonneville and Silver Lake artifacts largely dominating the record across much of the area. Bonneville is a type offered in this study to classify a set of GBS items with shorter stems relative to their blades than seen in other parts of the Great Basin, but they are otherwise similar to Silver Lake in manufacture and maintenance, exhibiting both extensive reworking and minimal flake blank modification.

These distributional patterns carry technological associations. Just comparing obsidian and FGV, obsidian is more common among the west subarea types while FGV is more common in assemblages in the east subarea. This follows the expectation that if later groups stayed longer, they would more often draw from FGV because it is the nearest toolstone. Obsidian sourcing reveals no meaningful difference between the subareas for the nearest (Topaz Mountain) versus farther sources, but when individual projectile point types are compared, there is an expected statistically significant difference between Parman (obsidian) and Pinto (FGV); the remaining GBS types exhibit proportions between these two types. Thus, lithic resource use patterns tend to support the model that there is a more local toolstone profile for projectile point types representing later Paleoindian occupations. Given the distance to any toolstone, the subtlety of these patterns is not surprising.

The GBS and Pinto assemblages also show expected patterning in size and reduction technology among types and between subareas. According to the risk and supply models presented in chapters 4 and 5, people who stay for relatively brief periods should invest more in toolkit transport efficiency than those who stay longer. Transport-efficiency-minded people should carry bigger tools and should reduce them through a lengthier process of production and maintenance. Moreover, they should discard tools at larger sizes because they would not risk operating near the minimum requirement (this may seem counterintuitive, but the excess stone will be abandoned when it no longer has value as a buffer). The opposite is expected for people who stay longer because their toolstone-use requirements and procurement costs are more predictable. There is a robust difference in artifact weight between the east (less) and west (more) subareas. This pattern is also strongly maintained for the earlier (Parman, Lake Mojave) and later (Bonneville, Pinto) for both obsidian and FGV.

Reduction aspects further attest to the spatial and temporal nature of this patterning. A lack of flake blank evidence in the east subarea compared to the west subarea, despite smaller projectile point sizes, further attests to the lack of emphasis on transport efficiency in this subarea. Rather than place toolstone supply into existing tools, flakes were likely carried from the source serve as the expedient blanks for tools manufactured at their location of use. Evidence of the reworking of projectile points into common tool types (e.g., beaked scrapers, spur tools, etc.) is more common in the east subarea than the west subarea at a statistically significant level, further indicating the economization of toolstone suggested by the weight data. This is also supported by a greater frequency of Stubby artifacts in the east subarea, which are the most extensively reworked of all the GBS types.

The tool assemblage follows similar technological patterning. Following the technological model, analysis focused on reduction variability as a means of tracking the importance of transport efficiency across the toolkit. My analysis finds reduction trajectories to follow expected trends with regard to lithic resource use and patterning in the GBS and Pinto assemblage.

East subarea assemblages characterize much of the archaeology of the distal ORB as a whole. Compared to the west-subarea toolkit, tools are more crudely worked and made from lower quality stone (i.e., FGV). Transported flake blanks are more often the source of simple unifacial and bifacial tools, including projectile points, indicating that people could more reliably predict their toolstone needs. For those items that have gone through extended reduction, they often exhibit intensive toolstone economization in the form of reworking and even bipolar smashing to extract any remaining tool utility. This evidences both the predictability mentioned previously, as people were more comfortable operating closer to their minimum required toolstone supply, and high costs of directly procuring fresh toolstone, which would not have been located within a normal foraging radius. East subarea sites are larger, more concentrated, and more overlapping than those in the west subarea.

Sites of the west subarea reflect toolkits that possessed a more transport-efficient design placed into fewer tools. The use of high-grade stone (i.e., obsidian) and biface thinning-oriented tool reduction are more prevalent than in the east subarea. There are proportionately more projectile points compared to the later assemblages. All artifacts made from obsidian and FGV are larger than their counterparts in later assemblages, indicating that people locked stone surpluses into working tools with plans to access this material through methods of reshaping. The sites are smaller and contain fewer tools than those found in the later sites of the east subarea.

An analysis of toolkit richness indicates that there is little authentic difference between the types of tools used in the respective toolkits, although east-subarea assemblages contain the greatest amount of miscellaneous tools and highly economized obsidian fragments. The crude tools in the east subarea represent a disassembly of transport-efficient tools into various expedient, functional parts. Pinto-style tools are the only items that appear to be introduced in later Paleoindian times, but their context and technological similarities suggest they do belong to the early record of the distal ORB.

Lithic Economy and Paleoindian Ecology

These findings have bearing on current ideas about Paleoindian ecology. Three models can be addressed, both of which follow from fundamental behavioral ecological premises but with different points of emphasis. One by Elston and Zeanah (2002) maintains that the Great Basin was a rich landscape at the Pleistocene-Holocene transition, and that Paleoindian foragers could maintain a surplus energy budget that allowed them to practice a risk prone (i.e., willing to take on risk), large game-oriented settlement and subsistence strategy. This is to say that there were few risks associated with incurring the travel costs of high residential mobility because the potential for high energetic returns would not be devastating if they did not materialize; i.e., they were effectively risk insensitive. If this model is correct, then inter-basin residential mobility would be highly conditioned by the number of available basins (i.e., wetland habitats) and associated large game abundances.

In a contrasting view, Pinson (1999) suggests that the highly variable climate of the time would have made large-game populations subject to great fluctuation, ultimately making them unreliable as primary food resources. Combined with variability throughout the food resource profile, Paleoindian foragers would have been in a risk-averse situation, staying close to reliable wetland resources such as small game, birds, fish, cattails, etc. This is more consistent with ethnographic patterns than the Elston and Zeanah (2002) model. Pinson (1999) argues that existing subsistence data support this strategy, and thus sees Paleoindian groups as highly sensitive to risk following from environmental uncertainties.

Outside of these competing models about large-game dependence, Madsen (2007) focuses on size and distribution of wetland habitats as conditioners of Paleoindian mobility. Consistent with the patch choice model in optimal foraging theory, people would not leave a wetland patch that was still harvestable at a return rate higher than they could expect on average at any other prospective patch after adding in the extra travel costs. People would always prefer large resource patches, as they would in the Elston and Zeanah (2002) model, but if they were averse to risk, they would be more inclined to stay longer in a patch to more fully exploit all the items in their diet. If this was the case, inter-basin mobility would be more relative to the absolute size of wetlands and would proceed more rigidly from the biggest and closest to the smallest and farthest. In this sense, both the Elston and Zeanah (2002) and Pinson (1999) models can have validity depending on changes in the regional size, distribution, and productivity of basin wetlands. My approach to the current study is consistent with this view, working under the assumption that the disappearance of wetland habitats could well have taken people that were originally adapted to a rich landscape to a position of discordance with an environment that declined markedly in the Early Holocene.

The distal ORB makes a good case study for evaluating these models because its remote location would have drawn out the cost-benefit decisions associated with its use. All toolstone is non-local, and people were farther removed from alternative basin choices than they could be anywhere else in the Great Basin. The temporal differences in technology indicate that earlier groups moved through more quickly than those that came later. These differences correspond with the west and east channel branches, respectively, both of which represent extended portions of the ORB delta when associated marshlands could have been expansive. By the Madsen (2007) model, all things being equal, the shift in mobility from more residential to more logistical should be interpreted as a response to regional conditions rather than those of the ORB distributary system only. If anything, a shift in hydrologic output toward the east subarea as the area dried is most likely, in which case the extended stays would further assert the importance of the distal ORB to regional populations nearer the end of the Paleoindian period.

By the latest dates, the distal ORB may well have been a refuge for people at odds with the deteriorating environment. Shortly thereafter, important changes in subsistence and technology are indicated in nearby Bonneville Estates Rockshelter and Danger Cave (Goebel et al. 2011; Rhode and Louderback 2007; Rhode et al. 2006). At Danger Cave, intensive use of pickleweed, a low-growing saltbush that covers the dry basin floor today, is found alongside the first use of ground stone by about 9700 cal BP. There is no ground stone associated with the early materials in the study area.

The fact that the distal ORB is at 60 km from known FGV sources and 90 km from obsidian means that all lithic resources are “exotic” by most archaeologists’ definition, farther than 10 to 20 km, or a day’s walk. Lithic technology effectively costs more here than anywhere else in the Great Basin. Distances of 60 to 90 km would not qualify as routine foraging grounds, indicating a direct procurement model rather than an embedded one, further heightening the expense. It is hard to say if people would have rated this factor much beyond negligible when moving through the area fast enough not to have to replace tools, but it appears that at times they did replenish. Later assemblages in the east subarea suggest crude artifact replacements and highly economized obsidian. Also, the four primary sources of toolstone are located in near cardinal directions from the distal ORB—obsidian north-south and FGV east-west—thus, there is no direction from which people could "gear up" with both raw materials on their way into the area. Longer stays would justify the trips to some extent because of a reduced need for transport efficiency, but the shed reduction investments should be minor by comparison to the additional transport costs.

If unfavorable environmental conditions pressured people to utilize the distal ORB, the unfavorable tradeoffs would continue to mount. A further implication of the patch choice model is that people would intensify and perhaps expand their diet breadth as foraging efficiency decreased. As encounter rates for higher-ranked resources fell, they should have intensified the use of their full diet breadth to increase the time they spent pursuing food relative to the time they spent searching for it (Charnov 1976; MacArthur and Pianka 1966). Population increase seems likely over the course of the Paleoindian period, which would have exacerbated resource stress. As mentioned previously, toolkit richness expands in the later assemblages, and the use of projectile points declines in favor of other types of tools.

Finally, the distal ORB record is the most telling in the Great Basin of how specialized regional Paleoindians were to wetland habitats. The remote distance from basin margins combined with the factors discussed above suggest that while environmental conditions worsened, people clung to these habitats rather than expand to other habitat types, likely because a large-scale changeover in strategies entails uncertainty and risk that would only be made more risky by the increasing demands to lean on reliable, i.e., risk-averse, strategies as much as possible. This is interesting to consider in light of the ethnographic models often used by archaeologists. The Steward (1938) model essentially considers wetlands and uplands as different patches. This model reflects modern adaptations to existing resource distributions, and has been applied with success to archaeological assemblages going back 5,000 years and to optimal foraging models that predict past behavior (e.g., Kelly 2001; Zeanah 2004). In separate studies, foraging peoples who relied on wetland resources appear to have centrally placed themselves in residential positions that maximized upland game opportunities but also kept them anchored to the lowland food base. Paleoindian foragers, however, targeted these same resources in the wetland patch to such an extent that this habitat was used more intensively as the environment deteriorated.

Returning to the Elston and Zeanah (2002) and Pinson (1999) models—which model is best supported by the distal ORB data? In their critique of Pinson, Elston and Zeanah (2002:116) state, "…if foragers are risk-averse, they should not even bother to move from one basin to another." It is clear that Paleoindian groups moved within larger foraging territories than Archaic or Late Prehistoric peoples (Jones et al. 2003; Smith 2010), and the data from the distal ORB suggest that people moved in and out of the area according to broader regional resource expectations. By contrast, Pinson (1999, 2007) notes the paltry Paleoindian subsistence record supporting large game emphasis. Hockett (2009; also see Pinson 2007) further argues the subsistence record through time indicates that large game was more emphasized in the Middle Archaic than it was during Paleoindian times. Looking at Paleoindian adaptation on the whole, the Elston and Zeanah (2002) model seems to provide the most parsimonious explanation of general regional patterning, but taking a dynamic view of how Paleoindian people responded to environmental conditions that changed through time, there is room for both to be true if we are to understand how and why this way of life came to an end. The shifting patterns in lithic economy represented on the distal ORB are consistent with such an interpretation.

Lithic Resource Use

The use of obsidian between early and late portions of the distal ORB is predictable with proportionately more local sources occurring later. It is important to remember, however, that across the study area, obsidian comes from widely scattered sources in all directions except the east. This suggests that if people ever got to a desperation point on the distal ORB that they stopped traveling beyond the closest sources, there is no evidence of it at my scale of analysis (i.e., only particular sites could indicate this).

The possibility remains that later groups scavenged artifacts from earlier sites, which would increase the source profile, but this is not seen as a driving mechanism for toolstone diversity. Earlier tools are bigger, but later ones are "flakier" indicating that they are produced in modified lithic economy. Later assemblages, however, also exhibit extensive economization of obsidian. This behavior supports Surovell's (2009) supply model described in Chapter 5, which predicts that with longer residential stays comes predictability in toolstone needs, manifest by realizing tool utility closer to its full potential. Thus, toolstone-economizing behavior is predicted for people who stay in the basin longer as a routine aspect of lithic economy. While scavenging of earlier sites (where larger discarded tools would occur) likely took place opportunistically, the risks of relying on this behavior would increase the farther into the basin people traveled. We must also remember that the distal ORB was not the deflated playa it is today; it was a wetland context where things more likely would be lost than found.

Jones et al. (2003) discuss the large-scale geographic distribution of obsidian archaeological assemblages in the eastern Great Basin and find that toolstone traveled up to 450 km from its source. They propose that in the eastern portion of Nevada obsidian can be tracked north-south from the Nevada-Idaho border to southeastern Nevada, with fewer artifacts coming from east or west. They argue that this “conveyance zone” is one among four others that make the maximum mobile ranges of Paleoindian foragers in the Great Basin. At their peak mobility, groups could have transited this space until limited by the declining environment, as Jones et al. (2003) note. The distal ORB sits in the Bonneville basin, which dominates the landscape of northwestern Utah. There is no toolstone available in the flats, and the obsidian source profiles come from nearly all directions. The maximum distances to sources seen in the assemblages are 300 to 400 km away—west, south, and north—but the vast majority of stone comes from less than 200 km. And as mentioned, these primary sources are in the north and south, while FGV sources are found east-west.

These patterns imply more of a convergence on the distal ORB than a mobile round. Smith (2010) questions the vast size of the conveyance zones with geochemical source findings from northwestern Nevada. There, a similar size (~400 km) north-south conveyance zone to that in eastern Nevada is proposed by Jones et al. (2003). Smith (2010) finds that splitting the area into north and south halves would be more representative of toolstone source profiles, with the north portion tied tightly to the obsidian of northwest Nevada, northeast California, and southeast Oregon. In a recently presented paper, Jones and Beck (2011) confirm a similar pattern in their eastern conveyance zone, with overlapping latitude in the Ely, Nevada, vicinity.

Likewise, the distal ORB could be viewed as the farthest extent of northern and southern ranges, but unlike the other conveyance zones, people would have had to travel over much of their full range just to get here. This suggests the ORB delta was a more dominating feature of the residential round than would be present in other foraging territories. At this time it is difficult to say what its connection with the neighboring east Nevada conveyance zone is, but the ORB delta and the east Nevada conveyance zone appear to be mostly related in the north, as Browns Bench obsidian dominates the northern sources for both. The pattern to the south, however, shows sources from southeastern Nevada to predominate in Nevada—Tempiute Mountain, Kane Springs, Modena—but only Modena can be found in small proportions on the distal ORB.

The Jones et al. (2003) model is much like that of Elston and Zeanah (2002) in suggesting that early foraging groups moved serially through different wetland habitats; thus, the movement of all this stone is a product of residential mobility. Elston and Zeanah's (2002) model adds the aspect of division of labor, whereby small task groups primarily composed of men would have extended out from residences logistically to engage in hunting. This could warrant the travel costs and provide a way of cost-effectively embedding toolstone procurement. Madsen (2007) argues that the dependence on lithic artifact sourcing in the Jones et al. (2003) model could under-represent the contribution of the wide-traveling hunters described by Elston and Zeanah (2002). Even if people relied on only a few of the largest patches, the activities of small hunting parties could generate a misleading archaeological record that suggests entire groups moved long distances.

For small task groups to so-routinely procure distant lithic resources that they account for fundamental patterns in the regional distribution of toolstone at archaeological sites seems a lot to ask. These groups would have stayed briefly and left low-visibility imprints. Moreover, it seems odd to place them in other valleys in exactly the kinds of habitats they would have just left; rather, these activities should represent little more than a few nights stay, and are probably better reflected by small-scale upland lithic scatters, and perhaps even upland cave and rockshelter occupations. People would have likely only traveled to neighboring uplands for game before the transport costs became excessive. Smith (2010) raises this concern, even in the smaller foraging territories he proposes.

I would further add that to even consider uplands as crucial hunting grounds in the same way as in the ethnographic record and implied by the later period archaeology could be flawed at the outset. In an ethnographic "two-patch" scenario, people needed to split the difference between areas that they hunted and the lowland wetlands that they relied upon (e.g., Kelly 2001; Zeanah 2004). Paleoindian foragers appear to have targeted wetlands because this is where they encountered all the other resources in their diet. For them to have moved so far so frequently suggests that large game would be an important part of wetland resource expectations. The problem with this interpretation is that there is little to no faunal evidence to support it. At a glance, the Jones et al. (2003) conveyance zones might match well with north-south migratory patterns of some herd animals, such as bison, but the lack of data keep this possibility speculative.

Regardless of the subsistence orientation, far flung excursions outside of foraging radii were more likely about information gathering for future inter-basin moves and/or social connections. Given the low, dispersed population, distant social interaction would be a necessity, and sex alone could be enough to make such movement by small parties worthwhile; toolstone acquisition would be one of any number of other secondary tasks. It is certainly conceivable that for some portion of the timeframe, the region remained a colonizing context for people (cf. Haynes 2002; Meltzer 1995, 2002). Small traveling parties, probably young men, could have fended for themselves on an encounter basis supplemented by packed foods.

The distal ORB data support a "one-patch" model. People residing in the marsh were farther from adjacent uplands than they could be anywhere else in the Great Basin. Change through time indicates that as wetlands in other basins vanished, Paleoindian foragers intensified their use of this remote area over expanding their use of upland areas. Yet still, the evidence for obsidian from great distances indicates that to whatever level people needed to use the distal ORB, it never reached the point of intensive seed processing. Currently, the latest dates known on the distal ORB are at about 9900 cal BP, with pickleweed grinding apparent just a few hundred years later in nearby Danger Cave (Rhode et al. 2006). Ground stone associated with some stemmed and, especially, Pinto points elsewhere in the Great Basin (e.g., Basgall 1993; Campbell and Campbell 1935; Haynes 2004a; Warren and Crabtree 1986), and Beck and Jones (1997) suggest that the latest reliable dates for the Paleoindian period may extend over 1,000 years later than apparent on the distal ORB. All these associations and dates could be dubious on some level, but they may represent transitional times that could have started earlier and continued later than in the eastern Great Basin. Rhode and Louderback (2007) find that at Bonneville Estates Rockshelter people were likely eating some of the same small seeds raw that would later be ground to make flour or meal to maximize their caloric value.

The Value of Formal Lithic Reduction Models and the Distal ORB Case

The archaeological record on the distal ORB follows the expectations of a formal mathematical model, which predicts that people should invest in the production of proportionately thin bifaces when they care about transport efficiency and need to use bifaces of any size as tools. They will otherwise carry flake blanks to minimize transportable weight. When transport efficiency is of less importance, investments turn to transport of minimal required toolstone to its location of use; i.e., the loss of efficiently transporting tool utility is made up for by the efficient procurement and use of known toolstone amounts. This was often the case on the distal ORB, especially late in time when stays were longer. This should be applicable on a basin-specific level because the local toolstone logistics remain the same even if people are residentially mobile within the wetland patch (Duke and Young 2007).

One notable aspect of this applies to the relationship between bifaces and mobility. Owing to the common association of large, thinned bifaces with Paleoindian assemblages across North America, this tool class, which encompasses a broad set of forms, is often considered evidence of high residential mobility regardless of whether they have been intentionally thinned. This is true even in the Great Basin (Beck and Jones 1997; Elston and Zeanah 2002; Goebel 2007), but many of the bifaces seen are crudely made from low-quality materials (e.g., Campbell and Campbell 1935; Campbell et al. 1938; Davis et al. 1969; Duke and Young 2007), running opposite to this generalization. There are actually more bifaces compared to other non-projectile point tools in later assemblages on the distal ORB than there are earlier, and this is largely accounted for by proportionately more non-thinned items made from FGV, either expediently or simply with no attention to thinning.

Also unique to Great Basin Paleoindian assemblages is the frequent use of relatively low-quality stone in the form of FGV. This is no doubt partly because it was readily available in most areas and in large cobbles. The basin-oriented mobility pattern of Paleoindians would have facilitated its use, especially as occupations increased in duration and the need for transport efficiency decreased. This is the case on the distal ORB. The physical constraints are discussed thoroughly in Chapter 5, and I also have discussed them elsewhere at length (Duke and Young 2007; Duke and Haynes 2009; also see Haynes 2004b). The limitations of FGV relate to its flakeability, but this was likely a secondary consideration to its functional value for the crude bifacial tools and steep-sided scrapers so common to early assemblages. This is a useful reminder when the interpretations of this study are considered, which is not targeted toward functional aspects.

A broader value of the distal ORB case is that the area is located much farther from raw materials sources than people operating within any normal foraging radius would normally access while conducting other routine food procurement activities. The overall technological patterning in the study area supports a toolstone supply model predicting that people should either place anticipated raw material needs into their existing tools or directly procure new material when needed. The longer the residential stays, the more the latter scenario should play out. This is evidenced on the distal ORB. Later groups appear to have stayed longer, used obsidian tools to their maximum utility extent, then procured flake blanks to replace these tools, often with less sharp and less flakeable, but nearer, FGV.

Stylistic Variability and Chronology Among Stemmed and Pinto Artifacts

My analysis identified six primary GBS series types—Cougar Mountain, Parman, Lake Mojave, Silver Lake, Bonneville, and Stubby. The distribution of these across the distal ORB adds insight to their broader chronology in the Great Basin. The chronology of the study area begins in the late Younger Dryas at about 12,100 cal BP, and therefore the distal ORB exhibits a typological profile distinct from other areas in the eastern and northern Great Basin where people could have used various basin wetlands earlier and in the most biotically productive times.

Parman is the most regionally distinctive of the stemmed styles in the study area, and distal ORB examples are true to the descriptions by Layton (1970). Layton (1970, 1972b) argued that the prototypical forms were relatively older than the cruder forms based on obsidian hydration dating, stratigraphic differences in Hanging Rock Shelter, and surficial patterns at the Parman localities. The hydration interpretations are questionable because the data were not distinguished by geochemical source, which, as we now know, can possess different hydration rates. Smith (2007, 2010) reports almost 20 obsidian sources in use by Paleoindians at the Parman Localities, which is less than 30 km from Hanging Rock Shelter, collectively accounting for more than half of the stemmed point assemblage, with most originating more than 50 km away. The majority of obsidian found at the Parman localities is from nearby Massacre Lake.

Still, Layton's sense of his data relative to redundant patterning at multiple sites should not be discounted. Hydration often works well at the level of gross sorting, and Smith's data indicate that one or two sources tend to dominate the assemblages in the area; we do not yet know how variable the rates are for the relevant sources, and the temperature-controlled context of a rockshelter is optimal for archaeological application (Rogers and Duke 2011). Moreover, Layton was aware that obsidian chemistry may affect the hydration rate, and chose samples that were visually similar in an effort to control for this as much as possible at the time. His hydration data correspond well with the stratigraphy and reflect a widely recognized gap in human occupation following Paleoindian times during the early Holocene.

A Parman point resembling Layton's "earliest" Parman #1 subtype was found buried with the Buhl skeleton approximately 250 km to the northwest in southern Idaho (Green et al. 1998). The point is also much like those examined here that are associated particularly with the west subarea. A date of about 12,600 cal BP (10,675 ± 95 BP) on the Buhl bone predates the earliest proposed availability of the study area by several hundred years, but lends further credibility to use of the style during the Younger Dryas.

Layton (1972a) also proposed that the long stem points from Cougar Mountain Cave predate and overlap even early Parman. Again, obsidian hydration from the cave deposits is used to discriminate the types (stratigraphy is unknown), but their relative ordering is as expected. This is an interesting proposition given the wide, albeit sparse, distribution of

Cougar Mountain and related long-stem types across the Great Basin. Commonly attributed to the northern Great Basin, they can be found with varying frequencies throughout the published literature, but are rarer toward the south. This might be expected of the earliest stemmed type, flaked for transport efficiency and used by sparse initial populations. While the distal ORB sample is small at only 18 items, of the eight that have been XRF-sourced, four are made from Wild Horse Canyon obsidian located about 225 km to the south; the four others are made from Topaz Mountain (n=3) and Browns Bench (n=1). That is one-third of all the Wild Horse Canyon obsidian seen in the entire sourced assemblage of GBS and Pinto artifacts (n=12 of 486).

The Lake Mojave style appears to be closely related to Cougar Mountain and has been suggested as a late part of an extended Cougar Mountain reworking sequence (e.g., Beck and Jones 2009). Interestingly, however, this style is defined by its occurrence in the Mojave Desert. Silver Lake was also first defined in the Mojave Desert, and in contrast to the three previous types, generally represents an extensively reworked stemmed type.

Bonneville and Stubby types are defined by their presence on the ORB delta. I have distinguished Bonneville as similar to Silver Lake, but with a longer blade relative to its stem. They are common, and may simply be regional variations on the same technological processes that account for Silver Lake in the Mojave Desert. Stubby is defined by Beck and Jones (see Schmitt et al. 2007) as also being distinct to the area. Both types can be found in illustrations in published literature, but their rate of occurrence is much less than observed on the distal ORB, where the toolstone economics are unique. They can also be found in association with Pinto points, also typical of the Mojave Desert region.

This stylistic profile is unlike that seen in nearby valleys of eastern Nevada, which appear to represent Younger Dryas-era occupations of small-scale lakes and distributary wetlands that would have been sensitive to the warming and drying trend that followed. At the Sunshine Locality in Long Valley about 200 km to the southwest, long-stem Cougar Mountain/Haskett and Lake Mojave artifacts largely define a total GBS point assemblage numbering more than 700 items (Beck and Jones 2009). Even more notable are the fluted points and crescents present that cannot be found on the distal ORB. The Sunshine assemblage contains 17 fluted points and 72 similar unfluted lanceolate points (i.e., Black Rock Concave Base). These are made from chert about 90 percent of the time, contrasting with the roughly 10 percent among Sunshine stemmed points. There is one fluted point from the distal ORB, a Folsom style that is unlike most of the bigger, Clovis-like items at the Sunshine Locality, which Beck and Jones (2009) suggest may be over 13,000 years old; late dates on Folsom extend as late as about 12,000 cal BP and about the time the distal ORB became available for use. There are also relatively few split-stem points that could be called Pinto at the Sunshine Locality. Geomorphic dating at the Sunshine Locality suggests that people used the area during the Younger Dryas and later, but likely not as late as seen on the distal ORB.

There are 245 Great Basin crescents at the Sunshine Locality (Beck and Jones 2009), also made from chert more than 90 percent of the time. Only one true crescent has been found on the distal ORB, and it is made from obsidian; more are reported by Schmitt et al. (2007) on the proximal ORB delta, all made from chert, perhaps indicating the potential for earlier archaeology there. Beck and Jones (2009) find the Sunshine Locality assemblage to compare well to what they see in nearby Butte and Jakes valleys.

In Jakes Valley, Estes (2009) describes about 30 sites represented by long stemmed points of the Cougar Mountain/Haskett variety alongside fluted points and crescents. Block surveys appear to give a good representation of their distribution around the ancient (undated) lakeshore. Estes finds fluted points sites to be relatively confined to the lakeshore elevation, while stemmed point assemblages are found roughly two meters higher. Stemmed point sites are also more variable in the elevation they cover, extending up the distributary areas on the north and south sides of the lake. This might be expected during a Younger Dryas occupation, when water levels surged, following a dryer period in the Clovis era (Haynes 1991) that may correspond with the fluted points. As at the Sunshine Locality, the fluted points and crescents tend to be made of chert, while the stemmed points are typically made from obsidian and FGV.

Approximately 175 km to the south in Milford Flat, Utah, Mullins et al. (2009) report 13 fluted points (12 Clovis, 1 Folsom), 41 GBS points, several possible crescents, and one Pinto point. This case again suggests that there is a Paleoindian pattern in the eastern Great Basin that is quite distinctive and likely earlier than that seen on the distal ORB.

The distal ORB assemblage best resembles material found in the Mojave Desert (e.g., Basgall 1993; Campbell and Campbell 1935; Campbell et al. 1938; Warren 1984). The projectile points alternate between crudely manufactured to extensively reworked. Bonneville and Silver Lake points, which differ in minor morphological ways, characterize the point assemblage, and Pinto points can often be alongside them. These artifacts especially predominate near Wildcat Mountain where paleochannel dates indicate the latest distal ORB occupations. They are associated with technological patterning that represents longer stays, more reliance on FGV, and less emphasis on transport efficiency than seen in earlier assemblages in the Wild Isle Dunes vicinity.

Are These Projectile Points?

The results of this study indicate that GBS and Pinto artifacts are best considered projectile points unless their morphology otherwise indicates that they are a different type of tool. More often later than earlier, these items exhibit margins or tips that are consistent with other artifact types, such as awls, spurs, and scrapers. Lake Mojave specimens are prone to exhibit "chisel" tips, a pattern seen elsewhere in the Great Basin (Beck and Jones 2009; Tuohy 1969). Use wear analysis was not possible because of frequent and often extensive weathering, but frequent impact fractures and reworked basal breaks at every size scale and for all of the GBS types suggest that use as a projectile point was the primary function.

Beck and Jones (2009) argue that stemmed points probably were not projectile points most of the time, citing the presence of "sawing and cutting" evidence on some items, especially those typed as Silver Lake. However, this evidence comes from a small sample and is not well described. Experimental studies suggest that either could be possible, but these lack verification in the archaeological record (see Lafayette 2006).

Beck and Jones (2009) further propose, based on chronological relationships, that stemmed points originated as projectile points on the Columbia Plateau at an early date, but fluted/unfluted lanceolate served this function as a superior technology shortly thereafter (~13,400-12,900 cal BP). This is based on their hypothesis that these technologies represented culturally/ethnically different peoples, fluted points coming west from the northern Plains (also see Beck and Jones 2010). Beck and Jones offer this idea recognizing that supporting data are scant, but given the technological differences in toolstone selection and reduction strategies between the two styles, bringing the issue forward seems worthwhile. If stemmed points served primarily as multiuse tools throughout most of the Paleoindian time frame, then the implication is that early subsistence focus on large game could be highly overrepresented. This would support the view by Pinson (1999; also see Willig 1989) described above that these Paleoindian foragers were primarily focused on a broad set of lower ranking marsh resources.

The alternative is that stemmed artifacts are in fact projectile points in their primary function, and they replaced fluted points, this latter aspect being long argued by Bryan (e.g., 1980, 1988). Their expansion onto the Great Plains roughly coincides with the last use of fluted and lanceolate points, and there is little doubt that they served as projectile points there for the hunting of large migratory game through late Paleoindian times (Frison 1991; Pitblado 2003). Given the potential for streamlined reduction and reworking among certain GBS types, such as Cougar Mountain and Lake Mojave, it seems plausible that this technology rivaled and usurped fluted points. While fluted points are widely thought of as a gold standard for such efficiencies, the morphology and reduction technique behind certain stemmed points—such as the telling Cougar Mountain item ISO-GR3 shown in Figure 35a (also see discussion at end of Chapter 7)—begs of this being debatable. Testing reduction factors between stemmed and fluted points against functional constraints, such as breakage, would be an interesting avenue for experimental studies.

Perhaps more unsubstantiated but worth consideration is why such variability in form and reduction sophistication exists among GBS types. For all the potential for use, reworking, and perhaps even switching from non-projectile point tools back to projectile points, there are numerous of these artifact types that barely (or do not) qualify as even pointed (e.g., Stubby) or at all symmetrical. Many may never have been made to see functional use in this way, or at least this was not the intention with their last use. If these were produced in a cultural tradition that fostered hunting on a scale suggested by Elston and Zeanah (2002), such items could be toys or training pieces (c.f. Dawe 1997). This is unknowable but reasonable from a sociocultural perspective. My primary purpose in this suggestion is simply to recognize that we would do well not to overthink the functional and techno-economic implications of the extensive variability seen in stemmed point assemblages.

Expected Differences with the Proximal ORB

The distal ORB has been emphasized in this study as a remote wetland area with unique characteristics, but it is one large part of a continuous distributary system that extends south to the basin margins. Reports from the proximal portions of the ORB suggest that the archaeology is much the same, attesting to a similar time frame for activity. Schmitt et al. (2007) report at least six quintessential Great Basin crescents, for which there is one on the distal ORB, and based on my own visits to the area and personal communication with DRI archaeologists working there, there are relatively more of the long-stem items (e.g., Cougar Mountain, Lake Mojave) seen at other eastern Great Basin Paleoindian sites, such as the Sunshine Locality and Jakes Valley. During my few visits to the area, I have also seen large biface thinning flakes indicative of more controlled tool maintenance than on the distal ORB. These patterns hint at predictable differences between the two areas based on the models discussed in this study.

The distal ORB's distance from toolstone requires people to incorporate more direct costs of procurement than should be the case elsewhere in the Great Basin because at 60 to 90 km for FGV and obsidian, respectively, people would not access these sources within a normal foraging radius. These distances can be cut almost in half at the southern parts of the proximal ORB, but these are still farther than we should expect people to be able to routinely embed toolstone acquisition into their procurement tasks. Thus, even here there seems good reason to expect the lithic record to look similar in most respects.

There are other characteristics of the proximal ORB that may produce differences. For one, the potential exists for a larger time frame for use, extending both earlier and later. Dates on the wetland going back to almost 13,000 cal BP have been collected from this area, and while no later dates than those seen on the distal ORB have been found, the potential must exist corresponding with decreasing hydrological output that would put the last wetland areas closer to the southern parts of the basin. As mentioned, there are several Great Basin crescents and long-stem points that suggest an earlier component than seen on the distal ORB and numerous Pinto sites may attest to the later occupations. Still, the ORB delta in general does not appear to have been operating at its peak as far back as seems possible for other basin wetland habitats in the eastern Great Basin—there are still no obvious Clovis-like fluted points reported (but see Schmitt et al. 2007:Figure 6.4)—so these differences may be minimal. Just being closer to the basin margins may be another reason to expect earlier components. If people at this time were moving through more quickly, they may not have had cause to extend themselves into the distal reaches of the system if they perceived better resource payoffs elsewhere.

Finally, the high-energy streams of the proximal ORB were more entrenched than those seen on the distal ORB, and may have represented prominent places that people could visit repeatedly, perhaps for many years. Site reoccupation patterns are difficult to discuss for either area, but these locales should possess the greatest potential. Although the entire ORB delta represents a dynamic marshland ecosystem, people may have been able to more-often cache tools for later use on the proximal ORB than on the distal ORB. Scavenging of artifacts, which is downplayed for the distal ORB, could have been a more common practice than on the proximal ORB if certain channels and levees remained prominent later in the period. With these considerations in mind, tracking the typological and technological variability discussed in this study against the overlapping channel relationships seen on the proximal ORB would be an intriguing exercise for future research.

Conclusions

The archaeology of the distal ORB provides a unique look at Paleoindian adaptation in the Great Basin at a time when core resource habitats—basin lake-margin and distributary wetlands—were deteriorating toward complete desiccation. As the cooler, wetter conditions of the Younger Dryas climate episode turned toward warming and drying in the Early Holocene, the ORB delta emerged from the last pluvial stand of Lake Bonneville sprawling onto the expansive Great Salt Lake Desert. While smaller basin wetlands in the region likely disappeared soon into this trend, the ORB delta persisted, benefiting from groundwater draining into the largest collection basin in the desert west. As rich a resource landscape as the ORB delta may have been at any given time, the distal ORB portion was remote by almost any measure; it is farther into the middle of the basin than can be found anywhere else in the Great Basin, and its distance from ready exit or utilization of adjacent uplands exceeds what the breadth of ethnographic research would suggest is a normal foraging radius. The cost dynamics of exploiting the distal ORB are therefore telling of Paleoindian land-use priorities as the environment they were originally adapted to take advantage of entered an unrelenting decline.

This study centers on lithic economy as a means of tracking Paleoindian response to this trend. The data indicate that from the beginning to the end of the distal ORB timeframe, ca. 12,100-9900 cal BP, people deemphasized stone tool transport efficiency. A formal technological model predicts that differential emphasis on transport efficiency relates directly to the duration of residential occupations via their affect on the cost-benefit economics of supplying people with toolstone. Residential occupation span, as it is defined in this study, represents the extent of stays within the basin, not necessarily at particular sites. Highly mobile Paleoindian groups would have needed to maximize transport efficiency to ensure that tool-use requirements were met even when toolstone sources were not nearby, while less mobile groups would have relied on acquiring additional toolstone as needed from the closest sources. I infer that Paleoindian foragers using the distal ORB stayed in the area for relatively shorter periods earlier in time than they did later.

These findings are relevant to current ecological models for Paleoindian settlement and subsistence. The ORB delta, inclusive of the distal ORB, was such a large marshland that if people intended to gather all the caloric returns available they may never need to leave, so following from optimal foraging theory, the differential patterning in occupation span is taken to represent people's expectations for returns of the highest rank order in other basin wetland patches. The trend through time toward longer occupations on the distal ORB is therefore interpreted to represent the broader decline in wetland options in the eastern Great Basin. Wetlands are generally reliable resource bases full of mid- to low-ranking resources that would not themselves necessitate such high mobility as is apparent for Paleoindian groups. Despite a virtually non-existent faunal record, the likely motivator was large game. This explanation is consistent with a model by Elston and Zeanah (2002), who argue that people operated at such an energetic surplus in the rich environment that they were willing to take on the risks of pursuing large game across wetland patches to take advantage of potentially high payoffs.

However, for an environmental decline to have such an effect that its culmination leads to the end of a long-standing hunter-gatherer adaptation suggests that at some point such plentitudes had to have ceased. Pinson (1999) argues that the variable climate of the times made resource abundances highly unpredictable, particularly for large game animals, and constantly pressed people to avoid risk and focus on a reliable and lower-ranking suite of marsh resources. High mobility is difficult to explain by this model, but it must certainly be considered in a dynamic explanation for Paleoindian settlement responses to resource stress. The later occupations of the distal ORB lasted longer than earlier occupations, suggesting some pressure to intensify the use of lower ranking resources, and proportions of projectile points to other tool types diminish. The latest dates collected on the distal ORB of about 9900 cal BP are just a few hundred years prior to significant changes in subsistence focus marking the Archaic, with intensive seed processing evident by 9300 cal BP at Danger Cave. Paleoindian groups on the distal ORB may well have undergone significant hardship before its final desiccation. Perhaps this was even more pronounced in proximal portions of the ORB delta, where the distributary system finally disappeared.

Lithic data alone cannot resolve any of the above issues, but they do provide an important body of evidence on the economic dynamics at play. Stone tools represent unique successions of decisions indicative of an array of socioeconomic priorities. This is especially the case for Paleoindian technology, where tools were used to buffer against the unknown factors that follow from high levels of mobility and transport. My aim in this study has been to use lithic technology to better relate the physical archaeological record to general ecological models. Lithic artifacts represent indirect data, but they can be found patterned throughout the region in comparable surface contexts, such as different basins and pluvial shoreline levels. Geomorphic dating can often be used to add some chronological detail to such comparisons. There is still a great deal of Paleoindian surface archaeology to discover in the Great Basin, and I hope the patterns observed on the distal ORB can be useful to future research.

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