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Quantifying the Pre-Archaic to Archaic Transition: A Study of Movement and Land-Use in the Old River Bed of Western Utah

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts in Anthropology

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ABSTRACT

Current models of prehistoric movement and land-use in the Old River Bed (ORB) of western Utah suggest that a wetland environment restricted Pre-archaic (pre-8,000 ^{14}C yr BP) occupants of the region to movement along a system of raised sand and gravel channels. I test these models using lithic- and GIS-based methods of analysis to compare Pre-archaic and Archaic (post-8,000 ^{14}C yr BP) land-use. I analyzed the attributes of lithic assemblages and individual tools relative to their distance to the ORB's margins. I then compared the relationships of Pre-archaic and Archaic sites and projectile points with the inverted channel system of the ORB and compared the degree of clustering demonstrated by sites from both periods. Further, I utilized least cost path analysis to determine whether or not the presence of a Pre-archaic wetland altered the costs of travel between the ORB and obsidian toolstone sources, and I compared these modeled travel costs to directions of procurement and frequencies of obsidian sources represented in the ORB. The results show little variance between Pre-archaic and Archaic land-use in the ORB and suggest that the presence of an expansive wetland may not have been a primary influence on Pre-archaic land-use in the area.

DEDICATION

To my grandfather Tom and my godfather Lewis – this accomplishment is tribute to your steadfast encouragement and support. I know you would both be teeming with pride.

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CHAPTER 1

Introduction

Prehistoric mobility and land-use strategies are common topics of archaeological inquiry (Beck et al. 2002; Duke and Young 2007; Eerkens et al. 2008; Elston and Zeanah 2002; Jones et al. 2003; Schmitt et al. 2007; Smith 2007, 2011; Zeanah 2004). Such studies have recognized that climatic shifts have influenced human behavior in the past (Beck and Jones 1997; Duke and Young 2007; Madsen 1999, 2002). For example, a general deterioration of environmental conditions in the Great Basin beginning near the end of the early Holocene (ca. 8,500 radiocarbon years before present [^{14}C yr BP]) has been associated with changes in hunter-gatherer mobility, settlement, and subsistence strategies (Elston and Zeanah 2002; Grayson 2011; Madsen 1999, 2002, 2007; Rhode 2008; Schmitt et al. 2004). Pluvial lakes in the Great Basin reached their highstands ca. 14,000-13,000 ^{14}C yr BP and while lake levels subsequently began to decline, many basins contained resource-rich remnant lakes and/or wetlands until ca. 8,500 ^{14}C yr BP and perhaps later (Adams et al. 2008; Benson et al. 2002; Grayson 2011; Thompson 1992). By the onset of the middle Holocene (ca. 8,000 ^{14}C yr BP), increased temperatures and decreased moisture had caused most of the region's lakes and wetlands to shrink to the point of desiccation (Benson et al. 2002; Elston and Zeanah 2002; Grayson 2011).

In this thesis, I test current models of prehistoric human behavior in the Old River Bed (ORB) of western Utah through the analysis of lithic assemblages and site and projectile point location data. My results, which suggest that the presence of an expansive wetland may not have been a primary influence on Pre-archaic movement and land-use in the area, increase our understanding of early and middle Holocene hunter-gatherer behavior within the ORB.

In the remainder of this chapter, I outline current knowledge of past climate and environment in the Great Basin and discuss human occupation of the region. I also discuss the relationship between mobility and technological organization, introduce several methods of geographic information systems-based (GIS) analysis, and provide examples of past studies that have utilized such methods to better understand prehistoric settlement and mobility strategies.

Background

Climate and Environment

The Great Basin has been defined according to its physiographic, floristic, and cultural features; the hydrographic distinction of the region, however, is most commonly used (Grayson 2011; Kelly 1997). Employing this definition, the Great Basin is the arid region of the Intermountain West that drains internally. Its borders extend north to south between the margins of the Columbia and Colorado River drainages and east to west from the Wasatch Range to the Sierra Nevada-Cascade Mountains (Grayson 2011)

(Figure 1.1). North-south-trending mountain ranges and their adjacent basins dominate the topography. The dramatic relief between mountaintops and adjacent basin floors, characteristic of the landscape, is demonstrated by the elevations of the region's highest point at 4,432 m above sea level (ASL) and its lowest point at -86 m ASL (Grayson 2011).

Biotic zones within the Great Basin exhibit significant diversity and while distributions show latitudinal variation, they are largely dictated by elevation and associated environmental conditions (Grayson 2011). In general, xerophytic shrubs dominate valley bottoms, progressively giving way to sagebrush-grass zones on alluvial aprons, pinyon-juniper woodlands farther upslope, and sub-alpine zones consisting predominantly of bristlecone and limber pines above the pinyon-juniper woodlands. Faunal communities follow a similar elevational zoning pattern as xeric adapted taxa that dominate valley floors are gradually replaced by more mesic and cold adapted taxa as elevation increases (Grayson 2000, 2006, 2011). While current biotic zones have been in place for much of the late Holocene (ca. 4,500 ^{14}C yr BP-Present), plant and animal communities of the Great Basin have continually responded to climatic change as demonstrated by shifts in both their distributions and abundances (Louderback and Rhode 2009; Mensing 2001; Grayson 2000, 2011).

Several lines of evidence inform our understanding of past conditions in the Great Basin. Wigand and Rhode's (2002) study of macro- and microbotanical data allowed regional climate models to be developed for the Great Basin extending from the historic period to ca. 250,000 years ago. Other studies focus on faunal assemblages (e.g., Grayson 2000; Hockett 2000; Schmitt et al. 2004) or geomorphology (Adams 2010;

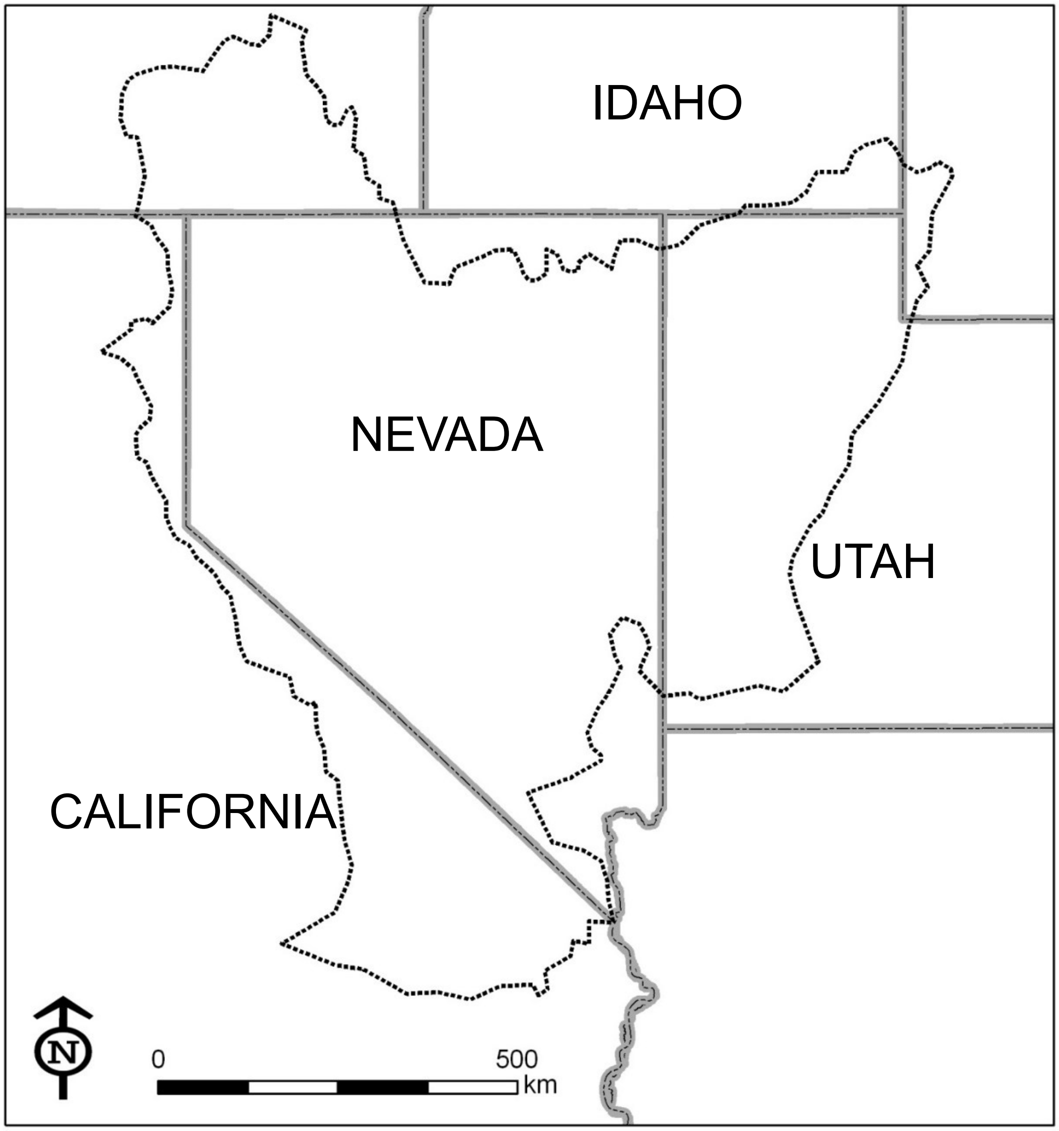

Figure 1.1. The Hydrographic Great Basin.

Currey 1990; Oviatt et al. 2003) to reconstruct past climates and environments. While spatial and temporal variability has been observed in records of past Great Basin climates (Adams et al. 2008; Mock and Bartlein 1995; Thompson et al. 1993; Wigand and Rhode 2002), a number of generalities can be stated regarding conditions within the region throughout the Holocene.

Proxy records indicate that lower temperatures and increased precipitation during the terminal Pleistocene/early Holocene (TP/EH), ca. 15,000-8,000 ^{14}C yr BP, resulted in relatively cool and wet conditions considerably different than those seen today (Grayson 2011). Climatic conditions during this period prompted a transgressive phase in many pluvial lake basins within the region (Adams et al. 2008; Bacon et al. 2006; Benson and Thompson 1987; Oviatt et al. 1992; Thompson 1992). A number of studies throughout the Great Basin reflect these conditions; for example, radiocarbon dates from the Lahontan basin in the western Great Basin indicate that a highstand occurred ca. 13,000 ^{14}C yr BP (Adams et al. 2008). Research in central-eastern Nevada shows that Jakes Lake reached its highstand ca. 13,870 ^{14}C yr BP (Garcia and Stokes 2006) and that Long Valley, Nevada supported a wetland environment as late as ca. 9,800 ^{14}C yr BP (Beck and Jones 2009). Data from the Bonneville basin of western Utah indicate similar TP/EH conditions. Lake Bonneville reached its highstand between ca. 14,500 and 13,500 ^{14}C yr BP (Benson et al. 2002; Oviatt et al. 1992, 2003, 2005). Research has also shown that shifts in vegetation occurred along with lake level changes; pollen records show that in Owens Valley in eastern California and the Ruby Marshes in northeastern Nevada, juniper woodlands and sagebrush -dominated vegetation persisted at lower elevations than at present (Mensing 2001; Thompson 1992). Louderback and Rhode's (2009) investigation of the pollen record at Blue Lake show that pine and sagebrush dominated the landscape during the TP/EH. Additional analysis from the Great Salt Lake shows the presence of conifer woodlands during the same period (Louderback and Rhode 2009).

Following this cool/wet interval, an increase in temperature coupled with a decrease in moisture led to a warming environment and declining lake levels. The

Younger Dryas (ca. 11,000-10,100 ^{14}C yr BP) provided a temporary reprieve with a return to near full-glacial conditions and associated lake level rises (Adams et al. 2008; Madsen et al. 2001, 2007; Oviatt et al. 2005). The period following the Younger Dryas brought a return to the warming and drying that had begun prior to the interval's onset. Despite these trends, however, the Great Basin remained cooler and moister than today, supporting shallow lakes and marshes in many basins throughout much of the early Holocene, between ca. 10,000 and 8,000 ^{14}C yr BP (Adams et al. 2008; Benson and Thompson 1987; Oviatt et al. 1992; Thompson 1992; Madsen et al. 2001).

After ca. 8,000 ^{14}C yr BP, the Great Basin experienced an abrupt and dramatic shift in climate that resulted in a much warmer and drier environment than that of the periods that came both before and after (Beck and Jones 1997; Grayson 2011; Louderback et al. 2010; Madsen et al. 2001; Thompson et al. 1993). Many lakes and wetlands disappeared during this interval (Adams et al. 2008; Benson et al. 2002; Lindström 1990; Mensing et al. 2004) and several lines of faunal and botanical evidence have been used as proxy for this change in climate. For example, small mammal abundances at Homestead Cave in north-central Utah show the replacement of several mesic adapted taxa (e.g., yellow-bellied marmots, pygmy rabbits, bushy-tailed woodrats) by the more xeric-adapted kangaroo rat during this period (Grayson 2000, 2006). At the Ruby Marshes, chenopod abundance increased while sagebrush decreased (Thompson 1992). Submerged tree stumps, indicating lowered levels at Lake Tahoe, date to this period (Lindström 1990) and Owens Lake may have desiccated completely (Bacon et al. 2006; Benson et al. 2002). In the Bonneville basin, the Great Salt Lake may have reached near complete desiccation (Madsen et al. 2001) and at Blue Lake, dryland shrubs increased at the expense of pine and sagebrush (Louderback and Rhode 2009). The environmental shift is also demonstrated by an increase in the relative abundance of jackrabbit remains at Camels Back Cave beginning after ca. 8,000 ^{14}C yr BP (Schmitt et al. 2004). Additional evidence from pollen core analysis at Mosquito Willie's Spring shows increasing aridity in the region that appears to have peaked shortly after 6,900 ^{14}C yr BP (Kiahtipes 2009). River flow from the Sevier basin into the ORB ceased after ca. 8,700 ^{14}C yr BP, beginning the transition to the desiccated conditions found there today (Oviatt et al. 2003; Schmitt et al. 2007). The environmental effects of this transition are discussed in detail in Chapter 2.

Humans in the Great Basin

Researchers debate the timing of the earliest occupation of the Great Basin (Gilbert et al. 2008, 2009; Goldberg et al. 2009; Jenkins et al. 2012; Poiner et al. 2009; Rasmussen et al. 2009). Traditionally, researchers believed that humans entered the region ca. 11,500 ^{14}C yr BP (Beck and Jones 2001; Beck et al. 2002; Grayson 1993); however, recent evidence from the Paisley Caves in southern Oregon suggests that an earlier migration into the region occurred (Gilbert et al. 2008, 2009; Jenkins et al. 2012). Coprolites containing human DNA from the Paisley Caves have been dated to as early as ca. 12,450 ^{14}C yr BP (Jenkins et al. 2012). Some researchers have, however, questioned some aspects of those findings. Poinar et al. (2009) argue that Gilbert et al.'s (2008) results likely reflect human DNA from overlying, younger sediment leaching down and contaminating older non-human coprolites. Poinar et al. (2009) further assert that the site's stratigraphy is not intact and that discrepancies in radiocarbon dates from one of four coprolite samples renders all Paisley Caves dates unreliable. Goldberg et al. (2009) argue that micromorphological analysis of the coprolites suggests a non-human herbivore rather than human origin. Nonetheless, the Paisley Caves currently represent the most convincing archaeological sites providing evidence for a "Pre-Clovis" occupation of the region (Grayson 2011; Jenkins et al. 2012).

The terms Paleoindian, Paleoarchaic, Pre-archaic, and Initial Archaic have all been used to describe the early occupants of the Great Basin. Following Elston and Zeanah (2002), I employ the term Pre-archaic here to emphasize differences between the behaviors of ORB hunter-gatherers during the TP/EH (pre-8,000 ^{14}C yr BP) and those of the region's occupants during the Archaic period (post-8,000 ^{14}C yr BP).

The climatic trends that began during the early Holocene continued through most of the middle Holocene. As warmer, drier environments increasingly characterized the landscape, wetlands deteriorated, shrinking in size or disappearing altogether (Elston and Zeanah 2002; Grayson 2011; Madsen 2002). Prehistoric populations who exploited wetlands almost certainly had to make adjustments to remain viable (Beck and Jones 1997; Elston and Zeanah 2002; Madsen 2002; Rhode 2008). Variation between the archaeological records of the Pre-archaic and Archaic periods exemplifies these adjustments.

Pre-archaic (Pre-8,000 ^{14}C yr BP). Models of Pre-archaic adaptation during the relatively cool and wet TP/EH frequently characterize Great Basin populations in a manner consistent with Bedwell's (1973) Western Pluvial Lakes Tradition (WPLT); however, current models also recognize increased variation in settlement and subsistence practices more so than the WPLT (Grayson 2011). These models have resulted from recent evidence for the Pre-archaic occupation of a number of different environments (Elston and Zeanah 2002; Graf and Schmitt 2007; Grayson 2011; Jones and Beck 1999; Madsen 2007; Middleton 2013) and the exploitation of both wetland and non-wetland resources (Adams et al. 2008; Hockett 2007; Rhode and Louderback 2007). Nonetheless, the adaptation to lacustrine environments and the importance of wetland resources emphasized in the WPLT model are still considered central components of Pre-archaic lifeways (Jones and Beck 1999; Graf and Schmitt 2007; Grayson 2011; Madsen 2002, 2007; Schmitt et al. 2007; Smith 2010). The importance of these components has been confirmed by the location of many TP/EH sites found along the margins of pluvial lakes and the presence of wetland resources in archaeological assemblages from this period (Beck et al. 2002; Hockett 2007; Pinson 2007). Elston and Zeanah (2002) argue that lake and wetland sites, a lack of residential structures, and widely distributed toolstone suggest that low population densities and relatively high mobility characterized the TP/EH. Seasonal variability of large-mammals, coupled with the presence of reliable wetland resource patches, may have accounted for the high mobility and lacustrine-centered adaptive strategies employed by Pre-archaic populations (Beck and Jones 1997; Elston and Zeanah 2002).

Archaic (ca. 8,000-4,500 ^{14}C yr BP). Warming and drying trends associated with the onset of the middle Holocene resulted in fewer and smaller wetlands, which required groups to modify their adaptive strategies (Elston and Zeanah 2002; Grayson 2011; Schmitt et al. 2004). In most places, the diminution of wetlands precluded continued use of wetland-centered strategies typically associated with Pre-archaic groups. Desiccation of all but the most expansive wetland habitats, a decline in biological productivity, and the redistribution of terrestrial plant and animal resources resulted in an environment that was once believed by some to have been abandoned during the middle Holocene (e.g., Baumhoff and Heizer 1965). Grayson's (2011:302) summary of the middle Holocene captures this view: "Were I to choose a time during the past 10,000 years to *not* live in the Great Basin, this would be it" (emphasis added). Despite periods of unfavorable conditions, however, people did remain in the region. Population densities appear to have declined (Louderback et al. 2010), but several lines of evidence demonstrate that Archaic hunter-gatherers persisted by relying upon different adaptive strategies than earlier populations. For example, at Bonneville Estates Rockshelter, a decrease in the availability of both terrestrial and wetland resources during the middle Holocene resulted in an overall decrease in dietary diversity (Hockett 2007). At Camels Back Cave, a shift from artiodactyl hunting to jackrabbit collecting occurred (Schmitt et al. 2004). Storage facilities, residential structures, ratios of local and non-local toolstone, and increased assemblage variation suggest that groups occupied sites for longer periods during the middle Holocene (Elston and Zeanah 2002, Smith 2011a). Increased numbers of grinding stones at Archaic sites indicate a greater reliance upon lower-ranking plant and seed resources (Elston and Zeanah 2002; Grayson 2011). Coprolite composition, small seed residues, and the distribution of grinding stones at several eastern Great Basin sites including Danger Cave, Camels Back Cave, Hogup Cave, and Bonneville Estates Rockshelter show increased use of lower-ranked resources during the middle Holocene (Rhode 2008; Rhode et al. 2006). While Archaic populations continued to occupy wetlands in areas where such environments persisted (Kelly 1997; Madsen 2002, 2007), the variety of environmental zones utilized expanded to include uplands more frequently than in the past (Elston and Zeanah 2002; Grayson 2011; Kelly 1997; Madsen 2002, 2007).

Reconstructing the Past Using Lithic- and GIS-based Analyses

The climatic and environmental changes that began near the end of the early Holocene clearly affected prehistoric lifeways in the Great Basin. An important detail that remains less clear, however, is how conditions during this period affected the manner in which people used and moved about lowland areas that once contained wetlands. Researchers have used both lithic- and GIS-based analysis to better understand the land-use strategies of past groups in other studies and these methods can be applied to determine whether or not the strategies of Pre-archaic and Archaic populations differed markedly in the ORB.

Lithic-Based Studies

An important factor in reconstructing prehistoric behavior is the cost involved with procuring raw materials for the production of stone tools. A number of researchers have considered raw material availability in their studies (e.g., Andrefsky 1994, 2010; Beck et al. 2002; Daniel 2001; Eerkens et al. 2007, 2008; Gramly 1980; MacDonald 2008; Shott 1986). This work has produced a wide range of information regarding the relationship between raw material availability, hunter-gatherer behavior, and the character of lithic assemblages. It has further served to demonstrate the utility of lithic analysis for reconstructing the past. Several studies have shown that lithic assemblages change in a predictable manner as the distance from the raw material sources from which they originated increases. For example, intensity of retouch of projectile points and bifaces often increases as tools are transported farther from their sources (Andrefsky 1994, 2010; Beck et al. 2002; but see Smith et al. 2013). Accordingly, the weight of these artifacts often decreases as the distance from their source increases (Clarkson 2002; MacDonald 2008). Andrefsky (2006) developed the Hafted Biface Retouch Index (HRI), which measures retouch intensity among projectile points. He employed this index to test the influence of raw material proximity upon the amount of retouch present on projectile points. The results show that the degree of retouch increases as distance to raw material source increases, and Andrefsky (2010) argues that this trend is a function of points being increasingly resharpened and modified when the raw material from which they are manufactured is procured from distant sources.

MacDonald (2008) used the HRI to show that projectile points discarded farther from lithic sources are more extensively retouched than those discarded closer to lithic sources. Additionally, MacDonald’s (2008) measurements of artifact weight and size show that non-local artifacts are on average both smaller and lighter than local artifacts. Shott (1986) notes that the relationship between artifact size/weight and distance from raw material sources reflects mobile hunter-gatherers manufacturing smaller, lighter tools to reduce transport costs. Alternatively, it may reflect increased stone tool reduction as distance from raw material sources increases and tools’ use-lives were extended (Andrefsky 2010; Eerkens et al. 2007; MacDonald 2008; Morrow 1997). Ultimately, efforts to reduce transport costs and extend tools' use-lives may have both influenced the size and weight of discarded artifacts (Morrow 1997).

Beck et al. (2002) have argued that the distance between raw material sources and residential bases explains variability in the degree of reduction of bifaces at quarry sites and associated residential bases. They modeled the relationship between biface reduction and the cost of transporting those bifaces by implementing a utility function. The utility function predicts that as distance between a quarry site and a residential base containing lithic material procured from that quarry increases, the degree of biface reduction that occurs at that quarry should also increase. The results of their analysis at two quarry sites and two residential sites conform to their expectations: bifaces at the quarry located farther from its associated residential base exhibit a greater degree of reduction than bifaces at the quarry located closer to its associated residential base. Furthermore, the assemblages at sites located farther from their associated quarries show that more late-stage biface reduction occurred at the residential base than at its distant lithic source.

The analysis of multiple components of lithic assemblages (e.g., debitage, tools) can also provide an understanding of past human behavior and assemblage formation processes (Eerkens et al. 2007, 2008; Shott and Scott 1995). For example, Eerkens et al. (2007) showed that large flakes are generally made on local material, representing initial procurement and reduction activities, whereas small flakes and formal tools are generally made on more distant sources, representing tool maintenance activities and tool discard.

In sum, considerations of raw material availability in studies of lithic technological organization have shown that distance to lithic sources influenced prehistoric behavior and the character of lithic assemblages related to that behavior.

Andrefsky (1994) notes that variation observed in lithic assemblages may be multidimensional, with different combinations of conditions resulting in different organizations of technology. It is nevertheless clear, however, that the distances that hunter-gatherers traveled to procure lithic raw materials were among the primary factors conditioning lithic assemblages.

GIS-Based Studies

Since being introduced to the field of archaeology, GIS-based methods of analysis have increasingly been incorporated into studies of prehistoric behavior. The application of spatial data to questions related to past land-use, along with the wide range of analytical techniques offered by GIS, has made the technology invaluable for managing and analyzing archaeological data (Conolly and Lake 2006; Smith 2011b; Wheatley and Gillings 2002). GIS-based distance, spatial, and statistical analyses have been used to examine the relationships between the locations and properties of archaeological sites and features of the surrounding landscape in efforts to understand settlement and mobility strategies. Additionally, employing methods such as least cost path analysis has allowed for costs of travel across a landscape to be measured. I describe these techniques in greater detail below and provide examples of how each has been used to address questions about the past.

Distance and Spatial Query Analyses. Distance is a primary consideration when attempting to explain the location of archaeological sites (Wheatley and Gillings 2002) and a number of GIS-based methods allow the distance between archaeological sites and environmental features to be measured (Wheatley and Gillings 2002). Distance (buffering) queries allow for a series of buffers to be generated around a given point, line, or polygon. The calculation of area for the resulting buffers can be important as a variable used in the application of statistical tests (Wheatley and Gillings 2002) and by associating each point within a dataset with the buffer that contains it, questions regarding the relationships between points and their surrounding features can be addressed. Conolly and Lake (2006:119) provide examples of such inquiries, illustrating the potential usefulness of this relatively simple technique. For example: "What proportion of sites fall within 1 km of the coast? What is the change in density of sherds moving away from the center of site *k* in 100-m intervals?… What proportion of all scrapers is found within 2 m of hearth features?"

Spatial queries allow for a clearer understanding of how point data may be related to particular characteristics of the landscape. For example, archaeological sites can be characterized according to selected attributes, overlaid on a digital elevation model (DEM), and by implementing a spatial query, each site point can be assigned an elevation value based upon its location on the underlying DEM. Conolly and Lake (2006) utilize this method to distinguish differences in elevations between burial cairns and stone houses.

With the ability to separate archaeological sites by attribute and associated landscape features, GIS-based methods of statistical analysis become useful in testing relationships between site location and site type. Site attributes such as artifact density, relative densities of artifact types, and the presence or absence of site features or artifact types can be measured and their correlation with features of the landscape tested for significance with the application of statistical analyses. For instance, Conolly and Lake (2006) utilize a student's *t*-test to determine if densities of artifacts are significantly different between two distinct survey areas, one coastal and one inland. Their results show that although the mean artifact density of coastal areas is greater than that of inland areas, their resulting *p*-value indicates that they do not differ significantly.

The above examples of GIS-based methods highlight the technology's utility in analyzing archaeological data. Distance and spatial queries applied to archaeological datasets provide convenient means to classify sites and features and, when appropriate statistical tests are employed, associations between sites and/or sites and surrounding features can be quantitatively tested for significance. In addition to these relatively simple GIS-based analyses, more complex methods may be incorporated into studies to explore site patterning and to develop and test models of past human land-use.

Point distribution analysis is an important method for researchers interested in exploring the distribution of sites. When attempting to explain the distribution of archaeological sites, Wheatley and Gillings (2002) note the importance of setting out with questions regarding whether or not a perceived pattern within a distribution is truly patterned and, if so, what the nature of that patterning is. When observed on the ground or visualized on a map, site distributions may appear patterned; however, it is generally the case that robust arguments for such patterning and subsequent inferences regarding the nature of it cannot be made on the basis of visual inspection alone (Wheatley and Gillings 2002). The limitations of visual inspection as an analytical method place GIS-based anlayses of point distribution in a favored position to address questions regarding site distribution and patterning.

Nearest Neighbor Analysis. Although Conolly and Lake (2006:164) describe the analysis of point distribution using nearest neighbor analysis as being possibly "now old-fashioned" they concede that its straightforward application and easily interpreted results have contributed to a persistence of its popularity in archaeology. When using nearest neighbor analysis, the distance from each point in a dataset to its nearest neighboring point is first calculated. The statistic R is then generated as a ratio of the observed average nearest neighbor distance and an expected mean nearest neighbor distance. Conolly and Lake (2006) explain that the expected mean nearest neighbor distance is determined by the GIS software using an algorithm that generates a random distribution of the points under analysis. If the value of the R statistic is equal to 1, then the mean distance between observed points is equal to that of the expected distribution of points and is as such random. An R statistic greater than 1 indicates a dispersed distribution and an R statistic less than 1 indicates that the point distribution is clustered. The straightforward nature of nearest neighbor analysis and the relative simplicity of its results make it an attractive tool for analyzing the distribution of archaeological sites.

Niknami et al. (2009) utilized nearest neighbor analysis in a study of site distribution. In their study, several attributes of site location (e.g., elevation, slope, soil type, river network presence) were considered potentially influential upon prehistoric habitation decisions. Nearest neighbor analysis was used to determine whether or not previously recorded archaeological sites clustered in areas where the environmental attributes were present. Their results indicate that known archaeological sites within their study area were indeed clustered in areas demonstrating the attributes associated with the locations of their sample sites. Niknami et al. (2009) illustrate how nearest neighbor analysis may be useful for explaining the distribution of archaeological sites by testing for the presence of site patterning and providing results that aid in the interpretation of the nature of such patterning. The incorporation of environmental variables into the study reveal the capacity of nearest neighbor analysis to elucidate some of the variables that may have contributed to the decisions of past peoples regarding site location selection.

Least Cost Path Analysis. Least cost path analysis predicts routes of travel between points by using an accumulated cost path that determines the cost of travel across a landscape (Conolly and Lake 2006). A number of factors may be included to generate an accumulated cost surface. Depending upon the equation deemed appropriate for the study in question, factors may include slope, energy expenditure, and/or carrying load weight. Additionally, variables that would constrain movement (e.g., bodies of water, cliff-faces) may be incorporated into the accumulated cost surface equation. These factors ultimately act as variables affecting the cost of traversing the areas with which they are associated and are used to determine the route of a least cost path. Conolly and Lake (2006) discuss the usefulness of least cost paths for archaeologists, stating that in many cases exact routes of travel used in the past are unknown and least cost paths provide a manner in which archaeologists, lacking direct evidence of past routes, can predict routes based on environmental and physical variables.

Smith (2011b) investigated the potential for error when lithic sourcing-based studies infer prehistoric foraging ranges with the use of Euclidean distance measures for distances between raw material sources and the locations of lithic assemblages in which those sources are represented (e.g., Jones et al. 2003; Smith 2010). His results show that a least cost path, using slope as the sole cost variable, does not follow the straight-line paths typically used to estimate travel distances. Rather, the least cost path avoids "traversing areas of significant slope. Instead, it makes use of the deeply-incised drainages" (Smith 2011b:24). While the least cost path generated by Smith (2011b) nearly doubles the travel distance of the straight-line distance between his selected locations, the use of slope and distance alone is noted as a potential explanation and Smith (2011b) suggests that future analysis could benefit from the use of additional variables.

Taliaferro et al. (2010) conducted a second study involving mobility as it relates to lithic procurement patterns using least cost paths. Their cost variables included slope and travel time with a consideration of upward or downward momentum. Further, their model was anisotropic; that is, values were assigned based on the direction of movement across the landscape. Their results show that the dominant lithic sources represented at sites in their study area's northern region were most often not the sources of least cost, based on their least cost path analysis. The more southern sites, however, did show predominant procurement from their least costly sources. Taliaferro et al. (2010) conclude that this variation in source procurement activity may indicate the presence of toolstone exchange and social networks within the region.

RESEARCH GOAL

It is clear from the above examples that both lithic- and GIS-based methods of analysis are effective techniques for modeling prehistoric adaptive strategies as they relate to lithic technological organization, mobility, and land-use. The integrated use of these methods within a single research project stands to broaden our knowledge of past human behavior and the variables that influenced it. The relatively intact state of the archaeological record contained within the ORB, combined with its unique geomorphological composition and well-documented history of environmental change, furnish a study area in which the integrated use of lithic analysis and GIS-based methods of analysis can yield informative results regarding the activities of prehistoric people within the region. Using these approaches, I test the following hypothesis: hunter-gatherers occupying the ORB during its marshland period (pre-8,000 ^{14}C yr BP) were restricted to movement along the dry ground provided by the basin's inverted channels, while occupants of the ORB during later, more xeric conditions (post-8,000 ^{14}C yr BP) experienced decreased movement constraints.

CHAPTER 2

Materials: The Old River Bed, Bonneville Basin, Utah

Data used for this thesis originate from recent fieldwork conducted in the ORB of western Utah. Site locations and lithic assemblage attributes along with geomorphological analyses and raw material sourcing studies provide a wealth of information regarding the region's natural and cultural prehistory. Contributing to the abundance of data available from the ORB is its location in the remote, restricted-access Dugway Proving Ground (DPG) (Figure 2.1), which has allowed the area's archaeological record to remain largely intact (Grayson 2011; Page 2008; Schmitt et al. 2007). Additionally, cultural resource management contracts with DPG have mandated that large parcels of land be surveyed for archaeological material. This combination of factors provides a unique opportunity to test models of prehistoric adaptation, explore the effects of climate change on Great Basin foragers, and compare the lifeways of two prehistoric populations occupying the same region at different times and under very different environmental circumstances.

In this chapter I summarize the materials used in this study through descriptions of the ORB's geomorphology and the environmental changes that took place there between the early and the middle Holocene. I also provide an overview of the lithic technology characteristic of the region along with a brief discussion of the chronological associations of different ORB projectile point types. Finally, I discuss inferences of human adaptation associated with Pre-archaic site patterning in the ORB.

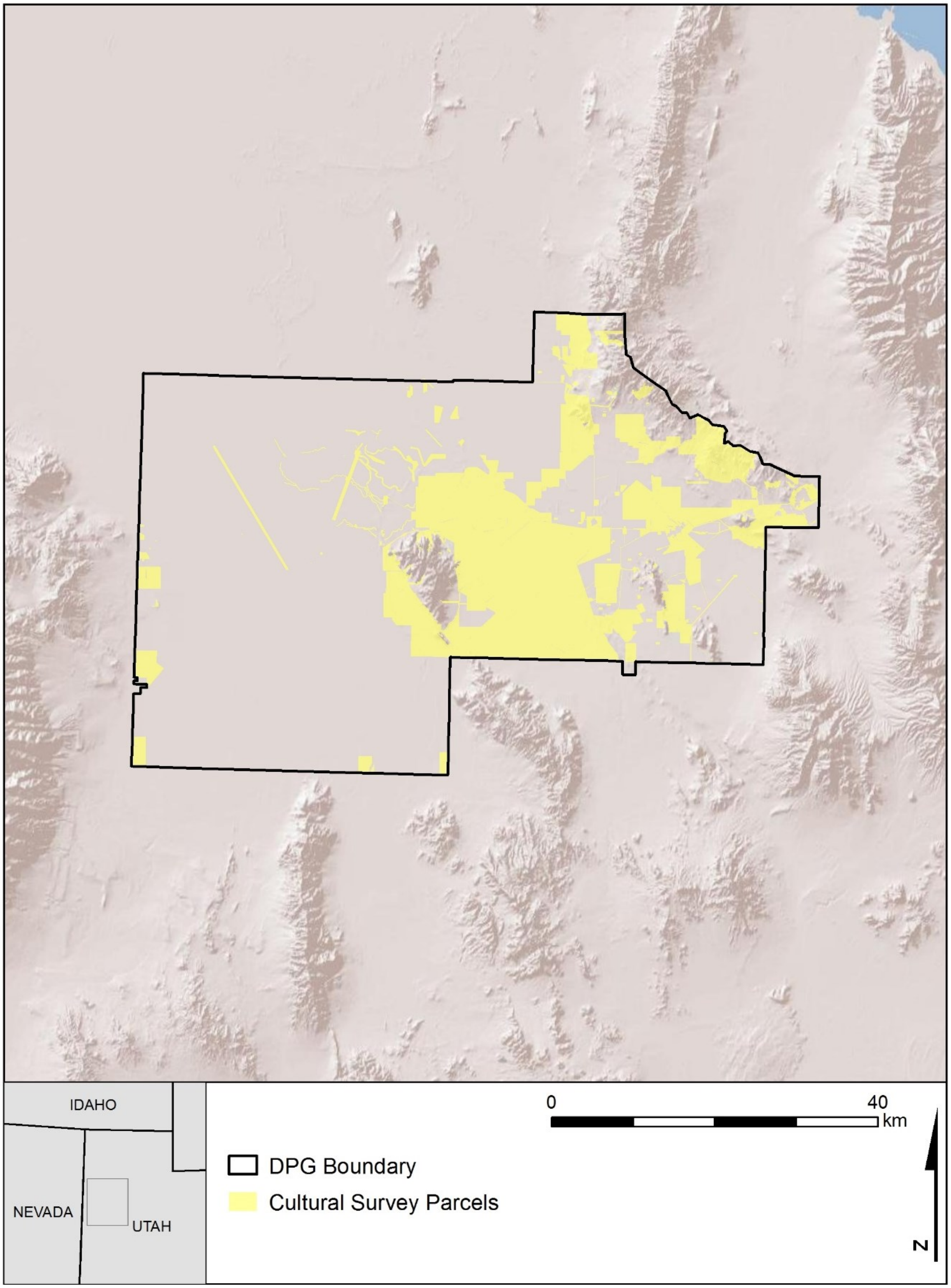

Figure 2.1. Map of the proximal Old River Bed's location within the borders of Dugway Proving Ground and of the parcels surveyed in the study area. Data source: DPG. Image source: ESRI.

The Old River Bed

Geomorphology

The ORB is a relict river valley connecting the Great Salt Lake Desert and Sevier sub-basins of the larger Bonneville basin that once contained pluvial Lake Bonneville (Oviatt et al. 2003; Schmitt et al. 2007). Throughout its duration, Lake Bonneville experienced several fluctuations in surface level, resulting in a minimum of five distinct shorelines (Oviatt et al. 2005). During its last highstand, Lake Bonneville stood between 1,293 and 1,297 m ASL. This level is known as the Gilbert shoreline and is associated with re-transgression of Lake Bonneville during the Younger Dryas interval, shortly after ca. 10,500 ^{14}C yr BP (Madsen et al. 2015a; Oviatt 2014; Oviatt et al. 1992, 2003). Research by Oviatt (2014) has placed the culmination of this highstand at the very end of the Younger Dryas (ca. 10,000 ^{14}C yr BP). Periods of regression of Lake Bonneville both prior to and following the Gilbert highstand resulted in two smaller, separate lakes: (1) the Great Salt Lake, located in the Great Salt Lake Desert sub-basin; and (2) Lake Gunnison, located in the more southerly Sevier sub-basin (Figure 2.2). Lake Gunnison experienced overflow of its northern sill between ca. 11,400 and 9,500 ^{14}C yr BP as an effect of its relatively small surface area and strong inflow from both the Sevier and Beaver rivers (Madsen et al. 2015a; Oviatt et al. 1992). This overflow resulted in an active river connecting the Great Salt Lake Desert and Sevier sub-basin lakes and contributed to the formation of much of the physical landscape observable within the ORB today (Oviatt et al. 2003; Page 2008).

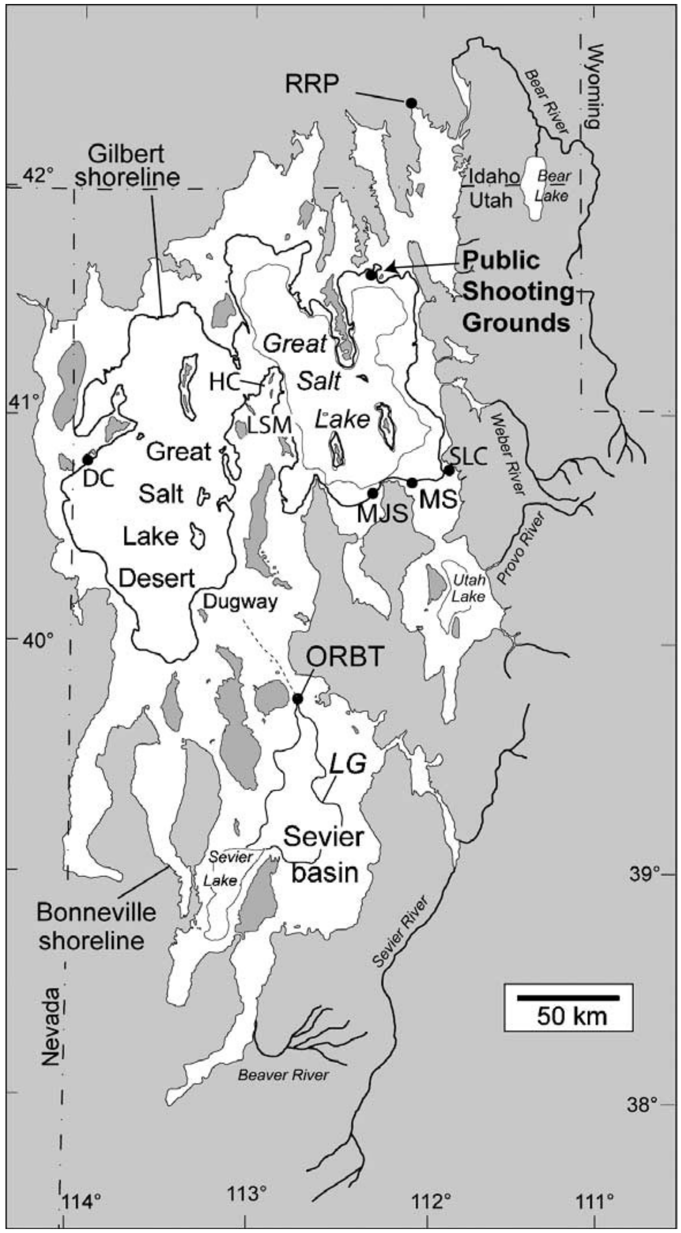

Figure 2.2. Map of the Bonneville basin showing the location of The Great Salt Lake Desert and Sevier sub-basins. Image adapted from Oviatt et al. (2003).

Occupying the southern end of the Great Salt Lake Desert basin, the ORB delta consists of both sheet-like fanned and channel-fill deposits. The delta formed as river flow deposited fine-grained sand and mud onto the floor of regressing Lake Bonneville

(Madsen et al. 2015a; Oviatt et al. 2003; Schmitt et al. 2007). Groundwater-discharge mudflats extend far north beyond the fine-grained deposits of the ORB delta and a series of aeolian dunes mark a boundary between the northern mudflats and the southern deltaic plain of the ORB (Madsen et al. 2015a; Oviatt et al. 2003; Schmitt et al. 2007). The formation of dunes at the transition from the ORB delta to the outlying mudflats is attributed to processes of denudation of the mudflat surface itself. Schmitt et al. (2007) and Madsen et al. (2015a) describe the mudflat denudation and subsequent dune formation as functions of a number of processes acting upon the landscape. Today, the region's mudflats experience alternating periods of being moist from groundwater discharge and then dry during the summer from increased temperatures and aridity. These oscillations result in loose particles that become windblown and accumulate to form the ORB dunes. Additional loosening of particles that contribute to dune formation may result from salt precipitation within the mud and from wind-born agitation of thin films of water that overlie the mudflats following heavy rains in the region. These three geomorphic features – deltaic plain, mudflats, and aeolian dunes – make up the primary landscape of the ORB; however, it is a fourth ORB landform consisting of fluvial channels that has been the recent focus of considerable research within the region (e.g., Madsen et al. 2015a; Oviatt et al. 2003; Page 2008; Schmitt et al. 2007).

Among the most unique features of the ORB is the system of braided channels that stretches from the basin's proximal southern end to its distal northern end, covering a substantial area of the ORB delta and mudflats (Figure 2.3). Investigations of the ORB channels – including channel mapping, radiocarbon dating, and trench excavation – have allowed substantial data to be compiled regarding the timings of channel deposition and

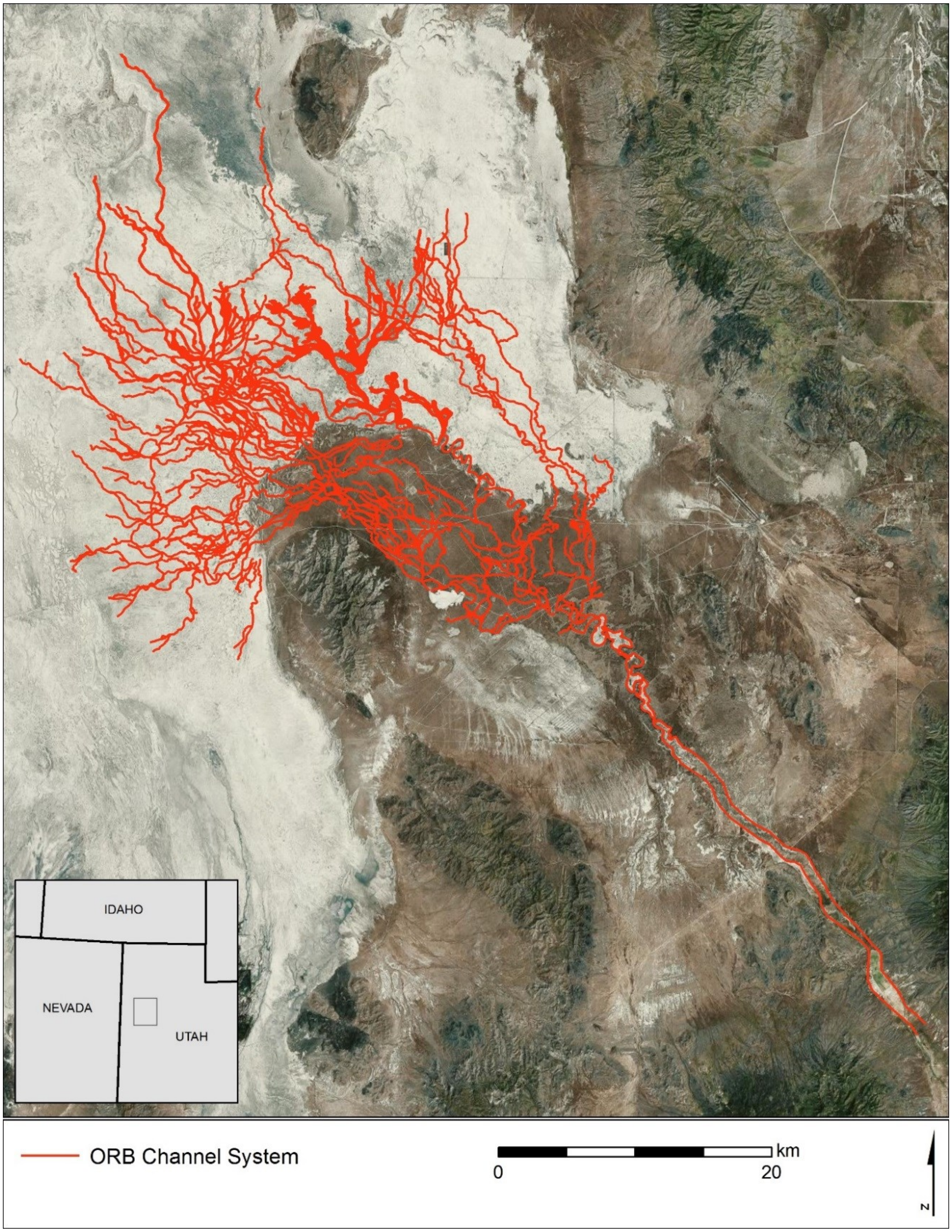

Figure 2.3. Satellite image showing the braided channel system of the ORB. Data Source: David Page, DRI. Image source: ESRI.

fluctuations of river flow into the ORB. River flow into the Great Salt Lake brought with it gravels and sediments deposited into the ORB basin (Madsen et al. 2015a; Oviatt et al. 2003; Page 2008; Schmitt et al.2007). Oviatt et al. (2003) describe the channels as being compositionally distinct and divide them accordingly into three categories: (1) gravel; (2) sand; and (3) intermediate. These categories are associated with changes in river discharge: gravel channels are associated with high-energy flow, sand channels are associated with relatively low-energy flow, and intermediate channels (consisting primarily of sand with some gravel) are associated with moderate river flow (Madsen et al. 2015a; Schmitt et al. 2007). The high-energy gravel channels are mounded in cross section, rising 1-4 m from the mudflats and delta upon which they were deposited (Oviatt et al. 2003; Schmitt et al. 2007). Sand channels are similarly topographically inverted but to a lesser extent, being truncated by the mudflat surface at some locations and standing 0.5-1.2 m above their surrounding surfaces at others (Madsen et al. 2015a; Oviatt et al. 2003; Schmitt et al. 2007). Oviatt et al. (2003) placed the fluvial production of gravel channels between ca. 12,500 and 11,000 ^{14}C yr BP and the production of sand channels between ca. 11,000 and 8,800 ^{14}C yr BP, with intermediate channel formation overlapping that of sand channels ca. 10,500-9,200 ^{14}C yr BP; however, growing numbers of channel-associated radiocarbon dates and continued investigation of ORB channel formation have led to shifts in this chronology. Limited evidence for high-energy river flow into the ORB prior to the Gilbert highstand of Lake Bonneville (ca. 10,500 ^{14}C yr BP) suggests that the deposition of channels in the ORB occurred between ca. 10,500 and 8,800 ^{14}C yr BP (Madsen et al. 2015a). Gravel and intermediate channels formed during the early portion of this period (until ca. 9,500 ^{14}C yr BP) from high to medium-energy streams carrying coarse-grained sediments into the basin, and lower-energy stream-flow between ca. 9,500 and 8,800 ^{14}C yr BP resulted in the formation of the basin's finer-grained sand channels (Madsen et al. 2015a).

Climatically Induced Environmental Shifts

The changes in Great Basin climate that began near the end of the early Holocene and continued through most of the middle Holocene resulted in the drying of many of the region's lakes and marshes, including those of the Bonneville basin (Grayson 2011; Madsen et al. 2001; Louderback and Rhode 2009). Between ca. 10,500 and 8,700 ^{14}C yr BP river flow persisted between the Sevier and Great Salt Lake Desert basins. During this interval the ORB was home to a vast (~750 km^2) marshland habitat, representing the largest wetland system of the period in the Great Basin (Madsen et al. 2015a; Oviatt et al. 2003; Schmitt et al. 2004, 2007). The environmental changes that took place in the ORB beginning near the end of the early Holocene are generally consistent with those observed throughout the Great Basin during the same period and as shown in the previous chapter, much of the evidence for middle Holocene environmental deterioration has been derived from research conducted in the Bonneville basin and surrounding areas (e.g., Grayson 2000; Kiahtipes 2009; Louderback and Rhode 2009; Schmitt et al. 2004). Akin to other areas of the Great Basin, the Bonneville basin experienced lower lake levels and the replacement of mesic adapted flora and fauna by more xeric adapted species beginning near the end of the early Holocene (ca. 8,500 ^{14}C yr BP). By the early middle Holocene, the ORB began to resemble its present-day desiccated landscape more than its early

Holocene marshland environment (Grayson 2011; Schmitt et al. 2007). Like the modifications to adaptive strategies necessary during this period in the rest of the Great Basin, this environmental shift likely led to shifts in land-use strategies across these two periods.

Human Adaptation and Archaeology

Similar to the division between early Holocene and middle Holocene climate and environments in the ORB, the prehistoric occupation of the basin can be separated into two broad time periods: the Pre-archaic (ca. 12,500-8,000 ^{14}C yr BP) and the Archaic (ca. 8,000-4,500 ^{14}C yr BP). In the previous chapter, differences in forager behavior between these two periods were discussed as evidenced by changes in prehistoric subsistence strategies, settlement patterning, and mobility. These differences have been observed throughout the Great Basin and several Bonneville basin studies have served to characterize the distinctions between Pre-archaic and Archaic adaptive strategies there. Hockett (2007) saw decreases in dietary diversity at Bonneville Estates Rockshelter, Madsen (2007) reported increased use of upland areas, and Schmitt et al. (2004) observed a shift towards increased exploitation of smaller game. Patterns in the character and distribution of lithic assemblages in the ORB provide an additional avenue to better understand prehistoric behavior within the region.

A rich and relatively well-preserved archaeological record is contained within the ORB (Grayson 2011; Page 2008). While cave and rockshelter sites (e.g., Danger Cave, Camels Back Cave, Bonneville Estates Rockshelter) are found nearby, open-air lithic scatters dominate the archaeology of the area (Oviatt et al. 2003). Pre-archaic sites in the ORB are perceived to be predominately located along channel margins or within channels themselves (Madsen et al. 2015a, Oviatt et al. 2003, Schmitt et al. 2007). While most sites appear to be associated with the channels, others have been found beyond channel margins on the surrounding mudflats and delta (Oviatt et al. 2003; Page 2008; Schmitt et al. 2007). Madsen et al. (2015a) suggest that these sites may be pre-Gilbert highstand in age (>10,500 ^{14}C yr BP) and were once associated with channels scoured by Gilbert highstand wave action and ultimately deflated to the mudflat level. Alternatively, Oviatt et al. (2003) explain these off-channel sites as the result of resource procurement activities conducted away from dry ground, directly within the ORB wetlands. Despite the presence of Pre-archaic sites in areas that were likely inundated by a wetland, the association of early sites and ORB channels may be informative regarding the adaptive strategies of Pre-archaic populations. Specifically, several researchers have linked ORB site patterning to pedestrian travel restrictions imposed by wetlands that confined Pre-archaic populations to the dry ground of the inverted channels. Page and Duke (2015:11) suggest that "access to portions of the [ORB] delta may have been geographically restricted by a large body of water to the north and west and deltaic wetlands to the south and east." Madsen et al. (2015a) support this proposal by suggesting that during the ORB's early marshland period, topographically inverted gravel channels may have been the only dry land available. Based on the locations of archaeological sites in the ORB, Oviatt et al. (2003:206) conclude that "it is clear that sites were placed so as to take advantage of relatively higher and dryer ground within the wetland system." Schmitt et al. (2007) also see the association between Pre-archaic sites and ORB channels as indicative of channel use as high ground from which marshland resources were exploited. Pre-archaic lithic assemblages within the ORB, which are typically characterized by high tool-to-debitage ratios and relatively small and extensively reworked projectile points and other formal tools, support the model that prehistoric foragers during this period were restricted to the channel system and that forays outside of the basin to procure toolstone were infrequent (Schmitt et al. 2007).

Many ORB sites include temporally diagnostic projectile points (Oviatt et al. 2003; Page 2008; Schmitt et al. 2007). Points associated with Pre-archaic occupations in the ORB are commonly referred to as Western Stemmed Tradition or Great Basin Stemmed (GBS) points. These points include Cougar Mountain, Parman, Lake Mojave, Haskett, and Silver Lake types (Beck and Jones 2015; Duke 2011; Grayson 2011) (Figure 2.4). While GBS points display morphological variability, similarities have led many researchers to incorporate them into a single technological tradition (Beck and Jones 1997). Radiocarbon dates from sites across the Great Basin indicate that GBS points were used between ca. 11,500 and 7,500 ^{14}C yr BP, with most postdating ca. 10,000 ^{14}C yr BP (Beck and Jones 1997, but see Goebel and Keene 2014). Although often associated with the later Archaic period (e.g., Holmer 1986; Thomas 1981), evidence suggests that Pinto points occurred in the eastern Great Basin prior to ca. 8,000 ^{14}C yr BP (Schmitt et al. 2007) and possibly as early as or earlier than ca. 9,000 ^{14}C yr BP (Oviatt et al. 2003). The results of obsidian hydration analysis of a sample of GBS and Pinto points from the ORB show no significant difference between hydration values of the two types, supporting their contemporaneity in the eastern Great Basin (Duke 2011). Some researchers (e.g., Aikens 1970; Beck 1995; Holmer 1986) have suggested that Elko points may also have been used as early as 8,000 ^{14}C yr BP; however, the majority of evidence from the eastern Great Basin place their occurrence later than this – generally between ca. 4,000 and 1,000 ^{14}C yr BP (Duke 2011; Grayson 2011; Thomas 1981, 1983). Thus, they are considered here to be diagnostic of the Archaic period.

Projectile points diagnostic of the later Archaic period (ca. 8,000-1,000 ^{14}C yr BP) include Gatecliff, Elko, Rosegate, Humboldt and both Rocker and Northern Side-notched series points (Page 2008; Thomas 1981) (Figure 2.5). Duke's (2011) obsidian hydration analysis of ORB projectile points showed a clear distinction between hydration values of some of these later types and those of GBS and Pinto points (see Duke 2011: Figure 13). The temporal distributions of these Archaic point types vary regionally but throughout the Great Basin they all postdate the desiccation of the ORB ca. 8,000 ^{14}C yr BP (Holmer 1986; Thomas 1981). The point types described above allow sites containing them to be assigned to the two periods defined in this study: (1) the Pre-archaic (i.e., the TP/EH, pre-8,000 ^{14}C yr BP); and (2) the Archaic (i.e., the middle and late Holocene, post-8,000 ^{14}C yr BP). While these time periods are very coarse-grained, they are nevertheless sufficient to test the hypothesis presented in Chapter 1 by comparing site location, stone tool attributes, and decisions regarding raw material procurement between the two periods. The methods used in these comparisons are outlined in detail in Chapter 3.

The Current Study

A total of 226 archaeological sites were selected for spatial analysis. These sites were recorded during systematic survey of the study area conducted by Desert Research Institute over eight field seasons between 2003 and 2010 (Figure 2.6). As part of the recording process, sites were assigned to temporal periods when diagnostic projectile points (or other time sensitive artifact classes) were noted. The sites selected for analysis contain such artifacts, allowing them to be assigned to either the Pre-archaic or Archaic periods. Additional site selection criteria included the availability of data regarding biface reduction stages and stone-tool-to-debitage ratios (Table 2.1). Also, 303 ORB projectile points (251 Pre-archaic and 52 Archaic) were selected for the analysis of spatial patterning associated with projectile point weights (Table 2.2). Lastly, 250 geochemically sourced artifacts (235 Pre-archaic and 15 Archaic) were selected for use in the analysis of raw material procurement practices (see Table 2.1).

Summary

The ORB once represented one of the richest marshland environments in the Great Basin. The middle Holocene desiccation of this once prosperous environment is exemplary of changes that took place during this period throughout the region and the associated shifts in adaptive strategies observed in other areas most certainly occurred in the ORB as well. The analysis of materials from the ORB, including archaeological site locations, lithic assemblage attributes, and raw material sourcing data as they relate to the region's geomorphology and climatic shifts, provides an exceptional opportunity to test for changes in the behaviors of prehistoric foragers in a unique and dynamic Great Basin environment. Specifically, analyses of these variables can be used to test the generally accepted hypothesis that Pre-archaic foragers used inverted channels as travel corridors into and throughout the ORB during its marshland period. Conversely, Archaic visitors did not face such travel constraints. While a reasonable model based on considerable geomorphological evidence, this hypothesis has not been rigorously evaluated using archaeological data and GIS- and lithic-based approaches. In Chapter 3, I outline the methods that I applied to the materials described here.

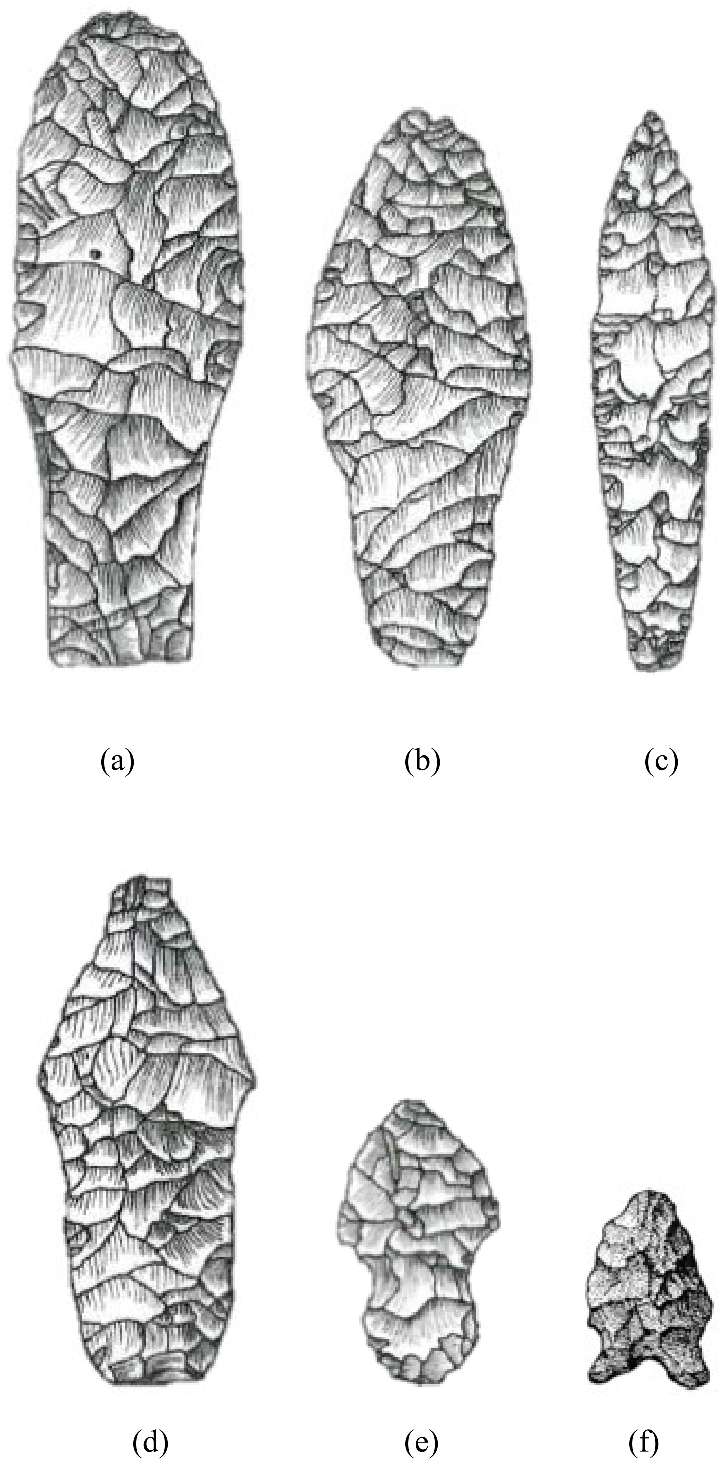

Figure 2.4. Projectile points diagnostic of the Pre-archaic period: (a) Cougar Mountain, 8.6 cm; (b) Parman, 6.9 cm; (c) Haskett, 6.6 cm; (d) Lake Mohave 5.8 cm; (e) Silver Lake, 4.1 cm; (f) Pinto, 3.1 cm. Measurements indicate the length of specimens; (a-e) after Grayson (2011) and (f) after Basgall and Hall (2000).

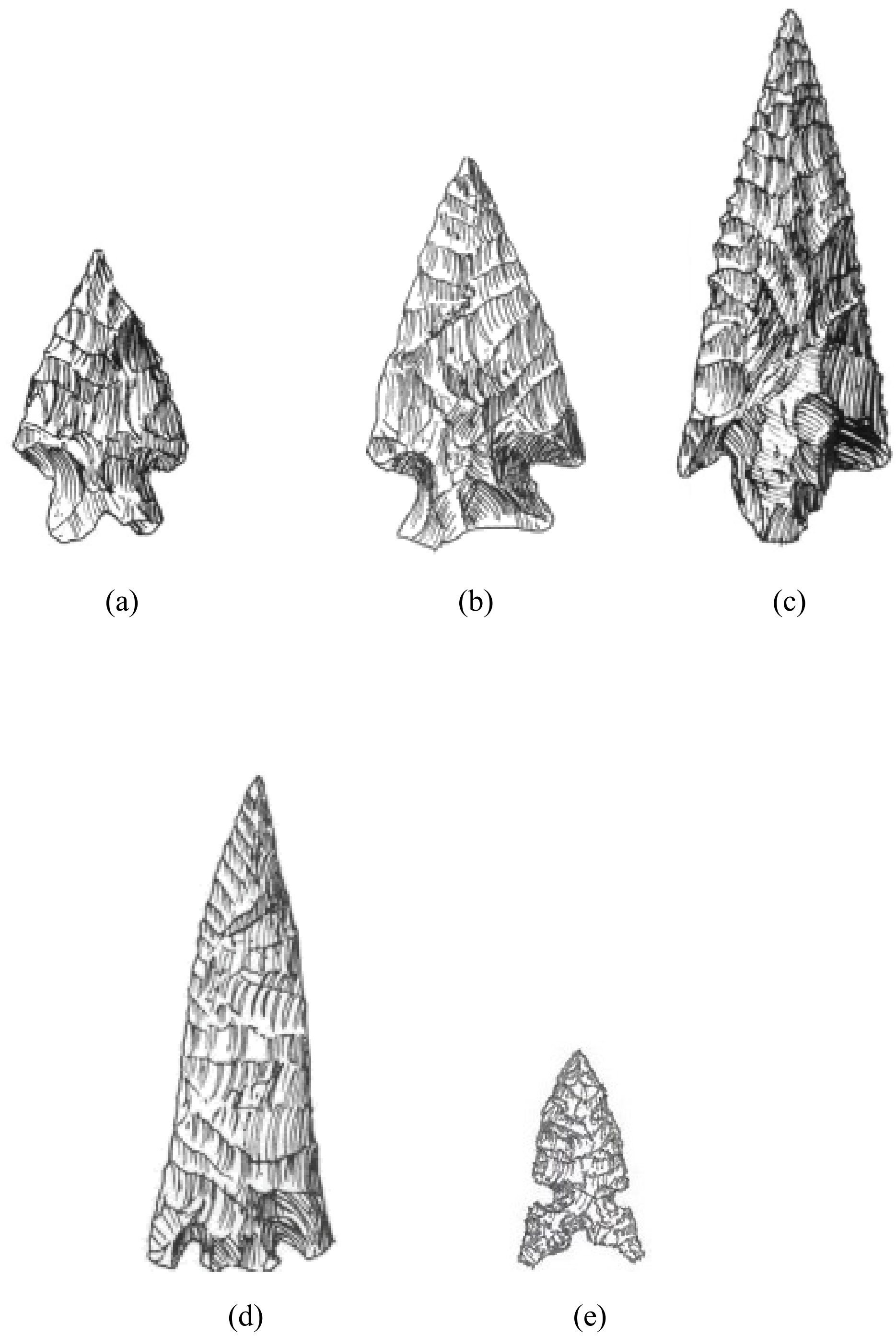

Figure 2.5. Projectile points diagnostic of the Archaic period: (a) Elko Eared 3.8 cm; (b) Elko Corner-notched, 5.1 cm; (c) Gatecliff Contracting Stem, 4.9 cm; (d) Rosegate 5.1 cm; (e) Desert Side-notched 2.5 cm; Measurements indicate the length of specimens; (a-d) after Thomas (1985) and (e) illustrated by Mike Wolverton (2014).

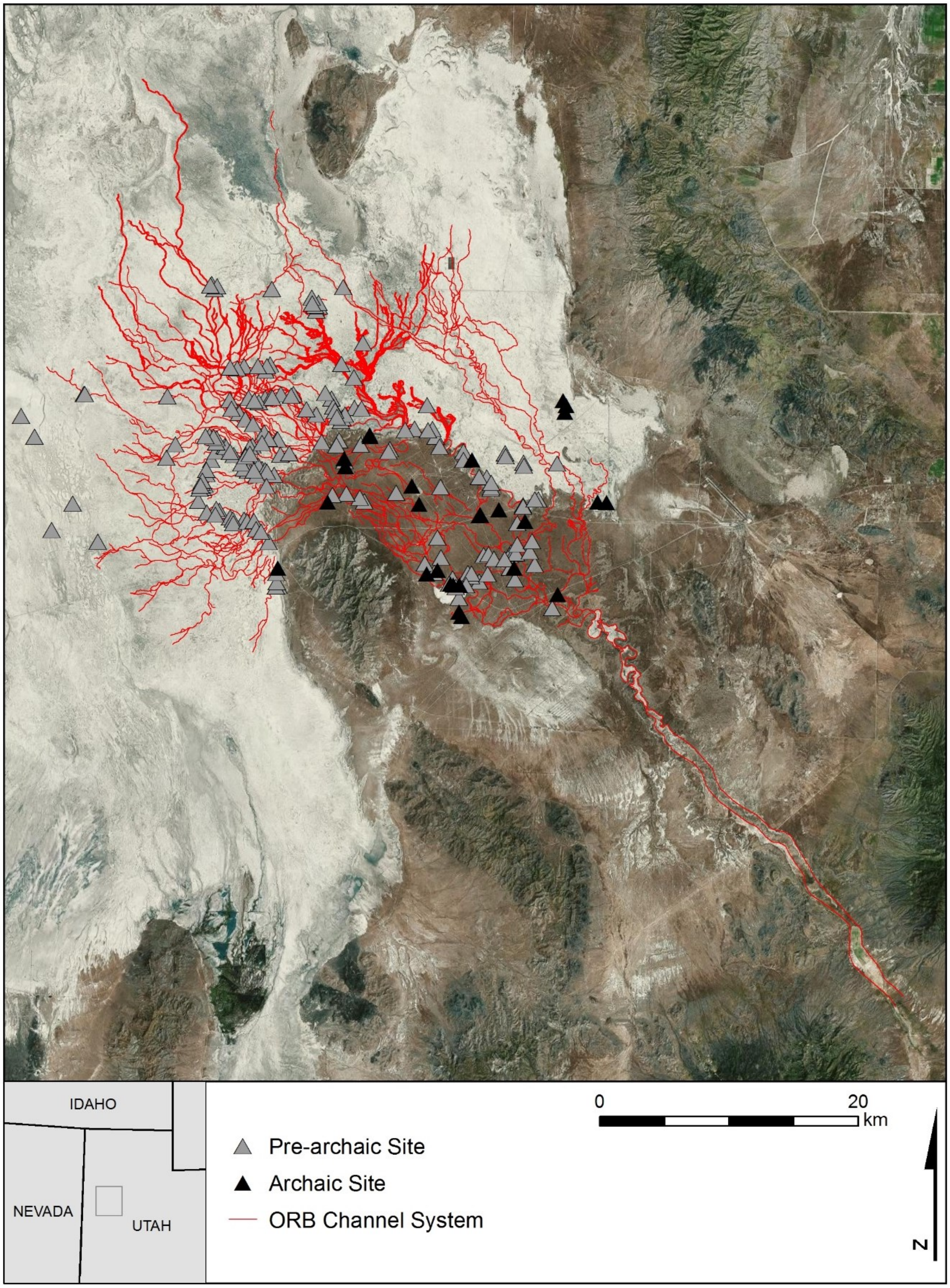

Figure 2.6. Satellite image showing the location of all archaeological sites included for analysis in this study and the ORB channel system. Data Source: David Page, DRI. Image source: ESRI.

Table 2.1. ORB Sites Selected for Analysis in this Study.

Site Number	Time Period			Reduction Stages	Tool/Debitage Ratios	Raw Material Sourcing
	Pre-archaic	Archaic	Multicomponent			
04-DM-03	x			+		
04-DM-04	x			+		
04-DM-05	x			+		
05-ORB-10	x			+		
07DM07	x			+	+	
07DP03	x			+		
08-DM-01	x			+		
08-DM-02	x			+		
08-DM-03	x			+		
08-DM-04	x			+		
08-DM-05	x			+		
08-DM-06	x			+		
08-DM-07	x			+		
08-DM-09	x			+		
08-DM-10	x			+		
08-DM-11	x			+		
08-DM-12	x			+		
08-DM-13	x			+		
08-DM-14	x			+		
08-DM-27	x			+		
08-DM-28	x			+		
08-DM-28	x			+		
08-DM-29	x			+		
08-DM-30	x			+		
08-DM-31	x			+		
08-DM-32	x			+		
08-DM-33	x			+		
08-DM-34	x			+		
42To0379		x				
42To0395		x				
42To0822		x				
42To1000	x			+		+
42To1152	x			+		+
42To1153	x			+		+
42To1157	x			+		
42To1161	x			+		+
42To1163	x			+		
42To1172	x			+		
42To1173			x			
42To1177	x			+		
42To1178	x			+		
42To1182	x			+		+
42To1183		x		+		

Site Number	Time Period			Reduction Stages	Tool/Debitage Ratios	Raw Material Sourcing
	Pre-archaic	Archaic	Multicomponent			
42To1195	x			+	+	
42To1352	x			+		
42To1353	x			+		
42To1354	x			+		
42To1357	x			+		
42To1358	x			+		+
42To1359	x			+		
42To1367	x			+		+
42To1368	x			+		
42To1369	x			+		
42To1370	x			+		+
42To1371	x			+		
42To1383	x			+		
42To1523	x			+	+	
42To1523		x		+		
42To1542			x			
42To1543b	x			+	+	
42To1666			x			
42To1668	x			+		
42To1669	x			+		+
42To1671	x			+		+
42To1672	x			+		
42To1673	x			+		
42To1674	x			+	+	+
42To1676	x			+	+	
42To1677	x			+	+	
42To1678	x			+		+
42To1679	x			+		
42To1681	x			+		+
42To1682	x			+	+	
42To1683	x			+		+
42To1684	x			+		+
42To1685	x			+		+
42To1686	x			+		+
42To1687	x			+	+	+
42To1688	x			+		+
42To1689	x			+		
42To1859	x			+		+
42To1861	x			+		+
42To1862	x			+		+
42To1872	x			+		+
42To1873	x			+		+
42To1874	x			+		+
42To1875	x			+		+
42To1876	x			+	+	+
42To1877	x			+	+	

Site Number	Time Period			Reduction Stages	Tool/Debitage Ratios	Raw Material Sourcing
	Pre-archaic	Archaic	Multicomponent			
42To1878	x			+		+
42To1920	x			+		
42To1921	x			+		+
42To1922	x			+		+
42To1923	x			+	+	
42To1924	x			+		+
42To1961		x		+		
42To1964		x		+		+
42To2141	x			+	+	
42To2145	x			+		+
42To2146	x			+		+
42To2148	x			+		
42To2149		x		+		
42To2152	x			+		+
42To2170		x		+		+
42To2172	x			+		+
42To2173		x		+		+
42To2177		x		+		
42To2345		x		+		
42To2346	x			+		
42To2349		x		+		+
42To2352	x			+		
42To2551	x			+		+
42To2552	x			+		
42To2553	x			+		+
42To2554	x			+	+	+
42To2555	x			+		+
42To2556			x			
42To2557	x			+		+
42To2558	x			+		+
42To2767	x			+		+
42To2855			x			
42To2943	x			+	+	+
42To2944	x			+		+
42To2945	x			+		+
42To2946	x			+		+
42To2947	x			+		+
42To2948	x			+	+	+
42To2949	x			+	+	+
42To2951	x			+	+	+
42To2952	x			+	+	+
42To2953	x			+	+	
42To2954	x			+	+	
42To2955	x			+		
42To2957	x			+	+	
42To3140	x			+	+	

Site Number	Time Period			Reduction Stages	Tool/Debitage Ratios	Raw Material Sourcing
	Pre-archaic	Archaic	Multicomponent			
42To3141	x			+	+	
42To3142	x			+	+	
42To3144	x			+	+	
42To3145	x			+	+	
42To3148	x			+	+	
42To3149	x			+	+	
42To3150	x			+	+	
42To3156		x				
42To3158		x				
42To3159		x				
42To3170	x			+		
42To3171		x		+		
42To3178	x			+		
42To3219	x			+		
42To3220	x			+	+	
42To3221	x			+	+	
42To3222	x			+	+	
42To3223	x			+		
42To3224	x			+	+	
42To3225	x			+	+	
42To3226	x			+	+	
42To3227	x			+	+	
42To3228	x			+	+	
42To3229	x			+	+	
42To3230	x			+	+	
42To3231	x			+	+	
42To3232	x			+	+	
42To3233	x			+	+	
42To3234	x			+	+	
42To3235	x			+	+	
42To3236	x			+	+	
42To3237	x			+	+	
42To3238	x			+	+	
42To3239	x			+	+	
42To3301	x			+	+	
42To3475	x			+	+	
42To3503	x			+		
42To3520	x			+	+	
42To3521	x			+	+	
42To3522	x			+	+	
42To3646	x			+	+	
42To3647		x				
42To3733	x			+	+	
42To3736	x			+	+	
42To3746		x		+		
42To3747		x				

Site Number	Time Period			Reduction Stages	Tool/Debitage Ratios	Raw Material Sourcing
	Pre-archaic	Archaic	Multicomponent			
42To3769	x			+	+	
42To3827	x			+		
42To3828			x			
42To3829		x		+		
42To3830		x		+		
42To3831	x			+		
42To3834			x			
42To3837			x			
42To3846	x			+		
42To3847	x			+		
42To3850		x		+		
42To3852	x			+		
42To3853	x			+		
42To3854	x			+		
42To3855	x			+		
42To3856			x			
42To3857	x			+		
42To3858	x			+		
42To3909	x			+		
42To3925	x			+		
42To3926		x		+		
42To3928		x		+		
42To3930	x			+		
42To3932			x			
42To3933	x			+		
42To3935			x			
42To3936	x			+		
42To3938	x			+		
42To3941	x			+		
42To3942	x			+		
42To3943	x			+		
42To3944		x		+		
42To3945	x			+		
42To3946	x			+		
42To3948	x			+		
42To3951	x			+		
42To3952		x		+		
42To3954	x			+		
42To3955	x			+		
42To4122			x			
42To4125		x		+		
42To4231	x			+	+	
42To4233	x			+	+	
42To4234	x			+	+	
42To4239	x			+	+	
42To4242		x		+		

Site Number	Time Period			Reduction Stages	Tool/Debitage Ratios	Raw Material Sourcing
	Pre-archaic	Archaic	Multicomponent			
42To4944	x			+		
42To4950		x		+		
42To5140	x			+		

Note: Sites with "+" indicate the presence of specified data.

Table 2.2. ORB Projectile Points Selected for Analysis in this Study.

Site Number	FS Number	PPT Type	Weight (g)	Temporal Association
04DM02	2	Cougar Mountain	9.71	Pre-archaic
04DM03	1	Cougar Mountain	23.58	Pre-archaic
42To1875	24	Lake Mohave	8.92	Pre-archaic
08DM30	1	Cougar Mountain	34.5	Pre-archaic
42To0385	3	Lake Mohave	5.86	Pre-archaic
42To1000	16	Silver Lake	3.31	Pre-archaic
42To1000	25	Silver Lake	4.83	Pre-archaic
42To1153	21	Cougar Mountain	4.86	Pre-archaic
42To1157	1	Cougar Mountain	2.46	Pre-archaic
42To1161	1	Lake Mohave	2.68	Pre-archaic
42To1166	1	Silver Lake	3.01	Pre-archaic
42To1177	4	Pinto	2.86	Pre-archaic
42To1182	3	Lake Mohave	3.2	Pre-archaic
42To1354	9	Cougar Mountain	6.49	Pre-archaic
42To1358	26	Lake Mohave	5.7	Pre-archaic
42To1370	9	Cougar Mountain	10.35	Pre-archaic
42To1371	59	Parman	2.79	Pre-archaic
42To1371	32	Pinto	2.56	Pre-archaic
42To1371	43	Silver Lake	3.97	Pre-archaic
42To1371	56	Silver Lake	7.68	Pre-archaic
42To1371	90	Silver Lake	1.91	Pre-archaic
42To1668	9	Pinto	4.18	Pre-archaic
42To1671	6	Haskett	11.6	Pre-archaic
42To1674	1	Silver Lake	5.08	Pre-archaic
42To1677	13	Pinto	2.71	Pre-archaic
42To1678	11	Pinto	2.2	Pre-archaic
42To1678	9	Pinto	3.24	Pre-archaic
42To1678	12	Silver Lake	4.81	Pre-archaic
42To1679	5	Parman	7.26	Pre-archaic

Site Number	FS Number	PPT Type	Weight (g)	Temporal Association
42To1679	7	Pinto	1.92	Pre-archaic
42To1679	4	Silver Lake	4.33	Pre-archaic
42To1681	3	Pinto	1.11	Pre-archaic
42To1683	4	Cougar Mountain	4.45	Pre-archaic
42To1683	12	Silver Lake	1.96	Pre-archaic
42To1683	8	Silver Lake	2.98	Pre-archaic
42To1685	11	Parman	6.72	Pre-archaic
42To1685	34	Silver Lake	3.5	Pre-archaic
42To1685	36	Silver Lake	2.68	Pre-archaic
42To1685	32	Silver Lake	3.4	Pre-archaic
42To1685	5	Silver Lake	3.96	Pre-archaic
42To1686	36	Lake Mohave	6.64	Pre-archaic
42To1686	16	Lake Mohave	3.81	Pre-archaic
42To1686	53	Lake Mohave	3.43	Pre-archaic
42To1686	5	Lake Mohave	1.48	Pre-archaic
42To1686	26	Lake Mohave	2.81	Pre-archaic
42To1686	72	Pinto	1.72	Pre-archaic
42To1687	8	Lake Mohave	2.55	Pre-archaic
42To1687	10	Silver Lake	5.53	Pre-archaic
42To1687	3	Silver Lake	2.36	Pre-archaic
42To1687	5	Silver Lake	1.69	Pre-archaic
42To1688	49	Parman	4.41	Pre-archaic
42To1688	2	Silver Lake	5.1	Pre-archaic
42To1688	11	Silver Lake	3.01	Pre-archaic
42To1688	13	Silver Lake	1.68	Pre-archaic
42To1688	32	Silver Lake	2.35	Pre-archaic
42To1689	3	Pinto	2.26	Pre-archaic
42To1859	5	Lake Mohave	3.88	Pre-archaic
42To1859	3	Pinto	2.26	Pre-archaic
42To1861	7	Silver Lake	3.2	Pre-archaic
42To1872	29	Lake Mohave	3.67	Pre-archaic
42To1872	13	Lake Mohave	3.4	Pre-archaic
42To1872	19	Parman	2.92	Pre-archaic
42To1872	4	Silver Lake	6.12	Pre-archaic
42To1872	49	Silver Lake	7.79	Pre-archaic
42To1872	37	Silver Lake	3.48	Pre-archaic
42To1873	1	Lake Mohave	4.29	Pre-archaic
42To1873	20	Parman	6.86	Pre-archaic
42To1873	17	Parman	2.32	Pre-archaic
42To1873	25	Silver Lake	6.24	Pre-archaic

Site Number	FS Number	PPT Type	Weight (g)	Temporal Association
42To1876	9	Lake Mohave	6.63	Pre-archaic
42To1878	14	Cougar Mountain	16.71	Pre-archaic
42To1878	11	Silver Lake	3.12	Pre-archaic
42To1921	9	Silver Lake	8.97	Pre-archaic
42To1922	10	Silver Lake	4.43	Pre-archaic
42To1924	13	Lake Mohave	4.19	Pre-archaic
42To1924	102	Silver Lake	3.62	Pre-archaic
42To1924	120	Silver Lake	2.39	Pre-archaic
42To2551	30	Cougar Mountain	80.5	Pre-archaic
42To2551	15	Silver Lake	7.29	Pre-archaic
42To2552	1	Lake Mohave	4.63	Pre-archaic
42To2552	4	Pinto	2.26	Pre-archaic
42To2552	12	Silver Lake	5.87	Pre-archaic
42To2554	12	Pinto	3.34	Pre-archaic
42To2554	44	Silver Lake	6.03	Pre-archaic
42To2554	6	Silver Lake	3.92	Pre-archaic
42To2554	7	Silver Lake	2.92	Pre-archaic
42To2555	4	Silver Lake	2.58	Pre-archaic
42To2556	23	Parman	5.61	Pre-archaic
42To2557	1	Silver Lake	3.34	Pre-archaic
42To2558	8	Lake Mohave	2.55	Pre-archaic
42To2558	3	Silver Lake	3.54	Pre-archaic
42To2558	7	Silver Lake	2.15	Pre-archaic
42To2558	9	Silver Lake	2.15	Pre-archaic
42To2559	52	Parman	2.9	Pre-archaic
42To2559	72	Silver Lake	5.09	Pre-archaic
42To2559	23	Silver Lake	4.72	Pre-archaic
42To2559	25	Silver Lake	4.53	Pre-archaic
42To2559	46	Silver Lake	3.31	Pre-archaic
42To2559	59	Silver Lake	3.02	Pre-archaic
42To2767	25	Lake Mohave	2.36	Pre-archaic
42To2767	19	Silver Lake	3.25	Pre-archaic
42To2944	5	Silver Lake	3.98	Pre-archaic
42To2945	17	Pinto	3.04	Pre-archaic
42To2945	36	Pinto	1.17	Pre-archaic
42To2945	30	Silver Lake	1.91	Pre-archaic
42To2945	1	Silver Lake	4.19	Pre-archaic
42To2945	10	Silver Lake	4.18	Pre-archaic
42To2946	6	Silver Lake	2.6	Pre-archaic
42To2947	6	Pinto	2.08	Pre-archaic

Site Number	FS Number	PPT Type	Weight (g)	Temporal Association
42To2948	6	Lake Mohave	5.78	Pre-archaic
42To2948	1	Silver Lake	2.82	Pre-archaic
42To2949	18	Lake Mohave	5.99	Pre-archaic
42To2949	25	Silver Lake	3.08	Pre-archaic
42To2949	26	Silver Lake	5.46	Pre-archaic
42To2951	17	Silver Lake	4.76	Pre-archaic
42To2951	26	Silver Lake	2.92	Pre-archaic
42To2952	13	Lake Mohave	4.87	Pre-archaic
42To2955	5	Cougar Mountain	18.84	Pre-archaic
42To3140	11	Haskett	10.6	Pre-archaic
42To3141	6	Pinto	2.57	Pre-archaic
42To3142	24	Haskett	7.1	Pre-archaic
42To3219	38	Parman	3.73	Pre-archaic
42To3219	54	Parman	10.04	Pre-archaic
42To3219	65	Parman	4.07	Pre-archaic
42To3219	59	Pinto	3.52	Pre-archaic
42To3219	50	Pinto	2.82	Pre-archaic
42To3223	18	Pinto	2.61	Pre-archaic
42To3226	8	Silver Lake	2.09	Pre-archaic
42To3228	5	Parman	3.96	Pre-archaic
42To3228	2	Silver Lake	3.39	Pre-archaic
42To3228	6	Silver Lake	4.98	Pre-archaic
42To3229	19	Silver Lake	3.09	Pre-archaic
42To3230	1	Cougar Mountain	13.34	Pre-archaic
42To3230	85	Parman	4.14	Pre-archaic
42To3230	71	Pinto	2.47	Pre-archaic
42To3230	52	Pinto	1.41	Pre-archaic
42To3230	94	Pinto	4.25	Pre-archaic
42To3230	5	Silver Lake	4.51	Pre-archaic
42To3230	113	Silver Lake	3.93	Pre-archaic
42To3230	59	Silver Lake	4.94	Pre-archaic
42To3230	92	Silver Lake	6.4	Pre-archaic
42To3230	46	Silver Lake	2.66	Pre-archaic
42To3230	84	Silver Lake	3.4	Pre-archaic
42To3230	97	Silver Lake	2.66	Pre-archaic
42To3231	7	Silver Lake	4.44	Pre-archaic
42To3233	23	Silver Lake	2.79	Pre-archaic
42To3233	19	Silver Lake	2.89	Pre-archaic
42To3233	26	Silver Lake	2.89	Pre-archaic
42To3234	15	Cougar Mountain	12.99	Pre-archaic

Site Number	FS Number	PPT Type	Weight (g)	Temporal Association
42To3234	21	Haskett	5.14	Pre-archaic
42To3234	28	Pinto	3.5	Pre-archaic
42To3234	10	Silver Lake	2.95	Pre-archaic
42To3234	32	Silver Lake	1.77	Pre-archaic
42To3235	109	Silver Lake	5.95	Pre-archaic
42To3235	23	Silver Lake	1.89	Pre-archaic
42To3235	56	Silver Lake	3.64	Pre-archaic
42To3237	32	Pinto	2.32	Pre-archaic
42To3237	56	Pinto	1.88	Pre-archaic
42To3237	58	Pinto	3.35	Pre-archaic
42To3237	44	Silver Lake	1.98	Pre-archaic
42To3237	16	Silver Lake	3.53	Pre-archaic
42To3237	29	Silver Lake	2.35	Pre-archaic
42To3237	4	Silver Lake	2.62	Pre-archaic
42To3237	42	Silver Lake	2.57	Pre-archaic
42To3237	75	Silver Lake	3.74	Pre-archaic
42To3237	77	Silver Lake	3.67	Pre-archaic
42To3237	79	Silver Lake	2.82	Pre-archaic
42To3238	18	Silver Lake	3.18	Pre-archaic
42To3238	27	Silver Lake	5.48	Pre-archaic
42To3238	25	Silver Lake	2.36	Pre-archaic
42To3520	12	Haskett	9.84	Pre-archaic
42To3520	43	Haskett	28.78	Pre-archaic
42To3520	37	Haskett	23.24	Pre-archaic
42To3520	16	Pinto	2.55	Pre-archaic
42To3522	12	Haskett	16.3	Pre-archaic
42To3522	7	Pinto	3.06	Pre-archaic
42To3522	2	Silver Lake	3.68	Pre-archaic
DPGIF	847	Cougar Mountain	9.99	Pre-archaic
DPGIF	735	Lake Mohave	5.68	Pre-archaic
DPGIF	885	Lake Mohave	5.63	Pre-archaic
DPGIF	380	Lake Mohave	6.35	Pre-archaic
DPGIF	521	Lake Mohave	4.35	Pre-archaic
DPGIF	479	Lake Mohave	3.79	Pre-archaic
DPGIF	624	Parman	8.3	Pre-archaic
DPGIF	208	Parman	4.08	Pre-archaic
DPGIF	526	Pinto	2.48	Pre-archaic
DPGIF	811	Pinto	1.38	Pre-archaic
DPGIF	876	Pinto	6.94	Pre-archaic
DPGIF	867	Pinto	4.16	Pre-archaic

Site Number	FS Number	PPT Type	Weight (g)	Temporal Association
DPGIF	902	Silver Lake	6.39	Pre-archaic
DPGIF	381	Silver Lake	3.92	Pre-archaic
DPGIF	452	Silver Lake	3.65	Pre-archaic
DPGIF	457	Silver Lake	5.09	Pre-archaic
DPGIF	686	Silver Lake	3.22	Pre-archaic
DPGIF	733	Silver Lake	4.62	Pre-archaic
DPGIF1169	-	Parman	6.99	Pre-archaic
DPGIF1932	-	Pinto	1.73	Pre-archaic
DPGIF1942	-	Haskett	27.12	Pre-archaic
DPGIF1946	-	Silver Lake	6.83	Pre-archaic
DPGIF2412	3	Silver Lake	5.44	Pre-archaic
DPGIF2414	1	Parman	5.2	Pre-archaic
DPGIF2415	1	Parman	25.75	Pre-archaic
DPGIF2447	-	Pinto	17.43	Pre-archaic
DPGIF2452	-	Cougar Mountain	37.18	Pre-archaic
DPGIF2453	-	Haskett	17.97	Pre-archaic
DPGIF2527	-	Cougar Mountain	30.49	Pre-archaic
DPGIF2529	-	Cougar Mountain	35.49	Pre-archaic
ISO-7	5	Lake Mohave	4.67	Pre-archaic
ISO-8	6	Silver Lake	3.46	Pre-archaic
42To1000	22	Rosegate	0.58	Archaic
42To1000	30	Rosegate	2.47	Archaic
42To1172	19	Elko	3.39	Archaic
42To1178	2	Humboldt	1.26	Archaic
42To1182	13	Humboldt	1.99	Archaic
42To1352	3	Elko	0.98	Archaic
42To1358	65	Elko	2.32	Archaic
42To1358	10	Elko	2.14	Archaic
42To1358	86	Elko	1.33	Archaic
42To1358	33	Elko	0.86	Archaic
42To1358	45	Elko	2.39	Archaic
42To1358	56	Rocker Side-notched	1.81	Archaic
42To1358	70	Rocker Side-notched	4.26	Archaic
42To1358	14	Rosegate	1.18	Archaic
42To1358	25	Rosegate	1.31	Archaic
42To1359	6	Humboldt	2.19	Archaic
42To1367	2	Elko	3.31	Archaic
42To1367	1	Humboldt	1.99	Archaic
42To1384	2	Humboldt	1.45	Archaic
42To1666	9	Elko	3.88	Archaic

Site Number	FS Number	PPT Type	Weight (g)	Temporal Association
42To1672	4	Elko	2.68	Archaic
42To1685	39	Gatecliff	3.84	Archaic
42To1685	38	Humboldt	3.17	Archaic
42To1689	8	Elko	2.7	Archaic
42To1875	23	Elko	2.29	Archaic
42To2945	32	Elko	2.53	Archaic
42To2948	16	Rocker Side-notched	10.31	Archaic
42To2948	3	Small Side-notched	1.23	Archaic
42To3230	80	Elko	3.71	Archaic
42To3230	95	Elko	3.22	Archaic
42To3230	56	Elko	3.81	Archaic
42To3230	83	Humboldt	2.15	Archaic
42To3230	78	Humboldt	2.86	Archaic
DPGIF	209	Elko	2.43	Archaic
DPGIF	376	Elko	9.41	Archaic
DPGIF	869	Elko	3	Archaic
DPGIF	193	Elko	5.51	Archaic
DPGIF	836	Humboldt	1.69	Archaic
DPGIF	842	Humboldt	2.06	Archaic
DPGIF	478	NSN	1.82	Archaic
DPGIF	363	Rocker Side-notched	3.48	Archaic
DPGIF	319	Rocker Side-notched	3.03	Archaic
DPGIF	224	Rosegate	1.8	Archaic
DPGIF2413	1	Elko	9.04	Archaic

CHAPTER 3

Methods

This study utilizes lithic- and GIS-based methods of analysis to test current models of prehistoric mobility and land-use in the ORB of western Utah. In this chapter I outline the methods employed to analyze data used in this study – lithic assemblage and tool attributes, site and projectile point locations, and geochemical sourcing information – and present my expectations for the results as they relate to the hypothesis presented in Chapter 1.

Identifying Changes in Travel Constraints

Lithic-Based Statistical Analysis

Studies of prehistoric technological organization reviewed in Chapter 1 show that characteristics of lithic assemblages often change as distance from the sources of raw material from which they are made increases. The presence of time-sensitive projectile points at sites allows these changes in assemblage and tool characteristics to be compared between the Pre-archaic and Archaic occupations of the ORB. This comparison can reveal potential differences in mobility and land-use strategies implemented by prehistoric groups occupying the ORB during two periods of different environmental conditions.

To test the hypothesis that pedestrian travel was constrained by a wetland during the Pre-archaic period, I used several types of data from site forms (IMACS from DRI and DPG) and technical reports (Beck and Jones 2015; Page and Duke 2015) including the locations of archaeological sites and isolated projectile points in the proximal ORB. Site forms were generously provided by DRI and DPG staff. Starting with this initial sample, I excluded sites if they failed to meet certain criteria. For example, to facilitate comparison of changes in the attributes of ORB lithic assemblages and stone tools for the two periods, I only included single-component sites (i.e., those containing only Pre-archaic *or* only Archaic artifacts). Additionally, I excluded sites and isolated points recorded during surveys on DPG that were clearly not associated with the ORB.

I established an "entry point" into the basin at the approximate location that individual channels become distinguishable from one another (Figures 3.1 and 3.2). The separation of channels here suggests that this may be where Pre-archaic pedestrian travel along them initiated. This point was chosen based on the assumptions that: (1) with the presence of a wetland, most Pre-archaic forager activities would have been necessarily tethered to the raised channels (Schmitt et al. 2007); and (2) Pre-archaic groups would have had limited access into the basin (Page and Duke 2015). Using distance from a modeled ORB entry point as the independent variable, I employed Spearman's rank correlation coefficient (Spearman's rho) to compare the changes of three lithic assemblage and stone tool attributes – tool-to-debitage ratios, biface reduction stages, and projectile point weights – between the Pre-archaic and Archaic samples. These attributes were selected for analysis because they were generally described in site forms or technical reports and because previous studies have linked them to prehistoric mobility

(Andrefsky 2010; Beck et al. 2002, Eerkens et al. 2007, 2008; MacDonald 2008; Shott and Scott 1995). I implemented these analyses a second time using an alternative entry point established at the margin of the ORB delta itself (Figure 3.3). While the locations of Archaic sites (predominantly beyond the delta) preclude a comparison of assemblage attributes between the two periods, the placement of the alternative entry point at the delta margin allows for changes in Pre-archaic assemblage and projectile point attributes to be measured in an area where the potential restrictions of an ORB wetland are less questionable. The use of Spearman's rho allows for the statistical dependence between pairs of observations to be measured. The method is similar to other statistical measures of correlation, such as the Pearson product-moment correlation coefficient (Pearson's *r*), in that Spearman's rho provides a numerical expression of the statistical significance, or strength, of the relationship between an independent variable (distance from the entry point into the ORB) and a dependent variable (tool-to-debitage ratios, biface reduction stages, or projectile point weights). Unlike Pearson's *r*, however, Spearman's rho uses ordinal (ranked) data rather than interval or ratio scale data, and it does not necessitate a strictly linear relationship between variables for the presence of a statistically significance correlation. Rather, it provides a measure of a monotonic relationship between two variables, one in which either an increasing trend (the dependent variable increases as the independent variable increases) or a decreasing trend (the dependent variable decreases as the independent variable increases) is present. Further, because Spearman's rho requires data values to be assigned ordinal ranks, it is less sensitive than Pearson's *r* to the presence of outlying data points within a sample.

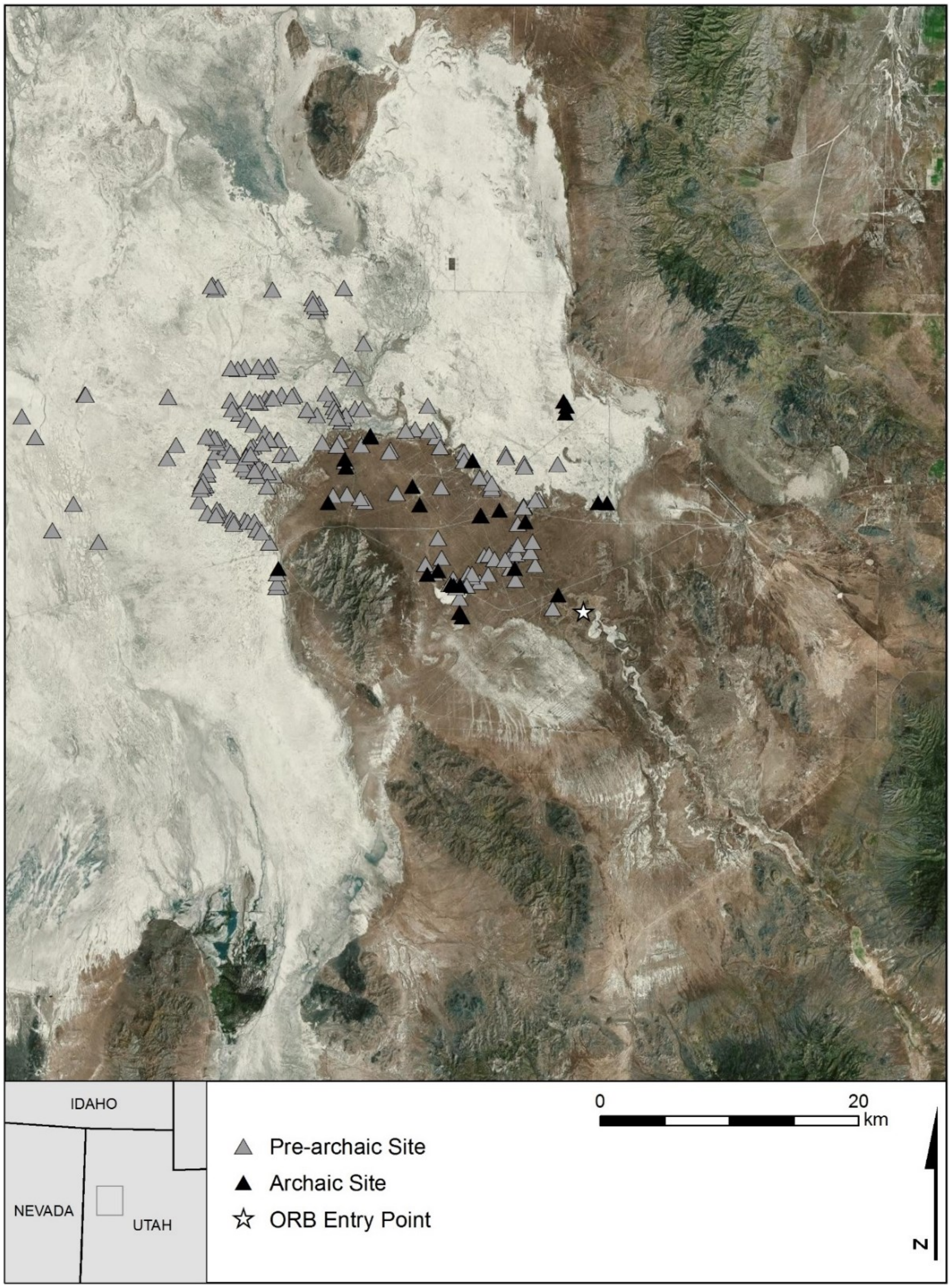

Figure 3.1. Satellite image showing the location of sites selected for analysis and the established entry point into the ORB. Data Source: David Page, DRI. Image Source: ESRI.

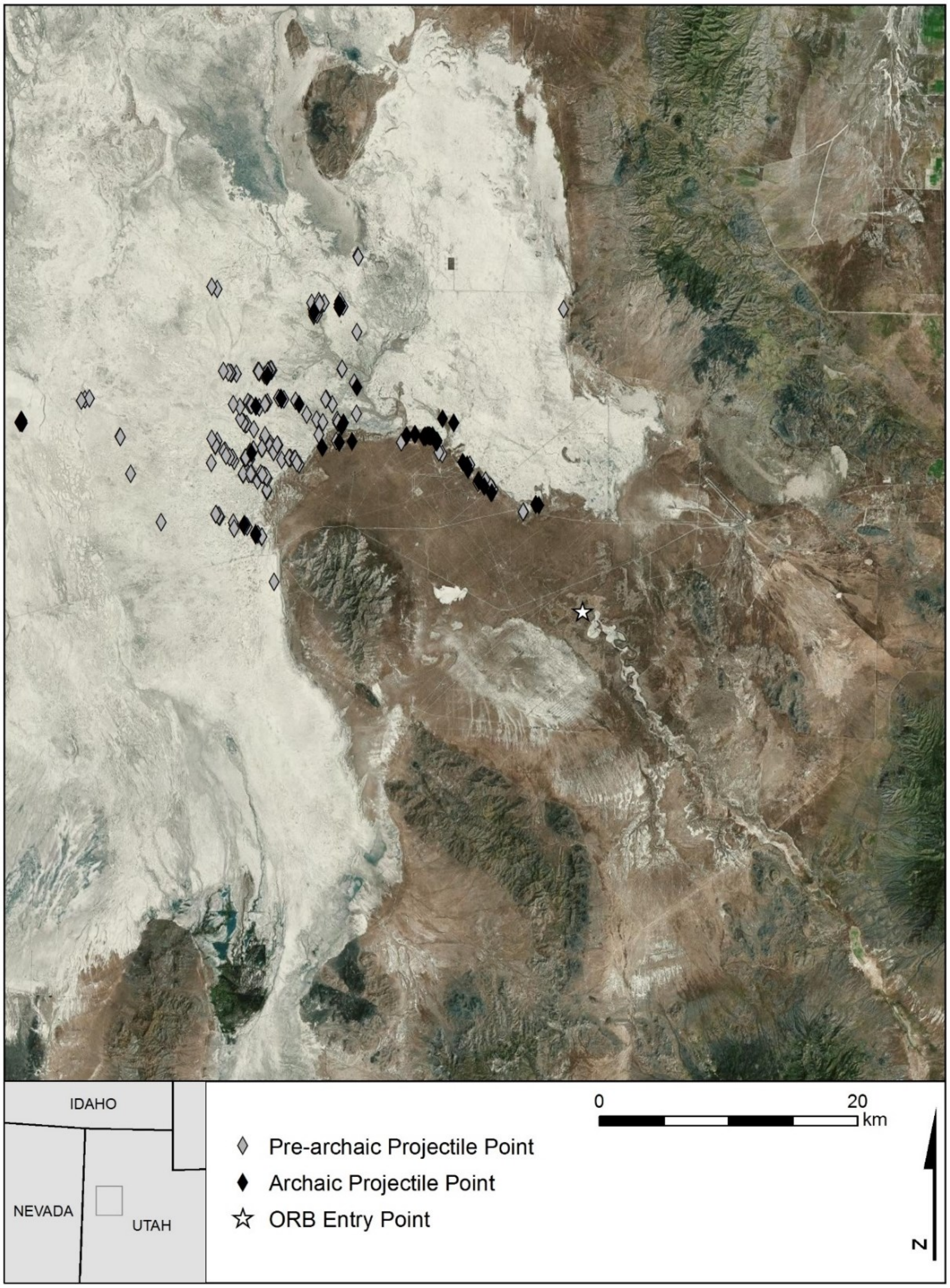

Figure 3.2. Satellite image showing the location of projectile points selected for analysis and the established entry point into the ORB. Data Source: DRI and Charlotte Beck. Image Source: ESRI.

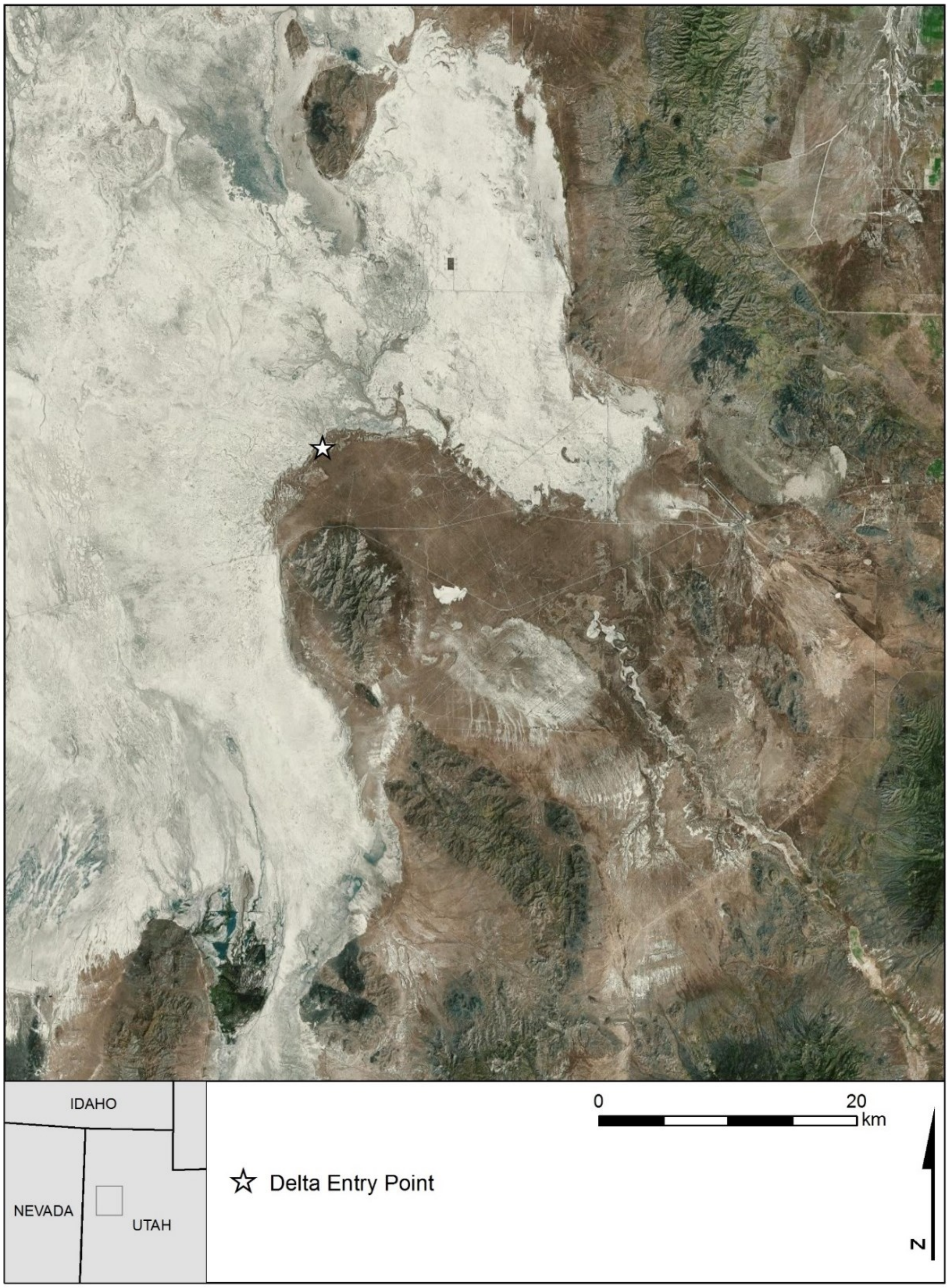

Figure 3.3. Satellite image showing the location of the delta entry point. Image Source: ESRI.

Distance-to-Channel Analyses

To further test the hypothesis that Pre-archaic travel in the ORB was largely restricted to higher ground (i.e., channels) whereas Archaic travel was not, I compared the locations of Pre-archaic and Archaic sites and projectile points as they relate to the inverted ORB channels. I included both single- and multi-component sites for these analyses. Multi-component sites were included in both the Pre-archaic and the Archaic sample because the presence of materials diagnostic of both time periods suggests that the location was occupied during both. I employed student's *t*-tests to compare the association of Pre-archaic and Archaic sites and projectile points with the ORB channels. Student's *t*-tests are used to determine if two sets of data are significantly different from one another – in this case, whether the distances of Pre-archaic sites and projectile points from the channels of the ORB are significantly different than those of Archaic sites and projectile points. The test produces a *t*-score, which corresponds to a *p*-value and the level of confidence at which the two sets of data can be considered different. Because there is a large range of distance-to-channel values within each of the samples, and because it may be possible for the Pre-archaic and Archaic datasets to be significantly different from one another at different distances from the ORB channels, student's *t*-tests were conducted four separate times for both the Pre-archaic and Archaic datasets with cutoff distances implemented to separate the data. That is, a *t*-test was performed first using the entirety of the Pre-archaic and Archaic site sample, regardless of the distance to the nearest channel. *T*-tests were then performed using three individual subsamples of sites: (1) those <100 m from the nearest channel; (2) those 100-500 m from the nearest channel; and (3) those located >500 m from the nearest channel. This same protocol was followed using the projectile point datasets.

Site Clustering Analysis

I conducted a final GIS-based method of site location analysis to further test the hypothesis that there were changes between Pre-archaic and Archaic land-use in the ORB. I employed a nearest neighbor analysis (NNA) using the site samples from each time period. As outlined in Chapter 1, the method measures the degree of spatial clustering or dispersal for a given set of points and calculates the statistical significance of observed patterns of clustering or dispersal based on a random distribution of the same number of points. For this study, I used NNA to determine whether or not Pre-archaic or Archaic sites in the ORB are clustered and whether or not they demonstrate significantly different degrees of clustering from one another.

Measuring Differences in Toolstone Procurement Strategies

To procure obsidian for the manufacture of stone tools, occupants of the proximal ORB had to travel at least 50 km from the basin to the nearest source, Topaz Mountain. Among the most distant sources of obsidian commonly utilized in the ORB, Browns Bench, is located 200+ km away from the southern end of the basin. The distances required to obtain toolstone – a critical prehistoric resource – would have represented a considerable cost to foragers (Madsen et al. 2015b; Oviatt et al. 2003; Page and Duke

2015; Schmitt et al. 2007), even in cases where foragers traveled in straight lines between the ORB and toolstone sources. The presence of a substantial wetland should have prevented Pre-archaic groups from traveling directly (i.e., in straight-line routes) to toolstone sources to the north and perhaps the west (Page and Duke 2015). In Chapter 1, I discussed a number of studies that have emphasized the influence that distance to toolstone sources had on technological organization (e.g., Andrefsky 2010; Beck et al. 2002; MacDonald 2008). While additional variables such as toolstone quality likely influenced technological organization (Andrefsky 2010; Beck et al. 2002; Jones et al. 2003), travel costs were likely an important consideration (Elston 1990). Page and Duke (2015) demonstrate this by showing that the majority (>75%) of the ORB's sourced artifacts are made using the nearest source of toolstone to the basin. As such, changes in the accessibility (i.e., cost) of toolstone sources related to major changes on the landscape (e.g., the presence/absence of an expansive wetland) should be reflected in changes in those sources' use by prehistoric groups.

I implemented two separate methods – least cost path analysis and a comparison of directions of procurement – to test the hypothesis that changes in toolstone source accessibility related to the disappearance of the ORB wetland led to changes in the toolstone procurement strategies between Pre-archaic and Archaic visitors to the ORB. I use these analyses, which are detailed below, to test the hypothesis that Pre-archaic occupants of the ORB experienced wetland-imposed movement restrictions not faced by their later Archaic counterparts. The quantitative results of these analyses will support/refute the idea that wetlands influenced Pre-archaic travel in the area.

Least Cost Path Analysis

Raw material sources that supplied obsidian used in the ORB are found predominantly to the north and to the south of the basin (Figure 3.3). The locations of these sources resulted in considerably different travel distances for hunter-gatherers occupying the proximal ORB – depending on the source they chose to exploit – with southern sources being the least distant and northern sources the most distant (Table 3.1). I implemented a least cost path (LCP) analysis to test the hypothesis that changes in the ORB landscape prompted differences in Pre-archaic and Archaic land-use strategies, including how toolstone was procured. For this study, the hypothesized restrictions imposed upon Pre-archaic movements by an expansive ORB wetland, and the subsequent lack of such restrictions for Archaic groups, warrant the use of LCP analysis to accurately measure the costs of travel to and from sources of toolstone. To make this comparison, I generated two slope- and distance-based cost surfaces – one using the present arid landscape representing the Archaic period and one incorporating a mobility-restricting wetland representing the Pre-archaic period. I chose an arbitrary site located near the northern end of the channel system in the proximal ORB from which to measure the cost of pedestrian travel to two well-represented obsidian sources in the ORB sample: Browns Bench and Topaz Mountain. Browns Bench is located approximately 240 km northwest of the study area and Topaz Mountain is located approximately 53 km southeast of the study area (Table 3.1 and Figure 3.4). These sources were selected for LCP analysis based on their dissimilar locations relative to the proximal ORB and the fact that they are well-represented during both the Pre-archaic and Archaic periods. Browns Bench and

Topaz Mountain constitute more than 80% of the sourced obsidian used in this study. I generated two LCPs (one using the Pre-archaic cost surface and one using the Archaic cost surface) between the selected site and each of the two obsidian sources. The resulting distance of travel values allowed me to develop expectations regarding toolstone procurement based on the multivariate cost of acquisition (slope and distance). Lastly, I calculated relative frequencies of Browns Bench and Topaz Mountain obsidian types for both the Pre-archaic and the Archaic samples by dividing the number of times each occurs by the total number of artifacts present in the sample. I then compared these frequencies to the results of LCP analysis to determine whether or not raw material procurement practices align with the developed cost-based expectations. This analysis allowed me to identify changes between the Pre-archaic and Archaic periods in terms of the efficiency of their respective procurement practices based on the costs of travel to and from sources and the frequency with which these sources occur in each sample.

Table 3.1. Obsidian Sources Represented in the ORB Sample, and their Distance and Direction from the Proximal ORB; after Page and Duke (2015).

Obsidian Chemical Source Group	Distance (km) from Proximal ORB	Direction from the Proximal ORB
Topaz Mountain	53	S/SE
Ferguson Wash	69	W
Black Rock	159	S/SE
Wild Horse Canyon	200	SE
Browns Bench	240	NW
Malad	256	NE
Kane Springs	368	SW
Paradise Valley	389	NW
Owyhee	406	NW

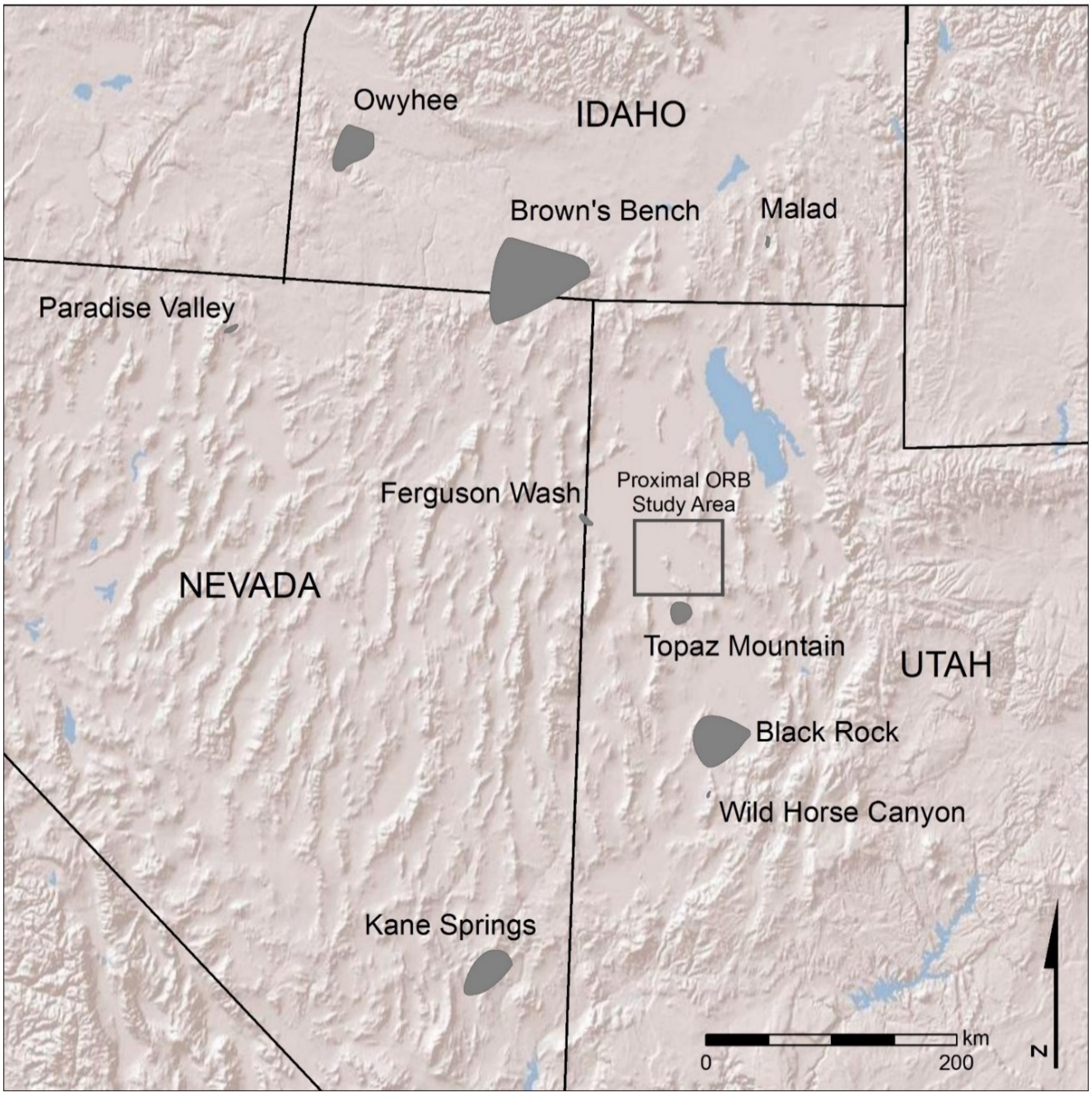

Figure 3.4. Locations of obsidian sources represented in the ORB sample. Data Source: David Page, DRI. Image Source: ESRI.

Direction of Procurement Analysis

Lastly, I performed a Fisher's exact test to compare northern versus southern toolstone procurement between the Pre-archaic and Archaic periods. Similar to a chi-square test, Fisher's exact tests allow for statistically significant differences to be detected between variables (e.g., northern and southern source use between the Pre-archaic and Archaic periods) within a contingency table. Unlike chi-square tests, Fisher's exact tests provide a more robust measure of significance when small or uneven samples are involved. This analysis provides a measure of whether Pre-archaic or Archaic groups procured significantly more toolstone from northern or southern sources and *vice versa*.

Hypothesis and Expectations

Using the materials described in Chapter 2 and the methods presented here, I set out to test the generally accepted hypothesis that Pre-archaic travel in the ORB was constrained by the expansive wetland present during the early Holocene whereas later, Archaic travel was not. I compared numerous variables between periods to identify differences in land-use and toolstone procurement strategies. Below, I summarize the materials and methods used to do so, and outline expectations for the results of each (Table 3.2).

If there were significant differences in how and where groups traveled into and within the ORB, then I expected them to be manifested in several ways. Regarding lithic assemblage and artifact attributes, I expected that Pre-archaic tool-to-debitage ratios should increase as distance from the entry points into the ORB basin increases; as groups traveled farther from toolstone sources, less tool production and more tool maintenance/discard should occur. Furthermore, I expected Pre-archaic bifaces to display increased retouch (i.e., more late stage bifaces and less early stage bifaces) as distance from the ORB entries and into the basin increases. Finally, because Pre-archaic projectile points were likely repeatedly reworked during their use-lives, I expected their weights to decrease as distance from the ORB entry points and into the basin increases. Without the same wetland-imposed restrictions to travel and ORB access and more random movements by later groups, I expected that these patterns will be significantly less pronounced in Archaic lithic assemblages.

Regarding the distribution of sites and isolated projectile points within the ORB, if Pre-archaic groups were tethered to the braided channel system – the "high ground" in the wetland – whereas Archaic groups were not, then Pre-archaic sites and points should be located significantly closer to the channels than Archaic sites and points. Additionally, I expected that with presence of a wetland greatly restricting the amount of habitable ground, Pre-archaic sites should demonstrate significant clustering. Conversely, with a substantial increase of dry land available in during the Archaic period, I expected site clustering to be minimal.

Finally, regarding the diminution of the ORB wetland and disappearance of a substantial geographic travel barrier, I expected significant differences in toolstone source representation in Pre-archaic and Archaic assemblages. With Pre-archaic access to and from the proximal ORB likely limited to the basin's southeastern margin, I expected southern toolstone sources to be overrepresented and northern sources to be underrepresented in that sample. With increased ORB accessibility after ca. 8,000 ^{14}C yr BP and less costly access to northern toolstone sources, I expected increased frequencies of northern raw material sources in the Archaic sample.

Summary

I employed the lithic- and GIS-based methods outlined in this chapter to identify differences in the movement, land-use and raw material procurement strategies of prehistoric groups occupying the same space during two very different temporal, and environmental, periods. I developed a series of expectations regarding my results. In sum, toolstone selection, site and projectile point locations, and artifact- and assemblage level attributes should all reflect patterned, constrained travel by Pre-archaic populations due to the presence of extensive wetlands and limited dry land – an idea that has been generally accepted by researchers working in the region but one that has yet to be rigorously evaluated using spatial and technological data. With the disappearance of the ORB wetland by ca. 8,000 ^{14}C yr BP and pedestrian travel constraints removed, there should be no such patterning later in time.

Table 3.2. Summary of Hypotheses, Materials, Methods, and Expectations.

Hypothesis	Materials	Methods	Expectations: Pre-archaic	Expectations: Archaic
Pre-archaic travel into and within the ORB wetland was restricted to inverted, elevated channels whereas Archaic travel was not.	Tool-to-debitage ratios	Distance to ORB entry and delta entry correlations (Spearman's rho)	Ratios increase as distance from ORB and delta entries increase	No correlation between ratios and distance from ORB entry
	Biface stages	Distance to ORB entry and delta entry correlations (Spearman's rho)	Biface reduction stages increase as distance from ORB and delta entries increase	No association between biface reduction stages and distance from ORB entry
	Projectile point weights	Distance to ORB entry and delta entry correlations (Spearman's rho)	Projectile point weight decreases as distance from ORB and delta entries increase	No association between projectile point weight and distance from ORB entry
	Site and projectile point locations	Distance to ORB channels correlation (student's *t*-test)	Sites and points are located in significant association with ORB channels	No association between sites or points and the ORB channels
	Site locations	Nearest neighbor analysis	Sites exhibit significant clustering	Sites do not exhibit significant clustering
	Geochemically sourced artifacts	Fisher's exact testing and least cost path analysis	Overrepresentation of southern sources and underrepresentation of northern sources	Increases in northern source representation

Chapter 4

Results

In this chapter, I present the results of analyses performed using the materials and methods described in chapters 2 and 3. First, I present the results of my analysis of lithic data including tool-to-debitage ratios, biface reduction stages, and projectile point weights, and evaluate them against my expectations for the hypothesis that Pre-archaic travel was restricted to the ORB channels. Second, I present the results of my comparisons of the locations of Pre-archaic and Archaic sites and projectile points in relation to the ORB channel system and of the degrees of spatial clustering demonstrated by Pre-archaic and Archaic sites. These analyses are used to identify if Pre-archaic sites are significantly associated with the ORB channels and compare trends in site location between the two time periods. Third, I present the results of LCP analysis and a Fisher's exact test, which are used to: (1) determine whether or not the presence of a wetland alters the costs of travel between the proximal ORB and toolstone sources; (2) identify whether or not toolstone was procured efficiently (i.e., at rates in accord with the modeled costs of travel to obtain it); and (3) compare the directionality of toolstone movement between the Pre-archaic and Archaic periods.

I employed this set of lithic- and GIS-based analyses to test the hypothesis that hunter-gatherer travel in the ORB was restricted to the basin's inverted channels during the Pre-archaic period (pre-8,000 ^{14}C yr BP) while later groups visiting the area during later, more xeric conditions (post-8,000 ^{14}C yr BP) were not.

Results of Lithic-based Analyses

I compiled a sample of 214 single component proximal ORB sites and separated it into two groups – Pre-archaic and Archaic – using diagnostic projectile points. A total of 188 Pre-archaic and 26 Archaic sites were included. These sites were further partitioned for analysis based on tool-to-debitage ratio and biface reduction stage data available from DPG and DRI site forms.

Tool-to-debitage Ratios. I expected that Pre-archaic tool-to-debitage ratios should increase as distance from the entry point into the ORB basin increases because as groups traveled farther from toolstone sources, less tool production and more tool maintenance/discard should have occurred. With the disappearance of both the ORB wetland and the potential obstacles it represented, the same patterning should not hold true for the Archaic sample. Of the 214 single-component sites, 123 (104 Pre-archaic and 19 Archaic) provided tool-to-debitage data. I ranked these sites first according to their tool-to-debitage ratios and second according to their distances from a hypothetical entry-point into the ORB basin. The entry-point was established with the assumption that the presence of a wetland would have restricted access into the basin to its southeastern margin where the ORB channel system originates. I employed Spearman's rho to test the significance of relationships between tool-to-debitage ratios and distances from the ORB entry-point to sites for both the Pre-archaic and Archaic samples. The results (Tables 4.1 and 4.2) indicate that both the Pre-archaic (r_s = -0.186, n = 104, p = 0.059) and Archaic (r_s = -0.279, n = 19, p = 0.248) site samples exhibit decreasing tool-to-debitage ratios as distance from the ORB entry-point increases; however, neither sample's correlation is statistically significant at the $\alpha = .05$ level.

Biface Reduction Stages. The samples for this analysis consisted of 152 Pre-archaic and 22 Archaic sites. The number of bifaces and their stages of reduction were recorded at each of these sites; this allowed me to rank the sites according to the dominant biface stage present. I then ranked the sites according to their distance from the ORB entry-point and again used Spearman's rho to test the significance of relationships between biface reduction stages and site distances from the hypothesized ORB entry-point.

The results of this analysis (Tables 4.3 and 4.4) correspond with my expectation that Pre-archaic bifaces should have been further reduced as distance from the ORB entrance increases, although the positive correlation, while statistically significant, is somewhat weak ($r_s = 0.179$ $n = 153$, $p = 0.027$). The results of my analysis of the Archaic sample also met my expectations: the relationship between Archaic biface stages and distance to the ORB entry point is not significant ($r_s = -0.216 n = 22$, $p = 0.334$).

Projectile Point Weight. I expected that Pre-archaic projectile point weights should decrease as distance from the ORB entry point increases. The same pattern should be less pronounced for Archaic projectile points. I compiled a sample of 251 Pre-Archaic and 52 Archaic projectile points using data from proximal ORB lithic assemblages (Beck and Jones 2015). I ranked each sample, first according to projectile point weight and second according to each specimen's distance to the ORB entry point (Tables 4.5 and 4.6). This analysis used projectile point weight as a proxy for retouch intensity, with more reworked/exhausted specimens assumed to weigh less than less reworked/exhausted specimens. The results indicate that both Pre-archaic (r_s = 0.053, n = 251, p = 0.407) and Archaic (r_s = 0.167, n = 52, p = 0.237) projectile points demonstrate weak, non-significant positive correlations with distance to the ORB entrance.

Delta Entry Point Analyses. I repeated the above analyses on 49 Pre-archaic sites and 202 Pre-archaic projectile points using an alternative entry point located at the margin of the ORB delta. My expectations for these analyses correspond with those noted above for the Pre-archaic sample. The results differ from those using the original ORB entry point in that my expectations for tool-to-debitage ratios (Table 4.7) to increase with distance from the delta entry point were met (r_s = 0.557, n = 49, $p < 0.05$), whereas they were not met for biface stages (Table 4.8), which demonstrate a non-significant negative correlation (r_s = -0.058, n = 44, p = 0.72). The results of Pre-archaic projectile point analysis (Table 4.9) are similar to those using the ORB entry point and indicate a non-significant positive correlation with distance to the delta entry point (r_s = 0.116, n = 205, p = 0.099).

Table 4.1. Tool-to-debitage Ratios, Distances to the ORB Entrance, and Results of Spearman's rho Analysis for Pre-archaic Sites.

State ID	Tool-to-debitage Ratio	Distance to ORB Entrance (m)	State ID	Tool-to-debitage Ratio	Distance to ORB Entrance (m)
04-DM-01*	10	37,914	42To3150	0.52	11,627
04-DM-02*	20	38,289	42To3170	0.55	17,112
04-DM-03*	30	37,882	42To3178	0.26	14,630
04-DM-04*	10	34,673	42To3219	0.6	30,535
04-DM-05*	10	38,303	42To3220	0.6	30,399
07DP03	0.3	27,182	42To3221	0.12	28,105
42To1157*	80	12,772	42To3222	1.44	28,102
42To1195	0.17	7,218	42To3223	0.18	28,478
42To1357	0.06	18,306	42To3224	0.85	28,817
42To1523	0.15	10,912	42To3225	1	29,592

State ID	Tool-to-debitage Ratio	Distance to ORB Entrance (m)	State ID	Tool-to-debitage Ratio	Distance to ORB Entrance (m)
42To1543b	0.09	10,913	42To3226	1.08	29,955
42To1674	0.43	25,508	42To3227	0.25	26,138
42To1676	0.27	24,975	42To3228	0.74	26,910
42To1677	0.52	24,679	42To3229	0.04	26,752
42To1678	0.34	24,274	42To3230	1.61	46,031
42To1682	1.4	29,176	42To3231	0.14	27,176
42To1683	0.4	28,811	42To3232	0.38	27,535
42To1687	1.25	30,950	42To3233	0.4	28,519
42To1859	0.24	25,644	42To3234	0.6	28,733
42To1862	0.17	28,035	42To3235	0.46	28,620
42To1876	4.33	32,688	42To3236	0.24	29,420
42To1877	0.86	32,360	42To3237	0.16	29,214
42To1921	0.4	31,729	42To3238	0.17	29,462
42To1922	1.2	32,111	42To3239	0.86	30,117
42To1923	120	31,479	42To3301	0.13	24,909
42To2141	0.26	12,775	42To3475	0.14	2,378
42To2172	0.09	21,827	42To3520	1.43	31,246
42To2346	0.11	11,898	42To3521	0.02	36,224
42To2352	0.15	11,750	42To3522	0.57	28,761
42To2943	0.57	26,388	42To3733	1.27	19,486
42To2944	0.22	26,898	42To3736	0.14	19,503
42To2946	0.18	28,001	42To3769	0.22	21,490
42To2948	0.11	26,084	42To3827*	90	9,636
42To2949	0.69	25,671	42To3831*	110	8,372
42To2951	0.7	26,353	42To3846*	160	10,406
42To2952	0.48	27,358	42To3847*	30	10,409
42To2953	0.55	27,687	42To3852*	30	9,277
42To2954	0.7	28,742	42To3853*	360	9,107
42To2957	0.75	31,197	42To3854*	20	9,060
42To3140	0.3	27,123	42To3855*	130	9,392
42To3141	0.67	42,050	42To3857*	540	8,843
42To3142	0.14	28,051	42To3858*	210	8,554
42To3144	0.9	13,651	42To3909*	190	7,915
42To3145	0.67	13,407	42To3925*	60	10,575
42To3148	0.18	12,393	42To3930*	60	10,002
42To3149	0.12	12,173	42To3936*	60	5,829
42To3946*	60	6,859	42To3938*	70	5,212
42To3948*	1890	6,197	42To3943*	50	6,588
42To3951*	50	7,271	42To3945*	70	6,988
42To3954*	30	6,716	42To4233	0.07	23,823
42To3955*	70	8,512	42To4234	0.18	23,805
42To4231	0.4	23,647	42To4239	0.02	23,910

Spearman's rho: $r_s = -0.186$, $n = 104$, $p = 0.059$. *Note:* Sites marked with "*" contained no debitage and were assigned a debitage value of 0.1 to facilitate the calculation of tool-to-debitage ratios.

Table 4.2. Tool-to-debitage Ratios, Distances to the ORB Entrance, and Results of Spearman's rho Analysis for Archaic Sites.

State ID	Tool-to-debitage Ratio	Distance to ORB Entrance (m)	State ID	Tool-to-debitage Ratio	Distance to ORB Entrance (m)
42To1961	0.02	8,541	42To3830*	40	9,389
42To1964	0.5	8,636	42To3850*	40	9,784
42To2173	0.14	21,933	42To3926*	80	10,471
42To2177	0.01	2,351	42To3928*	30	10,259
42To2345	0.02	12,447	42To3944*	120	6,294
42To2349	0.03	11,711	42To3952*	40	8,291
42To3171	1.21	16,428	42To4125	0.25	10,206
42To3746	5	21,434	42To4242	0.01	23,853
42To3747*	10	21,309	42To4950	0.12	15,147
42To3829*	110	9,597			

Spearman's rho: $r_s = -0.279$, $n = 19$, $p = 0.248$. *Note:* Sites marked with "*" contained no debitage and were assigned a debitage value of 0.1 to facilitate the calculation of tool-to-debitage ratios.

Table 4.3. Biface Reduction Stages, Distances to the ORB Entrance, and Results of Spearman's rho Analysis for Pre-archaic Sites.

State ID	Predominate Biface Stage	Distance to ORB Entrance (m)	State ID	Predominate Biface Stage	Distance to ORB Entrance (m)
07DM07	2	42,114	42To1687	2	30,950
07DP03	2	27,182	42To1688	2	31,507
42To1000	2	17,679	42To1689	2	24,106
42To1152	3	11,876	42To1859	2	25,644
42To1153	2	11,936	42To1861	2	26,506
42To1157	2	12,772	42To1862	2	28,035
42To1161	2	12,212	42To1872	2	30,690
42To1163	2	14,942	42To1873	2	29,633
42To1172	2	13,161	42To1874	2	29,879
42To1177	2	23,029	42To1875	2	30,198
42To1178	2	23,057	42To1876	2	32,688
42To1182	2	19,652	42To1877	2	32,360
42To1195	2	7,218	42To1878	2	33,187
42To1352	2	19,251	42To1920	2	31,206
42To1353	2	9,428	42To1921	2	31,729
42To1354	2	9,340	42To1922	2	32,111
42To1357	2	18,306	42To1923	2	31,479
42To1358	2	18,456	42To1924	2	31,113
42To1359	2	9,319	42To2141	2	12,775
42To1367	2	9,447	42To2145	2	19,375

State ID	Predominate Biface Stage	Distance to ORB Entrance (m)	State ID	Predominate Biface Stage	Distance to ORB Entrance (m)
42To1368	2	26,870	42To2146	2	18,957
42To1369	2	25,348	42To2148	2	20,455
42To1370	2	26,781	42To2152	2	21,391
42To1371	2	31,455	42To2172	2	21,827
42To1383	2	15,473	42To2346	2	11,898
42To1523	2	10,912	42To2352	2	11,750
42To1543b	2	10,913	42To2551	2	27,749
42To1668	2	23,676	42To2552	3	28,284
42To1669	2	23,252	42To2553	2	29,383
42To1671	2	23,847	42To2554	3	30,060
42To1672	2	23,887	42To2555	3	30,716
42To1673	2	23,884	42To2557	2	26,354
42To1674	2	25,508	42To2558	3	25,827
42To1676	2	24,975	42To2767	3	16,908
42To1677	2	24,679	42To2943	3	26,388
42To1678	2	24,274	42To2944	3	26,898
42To1679	2	26,123	42To2945	3	27,153
42To1681	2	29,304	42To2946	2	28,001
42To1682	2	29,176	42To2947	3	28,268
42To1683	2	28,811	42To2948	3	26,084
42To1684	2	28,096	42To2949	3	25,671
42To1685	2	30,831	42To2951	2	26,353
42To1686	2	30,837	42To2953	3	27,687
42To2954	3	28,742	42To3503	3	41,618
42To2955	3	27,908	42To3520	3	31,246
42To2957	3	31,197	42To3521	3	36,224
42To3140	2	27,123	42To3522	3	28,761
42To3141	2	42,050	42To3733	3	19,486
42To3142	3	28,051	42To3736	3	19,503
42To3144	2	13,651	42To3769	3	21,490
42To3145	3	13,407	42To3827	2	9,636
42To3148	2	12,393	42To3846	2	10,406
42To3149	2	12,173	42To3847	2	10,409
42To3150	2	11,627	42To3852	2	9,277
42To3170	2	17,112	42To3853	3	9,107
42To3178	2	14,630	42To3854	3	9,060
42To3220	3	30,399	42To3855	3	9,392
42To3223	3	28,478	42To3857	2	8,843
42To3224	2	28,817	42To3858	3	8,554
42To3225	3	29,592	42To3909	2	7,915
42To3226	2	29,955	42To3925	2	10,575
42To3227	3	26,138	42To3936	2	5,829
42To3228	3	26,910	42To3938	2	5,212
42To3229	3	26,752	42To3943	2	6,588
42To3230	2	46,031	42To3945	2	6,988

State ID	Predominate Biface Stage	Distance to ORB Entrance (m)	State ID	Predominate Biface Stage	Distance to ORB Entrance (m)
42To3231	3	27,176	42To3946	2	6,859
42To3232	3	27,535	42To3948	3	6,197
42To3233	3	28,519	42To3951	2	7,271
42To3234	3	28,733	42To3954	2	6,716
42To3235	3	28,620	42To3955	2	8,512
42To3236	2	29,420	42To4231	3	23,647
42To3237	3	29,214	42To4233	3	23,823
42To3238	2	29,462	42To4234	2	23,805
42To3239	3	30,117	42To4239	3	23,910
42To3301	1	24,909	42To4944	2	12,624
42To3475	2	2,378	42To5140	1	20,009

Spearman's rho: $r_s = 0.179$, $n = 153$, $p = 0.027$

Table 4.4. Biface Reduction Stages, Distances to the ORB Entrance, and Results of Spearman's rho Analysis for Archaic Sites.

State ID	Predominate Biface Stage	Distance to ORB Entrance (m)	State ID	Predominate Biface Stage	Distance to ORB Entrance (m)
42To2177	2	2,351	42To1523	2	10,910
42To3944	2	6,294	42To2349	2	11,711
42To3952	2	8,291	42To2345	2	12,447
42To1961	2	8,541	42To1183	2	14,547
42To1964	3	8,636	42To4950	2	15,147
42To3830	2	9,389	42To3171	2	16,428
42To3829	3	9,597	42To3746	2	21,434
42To3850	3	9,784	42To2149	2	21,491
42To4125	1	10,206	42To2170	2	21,530
42To3928	2	10,259	42To2173	2	21,933
42To3926	2	10,471	42To4242	2	23,853

Spearman's rho: $r_s = -0.216$, $n = 22$, $p = 0.334$

Table 4.5. Pre-archaic Projectile Point Weights, Distances to the ORB Entrance, and Results of Spearman's rho Analysis.

Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)	Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)
04DM02	2	9.7	37,746	42To1685	36	2.7	30,621
04DM03	1	23.6	38,167	42To1685	32	3.4	30,679
42To1872	67	7	29,605	42To1685	5	4	30,541
42To1875	24	8.9	30,417	42To1686	13	5.9	30,567
08DM30	1	34.5	31,237	42To1686	67	9.2	30,428
42To0385	3	5.9	23,443	42To1686	36	6.6	30,489
42To1000	16	3.3	17,414	42To1686	16	3.8	30,569
42To1000	25	4.8	17,433	42To1686	53	3.4	30,535
42To1152	1	16.9	11,613	42To1686	5	1.5	30,594
42To1153	21	4.9	11,809	42To1686	26	2.8	30,565
42To1153	23	21.5	11,700	42To1686	72	1.7	30,507
42To1157	1	2.5	12,613	42To1686	69	3.6	30,461
42To1161	1	2.7	11,982	42To1686	27	3.1	30,557
42To1166	1	3	14,444	42To1686	43	6	30,549
42To1177	4	2.9	23,196	42To1686	49	3.6	30,547
42To1178	4	2.3	22,938	42To1687	8	2.6	30,648
42To1182	3	3.2	19,254	42To1687	10	5.5	30,649
42To1354	5	7.2	8,950	42To1687	3	2.4	30,658
42To1354	9	6.5	8,961	42To1687	5	1.7	30,647
42To1358	26	5.7	18,069	42To1688	58	0	31,133
42To1369	4	5.3	25,021	42To1688	49	4.4	31,195
42To1370	3	11.4	26,455	42To1688	2	5.1	31,198
42To1370	9	10.4	26,450	42To1688	11	3	31,236
42To1371	59	2.8	31,061	42To1688	13	1.7	31,271
42To1371	32	2.6	31,109	42To1688	32	2.4	31,221
42To1371	43	4	31,147	42To1689	3	2.3	23,801
42To1371	56	7.7	31,037	42To1859	5	3.9	25,359
42To1371	90	1.9	31,157	42To1859	3	2.3	25,377
42To1668	9	4.2	23,267	42To1861	7	3.2	26,234
42To1671	6	11.6	23,568	42To1872	29	3.7	30,259
42To1674	1	5.1	25,160	42To1872	13	3.4	30,413
42To1677	13	2.7	24,101	42To1872	19	2.9	30,366
42To1678	11	2.2	23,923	42To1872	4	6.1	30,575
42To1678	12	4.8	23,951	42To1872	49	7.8	30,306
42To1679	5	7.3	25,797	42To1872	37	3.5	30,206
42To1679	7	1.9	25,781	42To1873	20	6.9	29,387
42To1679	4	4.3	25,822	42To1873	17	2.3	29,381
42To1681	3	1.1	25,824	42To1873	25	6.2	29,364
42To1683	4	4.5	28,522	42To1875	1	7.9	29,902
42To1683	12	2	28,619	42To1876	9	6.6	32,524
42To1683	8	3	28,505	42To1878	3	4.7	32,896
42To1685	23	7.1	30,484	42To1878	14	16.7	32,854

Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)	Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)
42To1685	11	6.7	30,550	42To1878	11	3.1	32,925
42To1685	34	3.5	30,649	42To1921	9	9	31,371
42To1922	10	4.4	31,789	42To2952	13	4.9	27,152
42To1924	13	4.2	30,821	42To2955	5	18.8	27,753
42To1924	102	3.6	30,904	42To3141	6	2.6	41,901
42To1924	120	2.4	30,988	42To3142	22	4.4	27,817
42To2551	24	4.5	27,331	42To3142	31	11.7	27,869
42To2551	57	6.1	27,437	42To3142	24	7.1	27,864
42To2551	30	80.5	27,083	42To3219	60	11.6	30,365
42To2551	15	7.3	27,536	42To3219	38	3.7	30,387
42To2552	1	4.6	28,070	42To3219	54	10	30,351
42To2552	4	2.3	28,081	42To3219	65	4.1	30,367
42To2552	12	5.9	28,105	42To3219	59	3.5	30,345
42To2553	3	17.6	29,108	42To3219	50	2.8	30,359
42To2554	12	3.3	29,868	42To3219	28	3.4	30,394
42To2554	44	6	29,783	42To3222	12	9.3	27,938
42To2554	6	3.9	30,018	42To3223	8	4.7	28,337
42To2554	7	2.9	30,056	42To3223	18	2.6	28,359
42To2555	4	2.6	30,426	42To3225	9	5.8	29,418
42To2556	23	5.6	26,979	42To3226	2	9.1	29,625
42To2556	46	4.4	26,907	42To3226	8	2.1	29,828
42To2556	28	2.3	26,964	42To3228	15	8.3	26,827
42To2556	54	2.1	26,925	42To3228	5	4	26,728
42To2557	1	3.3	26,100	42To3228	2	3.4	26,736
42To2558	8	2.6	25,556	42To3228	6	5	26,728
42To2558	3	3.5	25,657	42To3229	20	8	26,517
42To2558	7	2.2	25,556	42To3229	19	3.1	26,607
42To2558	9	2.2	25,630	42To3230	1	13.3	45,895
42To2559	55	12.5	24,733	42To3230	85	4.1	45,875
42To2559	52	2.9	25,182	42To3230	71	2.5	45,927
42To2559	72	5.1	24,944	42To3230	52	1.4	45,907
42To2559	23	4.7	25,268	42To3230	94	4.3	45,971
42To2559	25	4.5	25,260	42To3230	5	4.5	45,949
42To2559	46	3.3	25,212	42To3230	113	3.9	45,947
42To2559	59	3	24,913	42To3230	92	6.4	45,960
42To2767	25	2.4	16,344	42To3230	46	2.7	45,934
42To2767	19	3.3	16,577	42To3230	84	3.4	45,828
42To2944	5	4	26,797	42To3230	97	2.7	45,978
42To2945	17	3	26,995	42To3231	8	11.1	27,146
42To2945	30	1.9	26,977	42To3231	7	4.4	26,956
42To2945	1	4.2	26,985	42To3233	23	2.8	28,376
42To2945	10	4.2	26,986	42To3233	19	2.9	28,330
42To2946	6	2.6	27,812	42To3233	26	2.9	28,359
42To2947	6	2.1	27,920	42To3234	15	13	28,547
42To2948	6	5.8	25,844	42To3234	21	5.1	28,567

Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)	Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)
42To2948	1	2.8	26,008	42To3234	28	3.5	28,546
42To2949	18	6	25,519	42To3234	10	3	28,555
42To2949	25	3.1	25,516	42To3234	32	1.8	28,553
42To2949	26	5.5	25,499	42To3235	37	9.6	28,401
42To2951	17	4.8	26,140	42To3235	42	7.8	28,413
42To2951	26	2.9	26,206	42To3235	109	6	28,452
42To3140	1	9.6	26,870	42To3235	23	1.9	28,432
42To3140	11	10.6	26,940	42To3235	56	3.6	28,419
42To3237	32	2.3	29,119	DPGIF	479	3.8	27,573
42To3237	56	1.9	29,139	DPGIF	624	8.3	27,789
42To3237	58	3.4	29,138	DPGIF	208	4.1	14,306
42To3237	44	2	29,149	DPGIF	526	2.5	33,472
42To3237	16	3.5	29,147	DPGIF	811	1.4	30,504
42To3237	29	2.4	29,145	DPGIF	876	6.9	31,161
42To3237	4	2.6	29,051	DPGIF	867	4.2	30,165
42To3237	42	2.6	29,148	DPGIF	902	6.4	19,171
42To3237	75	3.7	29,116	DPGIF	381	3.9	28,348
42To3237	77	3.7	29,114	DPGIF	452	3.7	24,568
42To3237	79	2.8	29,106	DPGIF	457	5.1	24,899
42To3238	18	3.2	29,371	DPGIF	686	3.2	31,518
42To3238	27	5.5	29,371	DPGIF	733	4.6	31,316
42To3238	25	2.4	29,376	DPGIF1932	-	1.7	33,379
42To3520	12	9.8	31,188	DPGIF1942	-	27.1	36,591
42To3520	43	28.8	31,193	DPGIF1945	1	7.3	27,726
42To3520	37	23.2	31,194	DPGIF1946	-	6.8	27,813
42To3520	16	2.6	31,211	DPGIF2412	3	5.4	23,989
42To3522	12	16.3	28,733	DPGIF2414	1	5.2	41,613
42To3522	7	3.1	28,623	DPGIF2415	1	25.8	42,135
42To3522	2	3.7	28,681	DPGIF2447	-	17.4	30,112
DPGIF	215	7	12,851	DPGIF2452	-	37.2	38,298
DPGIF	506	6.8	30,886	DPGIF2453	-	18	38,260
DPGIF	879	19.3	31,009	DPGIF2523	-	14.9	30,988
DPGIF	847	10	30,026	DPGIF2527	-	30.5	31,675
DPGIF	735	5.7	31,304	DPGIF2529	-	35.5	31,442
DPGIF	885	5.6	31,097	ISO-7	5	4.7	32,553
DPGIF	521	4.4	33,109	ISO-8	6	3.5	32,465

Spearman's rho: $r_s = 0.053$, $n = 251$, $p = 0.407$

Table 4.6. Archaic Projectile Point Weights, Distances to the ORB Entrance, and Results of Spearman's rho Analysis.

Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)	Site ID	FS #	Weight (g)	Distance to ORB Entrance (m)
42To1000	22	0.58	17,301	42To1683	11	1.73	28,544
42To1000	30	2.47	17,361	42To1683	9	1.13	28,626
42To1163	12	0.72	14,805	42To1685	39	3.84	30,477
42To1166	2	1.2	14,418	42To1685	38	3.17	30,497
42To1172	19	3.39	12,947	42To1689	8	2.7	23,850
42To1178	2	1.26	22,932	42To1875	23	2.29	29,866
42To1182	13	1.99	19,263	42To2945	32	2.53	27,080
42To1352	3	1.4	18,860	42To2948	16	1.23	25,974
42To1352	5	0.98	18,896	42To2948	3	10.31	26,017
42To1358	65	2.14	17,933	42To3230	80	2.15	45,778
42To1358	10	1.18	18,009	42To3230	95	3.71	45,866
42To1358	86	1.31	18,045	42To3230	56	3.81	45,883
42To1358	33	0.86	18,098	42To3230	83	2.86	45,899
42To1358	45	4.26	18,168	42To3230	78	3.22	45,972
42To1358	56	2.39	18,180	42To3235	12	2.43	28,402
42To1358	70	1.33	18,231	DPGIF	882	5.51	11,566
42To1358	14	2.32	18,267	DPGIF	209	3.48	12,314
42To1358	25	1.81	18,280	DPGIF	376	2.43	14,095
42To1359	6	2.19	8,906	DPGIF	869	3.03	17,878
42To1367	2	1.99	9,025	DPGIF	193	9.41	18,448
42To1367	1	3.31	9,050	DPGIF	836	1.8	22,186
42To1384	2	1.45	24,612	DPGIF	842	1.82	27,171
42To1666	16	1.45	17,673	DPGIF	478	3	30,106
42To1666	9	3.88	17,677	DPGIF	363	2.06	30,161
42To1671	8	2.42	23,511	DPGIF	319	1.69	30,357
42To1672	4	2.68	23,590	DPGIF	224	7.57	31,168

Spearman's rho: $r_s = 0.167$, $n = 52$, $p = 0.237$

Table 4.7. Tool-to-debitage Ratios, Distances to the Delta Entrance, and Results of Spearman's rho Analysis for Pre-archaic Sites.

State ID	Tool to Debitage Ratio	Distance To Delta Entrance (m)	State ID	Tool to Debitage Ratio	Distance To Delta Entrance (m)
42To1859	0.24	2,544	42To3228	0.74	4,847
42To1678	0.34	2,564	42To3231	0.14	5,019
42To1677	0.52	2,957	42To3232	0.38	5,232
42To1676	0.27	3,199	42To3235	0.46	5,465
07DP03	0.30	3,626	42To2953	0.55	5,641
42To1674	0.43	3,805	42To3234	0.60	5,654
42To1683	0.40	5,231	42To3233	0.40	5,690
42To2951	0.70	5,340	42To3522	0.57	6,018
42To1682	1.40	5,461	42To2954	0.70	6,054
42To3224	0.85	6,460	42To3225	1.00	6,929
42To3226	1.08	7,187	42To3220	0.60	7,493
42To1687	1.25	7,596	42To3520	1.43	8,278
42To1877	0.86	8,719	42To3237	0.16	9,436
42To1876	4.33	8,979	42To3239	0.86	10,340
42To3238	0.17	9,561	42To2957	0.75	12,443
42To3236	0.24	9,852	42To3521	0.02	12,674
42To1923	12.00	10,948	42To2952	0.48	5,592
42To1921	0.40	11,124	42To3222	1.44	5,976
42To1922	1.20	11,588	42To3221	0.12	6,081
42To3141	0.67	18,873	04-DM-04	10.00	12,830
42To3230	1.61	23,486	04-DM-01	10.00	14,842
42To3140	0.30	3,558	04-DM-03	30.00	14,885
42To3227	0.25	4,372	04-DM-05	10.00	15,222
42To3142	0.14	4,724	04-DM-02	20.00	15,244
42To3229	0.04	4,772			

Spearman's rho: $r_s = 0.557$, $n = 49$, $p < 0.05$

Table 4.8. Biface Reduction Stages, Distances to the Delta Entrance, and Results of Spearman's rho Analysis for Pre-archaic Sites.

State ID	Predominate Biface Stage	Distance To Delta Margin (m)	State ID	Predominate Biface Stage	Distance To Delta Margin (m)
42To1859	2	2,544	42To3140	3	3,558
42To1678	2	2,564	42To3227	3	4,372
42To1677	2	2,957	42To3142	3	4,724
42To1676	2	3,199	42To3229	3	4,772
07DP03	2	3,626	42To3228	3	4,847
42To1674	2	3,805	42To3231	3	5,019
42To1683	2	5,231	42To3232	3	5,232
42To2951	2	5,340	42To3235	3	5,465
42To1682	2	5,461	42To2953	3	5,641
42To3224	2	6,460	42To3234	3	5,654
42To3226	2	7,187	42To3233	3	5,690
42To1687	2	7,596	42To3522	3	6,018
42To1877	2	8,719	42To2954	3	6,054
42To1876	2	8,979	42To3225	3	6,929
42To3238	2	9,561	42To3220	3	7,493
42To3236	2	9,852	42To3520	3	8,278
42To1923	2	10,948	42To3237	3	9,436
42To1921	2	11,124	42To3239	3	10,340
42To1922	2	11,588	42To2957	3	12,443
42To3141	2	18,873	42To3521	3	12,674
42To3230	2	23,486			

Spearman's rho: $r_s = -0.057$, $n = 41$, $p < 0.72$

Table 4.9. Pre-archaic Projectile Point Weights, Distances to the Delta Entrance, and Results of Spearman's rho Analysis.

Site ID	FS#	Weight (g)	Distance to Delta Margin (m)	Site ID	FS#	Weight (g)	Distance To Delta Margin (m)
04DM02	2	9.71	14,713	42To2559	52	2.90	2,334
04DM03	1	23.58	15,090	42To2559	59	2.90	2,334
42To1872	67	7.01	5,796	42To2559	46	2.90	2,334
42To1875	24	8.92	6,611	42To2559	25	2.90	2,334
08DM30	1	34.50	8,226	42To2559	23	2.90	2,334
42To1177	4	2.86	1,118	42To2559	72	2.90	2,334
42To1178	4	2.31	1,301	42To2559	55	2.90	2,334
42To1369	4	5.26	5,530	42To2951	26	2.92	5,501
42To1370	9	10.35	6,200	42To2951	17	2.92	5,501
42To1370	3	10.35	6,200	42To2952	13	4.87	5,717

Site ID	FS#	Weight (g)	Distance to Delta Margin (m)	Site ID	FS#	Weight (g)	Distance To Delta Margin (m)
42To1371	90	1.91	10,833	42To3140	1	9.58	3,470
42To1371	32	1.91	10,833	42To3140	11	9.58	3,470
42To1371	59	1.91	10,833	42To3141	6	2.57	18,800
42To1371	43	1.91	10,833	42To3142	22	4.38	4,682
42To1371	56	1.91	10,833	42To3142	24	4.38	4,682
42To1668	9	4.18	3,653	42To3142	31	4.38	4,682
42To1671	6	11.60	2,157	42To3219	50	2.82	7,598
42To1674	1	5.08	3,376	42To3219	28	2.82	7,598
42To1677	13	2.71	2,329	42To3219	59	2.82	7,598
42To1678	11	2.20	2,197	42To3219	38	2.82	7,598
42To1678	9	2.20	2,197	42To3219	65	2.82	7,598
42To1678	12	2.20	2,197	42To3219	54	2.82	7,598
42To1679	7	1.92	3,722	42To3219	60	2.82	7,598
42To1679	4	1.92	3,722	42To3222	12	9.27	6,112
42To1679	5	1.92	3,722	42To3223	18	2.61	6,528
42To1681	3	1.11	3,689	42To3223	8	2.61	6,528
42To1683	12	1.96	4,977	42To3225	9	5.76	6,980
42To1683	8	1.96	4,977	42To3226	8	2.09	7,269
42To1683	4	1.96	4,977	42To3226	2	2.09	7,269
42To1685	36	2.68	7,116	42To3228	2	3.39	5,027
42To1685	32	2.68	7,116	42To3228	5	3.39	5,027
42To1685	34	2.68	7,116	42To3228	6	3.39	5,027
42To1685	5	2.68	7,116	42To3228	15	3.39	5,027
42To1685	11	2.68	7,116	42To3229	19	3.09	4,971
42To1685	23	2.68	7,116	42To3229	20	3.09	4,971
42To1686	5	1.48	7,236	42To3230	52	1.41	23,442
42To1686	72	1.48	7,236	42To3230	71	1.41	23,442
42To1686	26	1.48	7,236	42To3230	46	1.41	23,442
42To1686	27	1.48	7,236	42To3230	97	1.41	23,442
42To1686	53	1.48	7,236	42To3230	84	1.41	23,442
42To1686	49	1.48	7,236	42To3230	113	1.41	23,442
42To1686	69	1.48	7,236	42To3230	85	1.41	23,442
42To1686	16	1.48	7,236	42To3230	94	1.41	23,442
42To1686	13	1.48	7,236	42To3230	5	1.41	23,442
42To1686	43	1.48	7,236	42To3230	59	1.41	23,442
42To1686	36	1.48	7,236	42To3230	92	1.41	23,442
42To1686	67	1.48	7,236	42To3230	1	1.41	23,442
42To1687	5	1.69	7,223	42To3231	7	4.44	5,163
42To1687	3	1.69	7,223	42To3231	8	4.44	5,163
42To1687	8	1.69	7,223	42To3233	23	2.79	5,772
42To1687	10	1.69	7,223	42To3233	19	2.79	5,772
42To1688	58	1.68	7,716	42To3233	26	2.79	5,772
42To1688	13	1.68	7,716	42To3234	32	1.77	5,659
42To1688	32	1.68	7,716	42To3234	10	1.77	5,659
42To1688	11	1.68	7,716	42To3234	28	1.77	5,659

Site ID	FS#	Weight (g)	Distance to Delta Margin (m)	Site ID	FS#	Weight (g)	Distance To Delta Margin (m)
42To1688	49	1.68	7,716	42To3234	21	1.77	5,659
42To1688	2	1.68	7,716	42To3234	15	1.77	5,659
42To1689	3	2.26	88	42To3235	23	1.89	5,494
42To1859	3	2.26	2,145	42To3235	56	1.89	5,494
42To1859	5	2.26	2,145	42To3235	109	1.89	5,494
42To1861	7	3.20	2,790	42To3235	42	1.89	5,494
42To1872	19	2.92	6,561	42To3235	37	1.89	5,494
42To1872	13	2.92	6,561	42To3520	16	2.55	8,330
42To1872	37	2.92	6,561	42To3520	12	2.55	8,330
42To1872	29	2.92	6,561	42To3520	37	2.55	8,330
42To1872	4	2.92	6,561	42To3520	43	2.55	8,330
42To1872	49	2.92	6,561	42To3522	7	3.06	6,008
42To1873	17	2.32	5,587	42To3522	2	3.06	6,008
42To1873	1	2.32	5,587	42To3522	12	3.06	6,008
42To1873	25	2.32	5,587	DPGIF	811	1.38	11,350
42To1873	20	2.32	5,587	DPGIF	526	1.38	11,350
42To1875	1	7.92	6,095	DPGIF	686	1.38	11,350
42To1876	9	6.63	8,773	DPGIF	452	1.38	11,350
42To1878	11	3.12	9,155	DPGIF	479	1.38	11,350
42To1878	3	3.12	9,155	DPGIF	381	1.38	11,350
42To1878	14	3.12	9,155	DPGIF	208	1.38	11,350
42To1921	9	8.97	10,692	DPGIF	867	1.38	11,350
42To1922	10	4.43	11,162	DPGIF	521	1.38	11,350
42To1924	120	2.39	10,236	DPGIF	733	1.38	11,350
42To1924	102	2.39	10,236	DPGIF	457	1.38	11,350
42To1924	13	2.39	10,236	DPGIF	885	1.38	11,350
42To2551	24	4.46	3,997	DPGIF	735	1.38	11,350
42To2551	57	4.46	3,997	DPGIF	380	1.38	11,350
42To2551	15	4.46	3,997	DPGIF	902	1.38	11,350
42To2551	30	4.46	3,997	DPGIF	506	1.38	11,350
42To2552	4	2.26	4,601	DPGIF	876	1.38	11,350
42To2552	1	2.26	4,601	DPGIF	215	1.38	11,350
42To2552	12	2.26	4,601	DPGIF	624	1.38	11,350
42To2553	3	17.58	5,529	DPGIF	847	1.38	11,350
42To2554	7	2.92	6,435	DPGIF	879	1.38	11,350
42To2554	12	2.92	6,435	DPGIF1942	.	27.12	15,043
42To2554	6	2.92	6,435	DPGIF1945	1	7.31	5,873
42To2554	44	2.92	6,435	DPGIF1946	.	6.83	5,959
42To2555	4	2.58	6,767	DPGIF2414	1	5.20	18,478

Site ID	FS#	Weight (g)	Distance to Delta Margin (m)	Site ID	FS#	Weight (g)	Distance To Delta Margin (m)
42To2556	54	2.06	3,838	DPGIF2415	1	25.75	19,073
42To2556	28	2.06	3,838	DPGIF2447	.	17.43	7,531
42To2556	46	2.06	3,838	DPGIF2452	.	37.18	15,743
42To2556	23	2.06	3,838	DPGIF2453	.	17.97	15,705
42To2557	1	3.34	3,377	DPGIF2523	.	14.87	8,755
42To2558	7	2.15	2,668	DPGIF2527	.	30.49	8,635
42To2558	9	2.15	2,668	DPGIF2529	.	35.49	7,676
42To2558	8	2.15	2,668	ISO-7	5	4.67	15,016
42To2558	3	2.15	2,668	ISO-8	6	3.46	14,931

Spearmans Rho: $r_s = 0.116$, $n = 205$, $p = 0.099$

GIS-based Spatial Analyses

Distance-to-Channel Analysis. To compare the relationships between Pre-archaic and Archaic sites and projectile points and the ORB channel system, I employed student's *t*-tests. This analysis included the entire dataset of 226 sites (188 Pre-archaic, 26 Archaic, and 12 multi-component) and 303 projectile points (251 Pre-archaic and 52 Archaic) (see Tables 2.1 and 2.2) and allowed the locations of Pre-archaic and Archaic sites and projectile points to be evaluated for significant differences. I expected Pre-archaic sites and points to be located significantly closer to the ORB channels than Archaic sites and points. I first ran a student's *t*-test on both the entire site and projectile point datasets, respectively. Because it may be possible for the Pre-archaic and Archaic datasets to be significantly different from one another at different distances from the ORB channels, I also conducted *t*-tests on three dataset subsamples for each period: (1) <100 m from the nearest channel; (2) 100-500 m from the nearest channel; and (3) >500 m from the nearest channel. The results of projectile point distance-to-channel analysis demonstrate variation between the *p*-values of the four *t*-tests conducted, indicating that distance cutoffs (i.e., buffers) do impact the results (Table 4.10); however, regardless of the buffer distance used, no results were statistically significant.

Table 4.10. Results of Projectile Point Distance-to-Channel Analysis.

	Mean Distance to Nearest Channel (m)		*t*-test Results		
Distance Cutoffs	**Pre-archaic**	**Archaic**	***t*-score**	***df***	***p***
No Cutoff	350 (σ = 976, n = 251)	630 (σ = 1,285, n = 52)	1.775	301	0.077
<100m	46 (σ = 29, n = 135)	45 (σ = 21, n = 19)	0.046	152	0.963
100-500m	168 (σ = 69, n = 94)	177 (σ = 60, n = 20)	0.51	112	0.611
>500m	3241 (σ = 1,761, n = 22)	2,464 (σ = 1,803 n = 13)	1.269	33	0.213

The results of site distance-to-channel analysis also demonstrate variation between *p*-values of the four *t*-tests conducted (Table 4.11), and in one case – sites located 100-500 m from the nearest channel – there is a significant difference: Pre-archaic sites (μ = 179 m) are located significantly closer to channels than Archaic sites (μ = 229 m). Sites from the two periods do not differ significantly when the other two buffer distances are used.

Table 4.11. Results of Site Distance-to-Channel Analysis.

	Mean Distance to Nearest Channel (m)		*t*-test Results		
Distance Cutoffs	**Pre-archaic**	**Archaic**	***t*-score**	***df***	***p***
No Cutoff	243 (σ = 615, n = 200)	463 (σ = 567, n = 38)	1.654	212	0.1
<100m	49 (σ = 29, n = 108)	31 (σ = 25, n = 12)	1.365	104	0.175
100-500m	179 (σ = 68, n = 77)	229 (σ = 110, n = 21)	2.366	86	0.02
>500m	1,850 (σ = 1,461, n = 15)	1,645 (σ = 657, n = 5)	0.288	18	0.777

Nearest Neighbor Analysis. I employed nearest neighbor analyses (NNA) on the Pre-archaic and Archaic site samples to further evaluate differences between the locations of Pre-archaic and Archaic sites. I expected Pre-archaic sites to demonstrate significant clustering due to a lack of habitable surfaces (i.e., dry ground) in the ORB during the wetland period. Conversely, I expected that Archaic sites should not be clustered since, following the disappearance of the ORB wetland, dry ground should have no longer been uncommon. The results of NNA show that both Pre-archaic (0.56) and Archaic (0.75) sites exhibit clustering as denoted by their nearest neighbor ratios (NNR) of <1.00 (Table 4.12). *Z*-scores for the two periods (Pre-archaic z = -11.584, p = <0.01 and Archaic z = -2.48, p = <0.05) indicate that both samples are significantly clustered but at different confidence levels.

Table 4.12. Results of Nearest Neighbor Analysis.

	Nearest Neighbor Analysis Results		
Period	**NNR**	***z*-score**	***p***
Pre-archaic	0.56	-11.58	<0.01
Archaic	0.75	-2.48	<0.05

Toolstone Procurement Analyses

If wetlands restricted pedestrian travel during the Pre-archaic occupation of the ORB, then I expected that toolstone procurement strategies should reflect differences in the accessibility of the region's toolstone sources due to the substantial barrier the wetlands would have represented. In the absence of such wetlands later in time, I expected that travel costs to different toolstone sources may have been significantly altered. I used LCP analysis and a Fisher's exact test to determine if Pre-archaic toolstone procurement choices may have been influenced by increased travel costs imposed by the presence of a large wetland in western Utah and to compare toolstone source representation between Pre-archaic and Archaic assemblages.

Least Cost Path Analysis. I expected that the presence of an ORB wetland during the Pre-archaic period would have caused differences in travel costs between the proximal ORB and northern and southern obsidian sources. Figure 4.1 and Table 4.13 show the variation in LCP travel from the proximal ORB to Browns Bench and Topaz Mountain obsidian sources between the wetland restricted Pre-archaic and later Archaic periods. Without the presence of wetlands, the LCP travel distance to Topaz Mountain, located southeast of the proximal ORB, decreases by 23.47 km – minimally altering its accessibility between the Pre-archaic and Archaic periods. Access to Browns Bench, however, is more dramatically affected, with a 103.09 km decrease in LCP travel distance between the two periods. These changes in travel distances suggest that Browns Bench obsidian became less costly for Archaic groups to access once the ORB desiccated.

The relative frequencies of Topaz Mountain and Browns Bench obsidian within the sample of sourced artifacts (Table 4.14) show increased procurement of Topaz Mountain obsidian and decreased procurement of Browns Bench obsidian during the Archaic period compared to the Pre-archaic period – exactly the opposite of my expectation that due to decreased travel costs, Browns Bench obsidian should be better represented in the Archaic sample.

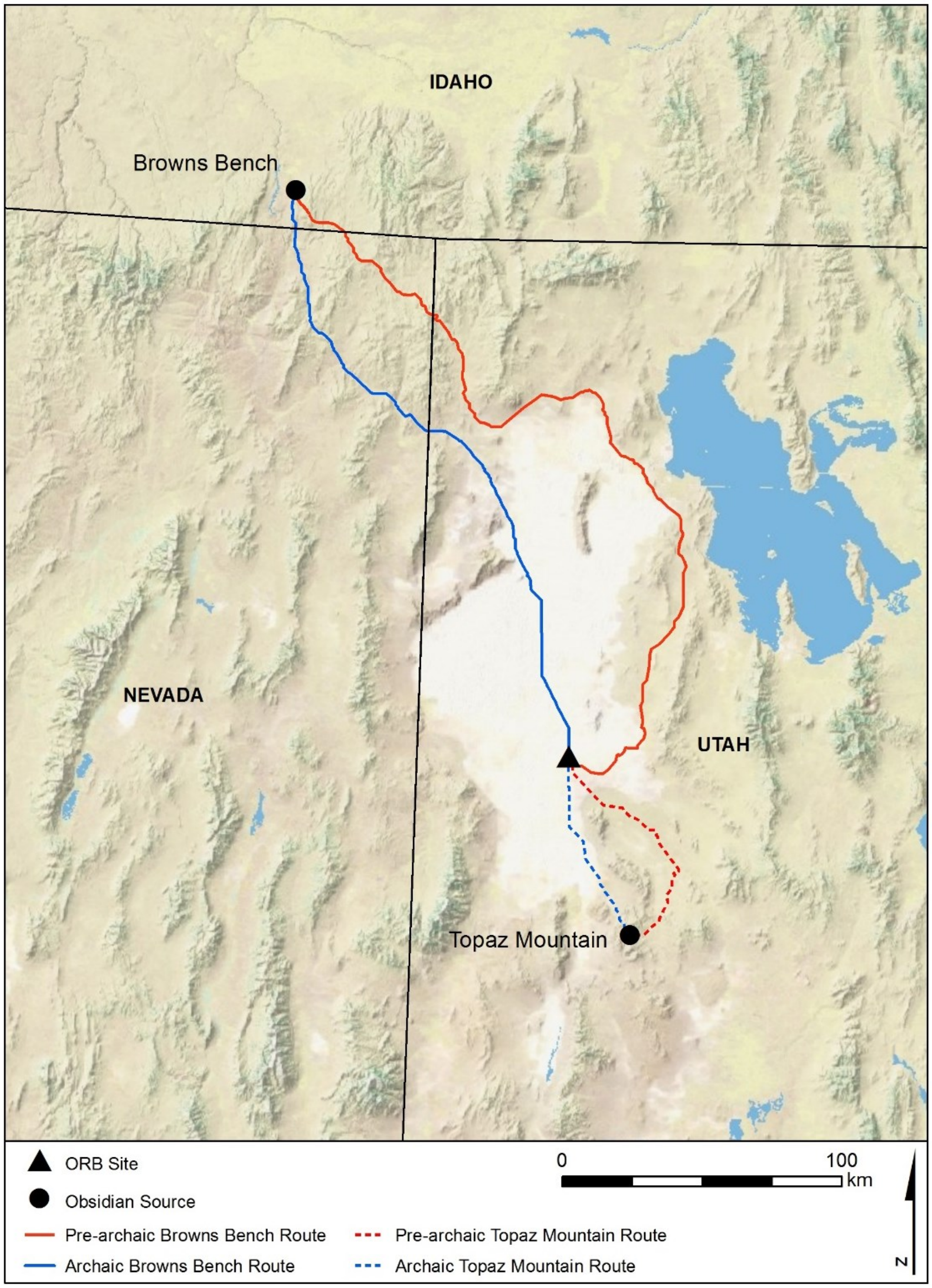

Figure 4.1. LCP routes from the proximal ORB to Browns Bench obsidian source and Topaz Mountain obsidian source for the Pre-archaic and Archaic periods. Image source: ESRI.

Table 4.13. LCP Travel Distances from the Proximal ORB to Obsidian Sources during the Pre-archaic and Archaic Periods.

Obsidian Source	Distance (km)	
	Pre-Archaic	Archaic
Topaz Mountain	95.55	72.08
Browns Bench	353.48	250.39

Table 4.14. Frequencies of Topaz Mountain and Browns Bench Obsidian in the Proximal ORB Samples.

Obsidian Source	Pre-archaic	Archaic
Topaz Mountain	153 (64.8%)	11 (73.3%)
Browns Bench	49 (20.8%)	2 (13.3%)

Note: Values in parentheses represent frequencies relative to the entire sourced obsidian sample.

Fine Grained Volcanic Toolstone in the ORB

Obsidian represents only one of the raw material types utilized in the ORB. Recent studies have identified a number of FGV sources in the region (Duke 2011; Page 2008; Page and Duke 2015). These studies have shown that FGV makes up a significant component of proximal ORB lithic assemblages, ~ 45% during the Pre-archaic period with diminishing frequencies during the Archaic period (Page 2008; Page and Duke 2015), and provide important information on the material's prehistoric use in the region. Despite FGV's importance as a toolstone resource in the ORB, changes in patterns of its procurement were not considered in the current study. This decision was based on the location of FGV sources, which occur mostly to the east and to the west of the ORB (Figure 4.2). The location of these sources relative to the ORB's southeastern entrance should have resulted in a less pronounced change in the accessibility of FGV (compared to that of north/south oriented obsidian sources) between the Pre-archaic and Archaic periods. Page and Duke's (2015) comparison of proximal ORB projectile points supports this inference: their results show no significant difference in the representation of western and eastern FGV sources through time.

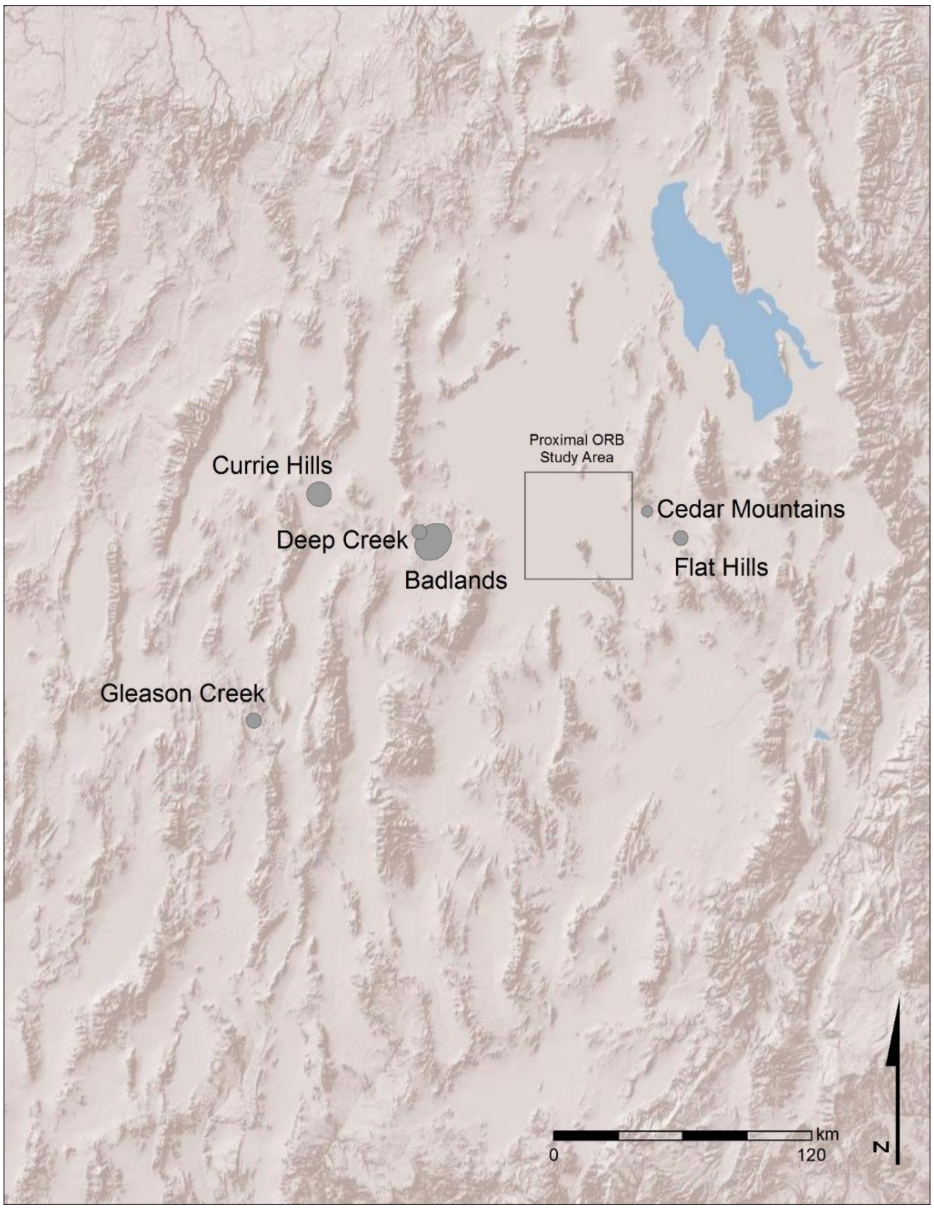

Figure 4.2. Location of FGV sources represented in the ORB. Data source: David Page, DRI. Image Source: ESRI.

Direction of Procurement Analysis. Figures 4.3 and 4.4 illustrate the frequency and general direction of obsidian procurement for the ORB study area during the Pre-archaic and Archaic periods, respectively. I simplified my analysis by combining sources of obsidian (based on their location relative to the ORB's southeastern margin) into northern and southern categories. I used a Fisher's exact test to compare the procurement frequencies of northern and southern obsidian between the Pre-archaic and Archaic periods. I expected that the exploitation of northern and southern obsidian sources should change significantly between the Pre-archaic and Archaic periods.

The results of the Fisher's exact test indicate no significant differences in the procurement of northern and southern obsidian between the Pre-archaic and Archaic periods (Table 4.15). Based on the distances of northern and southern obsidian sources from the proximal ORB (see Table 3.1), these results do not meet the expectation that the presence of a wetland would have resulted in significantly less frequent exploitation of northern obsidian by Pre-archaic occupants of the ORB relative to that of Archaic occupants.

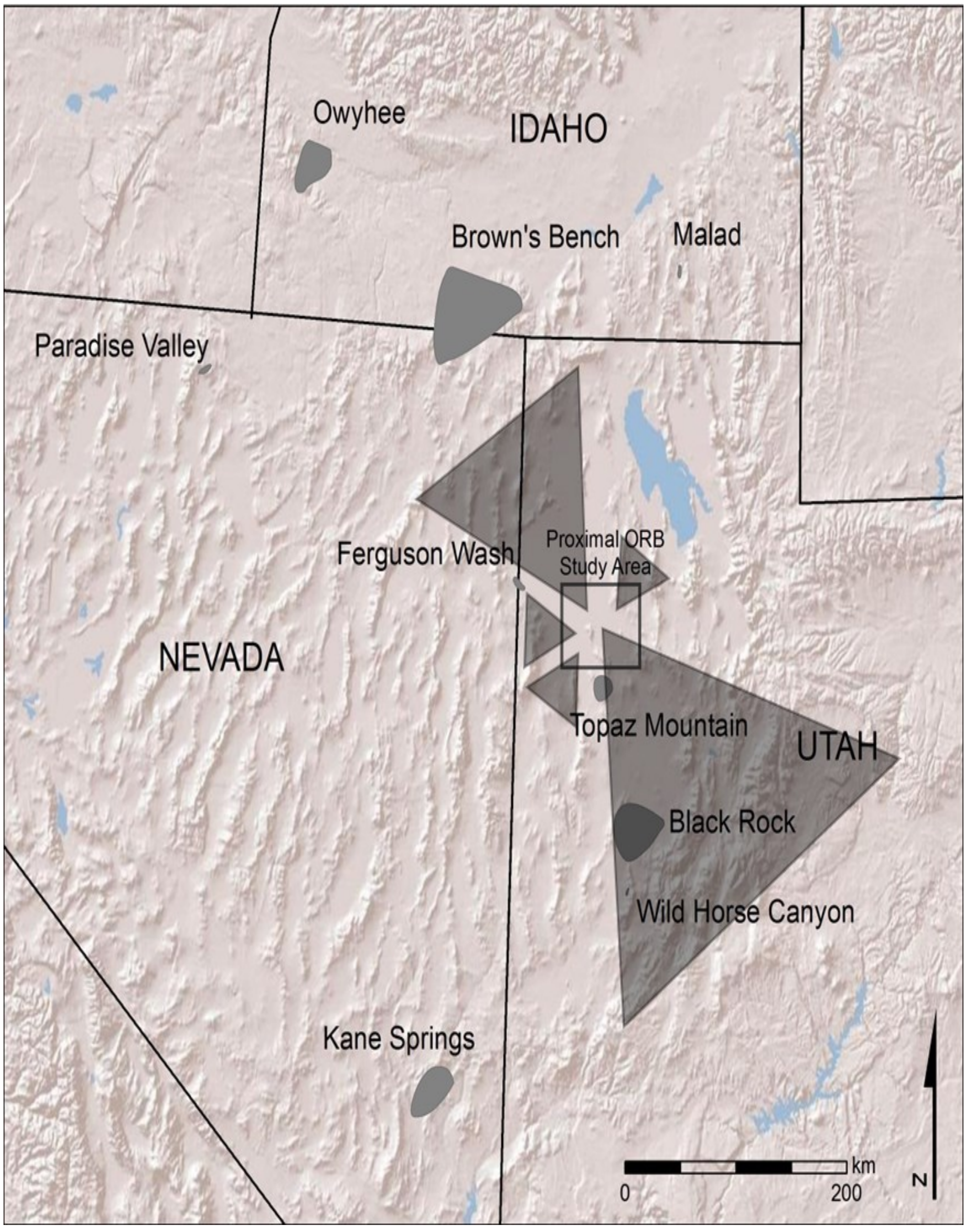

Figure 4.3. Direction and relative frequency of Pre-archaic obsidian procurement in the proximal ORB: small triangle = <10%; intermediate triangle = 10-50%; and large triangle = >50%. Data source: David Page, DRI. Image source: ESRI.

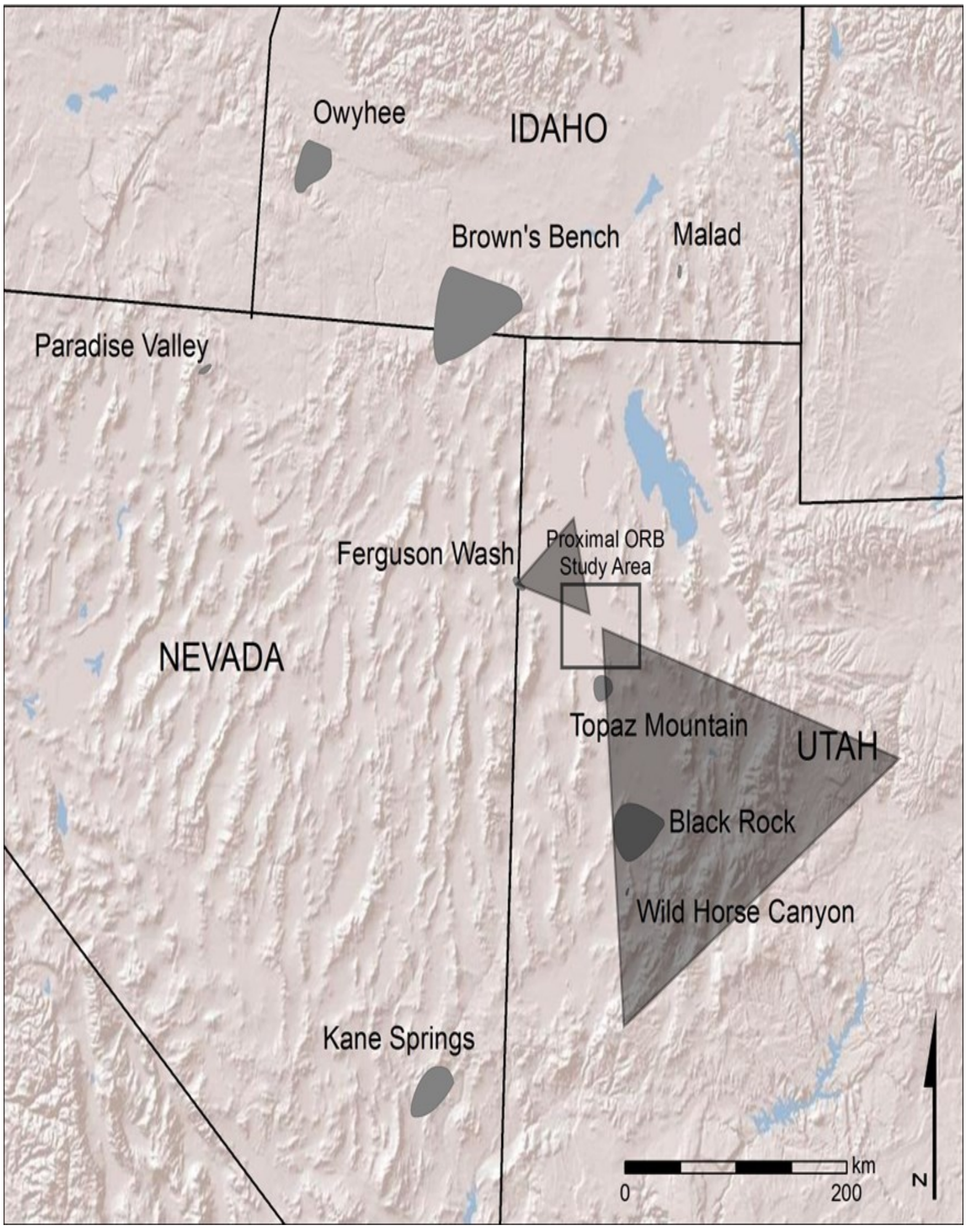

Figure 4.4. Direction and relative frequency of Archaic obsidian procurement in the proximal ORB: small triangle = 12.5%; large triangle = 87.5%. Data source: David Page, DRI. Image source: ESRI.

Table 4.15. Frequencies of Northern and Southern Sourced Obsidian in the Proximal ORB.

Time Period	Northern	Southern	Total
Pre-archaic	60	175	235
Archaic	2	13	15
Total	62	188	250

p = 0.370, Fisher's exact test

Summary

The results of these analyses provide several lines of evidence regarding the land-use practices of prehistoric hunter-gatherers in the ORB (Table 4.16). They help clarify perceived differences between the Pre-archaic and Archaic occupations of the region and contribute to the understanding of how environmental factors impacted the behaviors of prehistoric populations in the ORB. Lithic assemblages in the ORB show no patterning in terms of reduction sequences (i.e., tool-to-debitage ratios, biface stages, projectile point weights) that link Pre-archaic groups more significantly to the basin's inverted channels than Archaic groups. Neither Pre-archaic nor Archaic assemblages are located significantly nearer or farther from the ORB's channels (with the exception of significantly nearer Pre-archaic sites located between 100 and 500 m from channels). Pre-archaic sites do exhibit significant clustering but the same is true of Archaic sites. Furthermore, despite a decrease in travel costs to procure Browns Bench obsidian with the disappearance of wetland-imposed constraints during the Archaic period, the source was utilized less frequently. Lastly, the frequencies of obsidian procured from northern and southern sources did not change significantly between the Pre-archaic and Archaic periods. Combined, these results do not meet the expectations outlined in Chapter 3 and, ultimately, they do not support the hypothesis that Pre-archaic hunter-gatherers in the ORB were restricted to movement along the basin's channels by the presence of a wetland while Archaic occupants were not. In Chapter 5, I discuss the relevance of these results in detail as they relate to the hypothesis and consider their significance when applied to current models of prehistoric land-use and mobility in the ORB.

Table 4.16. Hypothesis, Expectations, and Results of Analyses in this Study.

Hypothesis	Analyses	Expectations: Pre-archaic	Expectations: Archaic	Results: Pre-archaic	Results: Archaic
Pre-archaic travel into and within the ORB wetland was restricted to inverted, elevated channels whereas Archaic travel was not.	Tool-to-debitage ratio analysis	Ratios increase as distance from ORB entry increases	No correlation between ratios and distance from ORB entry	No significant correlation present *Significant positive association present	No significant correlation present
	Biface stage analysis	Biface reduction stages increase as distance from ORB entry increases	No association between biface reduction stages and distance from ORB entry	Weak positive association present *No significant association present	No significant association present
	Projectile point weight analysis	Projectile point weight decreases as distance from ORB entry increases	No association between projectile point weight and distance from ORB entry	No significant association present *No significant association present	No significant association present
	Site and projectile point distance to ORB channels analysis	Sites and points are located in significant association with ORB channels	No association between sites or points and the ORB channels	Sites located 100-500 m from channels significantly nearer. No significant projectile point association	Sites located 100-500 m from channels significantly farther. No significant projectile point association
	Site clustering (nearest neighbor analysis)	Sites exhibit significant clustering	Sites do not exhibit significant clustering	Sites exhibit significant clustering	Sites exhibit significant clustering
	Direction of Procurement analysis	Overrepresentation of southern sources and underrepresentation of northern sources	Increased procurement of Northern sources	No significant difference in the procurement of northern and southern obsidians between the Pre-archaic and Archaic periods.	
	Least Cost Path Analysis	More costly than during the Archaic to travel to Browns Bench obsidian source	Increase in the use of Browns Bench obsidian	Travel to Browns Bench Obsidian is more costly during the Pre-archaic than in the Archaic	Frequency of Browns Bench obsidian declines during the less costly, Archaic period

Note: Results marked with "*" indicate the use of delta entry point for analysis.

CHAPTER 5

Discussion

Several researchers have suggested that the Pre-archaic occupants of the ORB centered their activities on a braided system of inverted channels that stand 0.5-4 m above the mudflats and delta of the basin (Madsen et al. 2015b; Oviatt et al. 2003; Schmitt et al. 2007). The presence of a large wetland, which persisted into the late early Holocene (ca. 8,500 ^{14}C yr BP), has led researchers to suggest that parts of the basin would have been inaccessible due to the presence of water (Page and Duke 2015), and that the inverted channels served as travel corridors (Oviatt et al. 2003) through which Pre-archaic populations accessed wetland resources (Schmitt et al. 2007). In addition to the apparent restrictions to Pre-archaic movement within the ORB, lithic assemblages from this interval frequently contain extensively reworked projectile points and tools, suggesting infrequent toolstone procurement forays (Schmitt et al. 2007), a consequence of restricted access to raw material sources outside of the basin (Madsen et al. 2015b). With the desiccation of the ORB near the end of the early Holocene, the subsequent Archaic occupation of the ORB should have taken on a different form than that of the wetland restricted Pre-archaic occupation (Madsen et al. 2015b). The primary purpose of this study has been to evaluate such ideas using quantitative evidence capable of supporting or refuting this model of ORB land-use.

At the outset of this study, I outlined the utility of lithic- and GIS-based approaches to evaluating archaeological data. Researchers (e.g., Andrefsky 1994, 2010; Beck et al. 2002; Jones et al. 2003; Page and Duke 2015; Smith 2011b; Smith et al. 2013; Taliaferro et al. 2010) have used these approaches in a variety of ways to model prehistoric adaptive strategies as they relate to lithic technological organization, mobility, and land-use. I employed such methods to evaluate attributes of ORB lithic assemblages (tool-to-debitage ratios, biface reduction stages, and projectile point weights), to analyze ORB site and projectile point locations, and to compare relative abundances of geochemically sourced toolstone at ORB sites with expectations derived from modeled costs of toolstone procurement. Performing these analyses allowed me to test the hypothesis that Pre-archaic travel into and within the ORB wetland was restricted to inverted, elevated channels whereas Archaic travel was not. At face value, the results generally do not support current models of Pre-archaic occupation in the ORB. Rather, they suggest that Pre-archaic land-use was no more focused on ORB channels than that during the Archaic period. I discuss my interpretation of these results and their significance to current models of ORB land-use below.

Lithic Assemblage Attributes

The lack of toolstone sources in the ORB delta provides a context in which examining patterns of lithic reduction, use, and discard can be useful for reconstructing prehistoric behavior. Previous research has shown that as lithic artifacts move farther from their geologic sources, they tend to decrease in both weight and size (Beck et al.

2002; Clarkson 2002; Eerkens et al. 2007; MacDonald 2008). This pattern is the function of continued resharpening and modification as artifacts are used and transported across the landscape (Andrefsky 2010). Additionally, rates of tool discard often increase along with distance from toolstone sources (Eerkens et al. 2007, 2008). Based on these observations, if Pre-archaic hunter-gatherers faced limited access to raw material sources and constrained movement within the basin while later Archaic groups did not, lithic procurement, use, and discard should have differed between the periods.

Tool-to-debitage Ratios, Biface Reduction Stages, and Projectile Point Weights

I began my lithic-based analyses with the expectation that Pre-archaic and Archaic lithic assemblages would differ significantly. Pre-archaic assemblages should exhibit higher tool-to-debitage ratios, increased biface reduction, and decreased projectile point weights as they increase in distance from the basin's entry point. Conversely, Archaic assemblages should not necessarily exhibit these trends because pedestrian travel would not have been confined to the channels and access into the basin would have been less restricted. The results of my analyses do not meet these expectations (Table 5.1). Both Pre-archaic and Archaic lithic assemblages demonstrate decreasing ratios of tools to debitage with increased distance from the ORB entry point. Bifaces from Pre-archaic assemblages do exhibit increased reduction with increased distance into the basin while Archaic bifaces do not; however, the positive association demonstrated by the Pre-archaic sample is relatively weak ($r_s = 0.179$ $n = 153$, $p = 0.027$). Projectile point weights from both periods show no significant decrease as distance into the ORB increases. While the results are altered by the use of the alternative entry point located at the delta margin, they too fail to meet my expectations (Table 5.2). In this case tool-to-debitage ratios do increase with increased distance to the entry point, however, neither biface reduction stages nor projectile point weights exhibit patterning consistent with my expectations. These results do not support the hypothesis that Pre-archaic hunter-gatherers in the ORB were tethered to the basin's channel system and faced increased travel constraints relative to later Archaic populations. Below, I consider possible reasons why the results did not conform to my expectations.

Table 5.1. Summary of Expectations and Results of ORB Entry Lithic Analyses.

Measure	**Pre-archaic**		**Archaic**	
	Expectation	Result	Expectation	Result
[a] T/D Ratio	Increase	Decrease	No Increase	No Increase
	Increase	Increase		
[b] Bi Reduction	Increase	Weak Increase	No Increase	No Increase
[c] PPT Weight	Decrease	No Decrease	No Decrease	No Decrease

[a] T/D – Tool-to-debitage
[b] Bi – Biface
[c] PPT – Projectile Point

Table 5.2. Summary of Expectations and Results of Delta Margin Lithic Analyses.

Measure	**Pre-archaic**	
	Expectation	Result
[a] T/D Ratio	Increase	Increase
[b] Bi Reduction	Increase	No Increase
[c] PPT Weight	Decrease	No Decrease

[a] T/D – Tool-to-debitage
[b] Bi – Biface
[c] PPT – Projectile Point

Lithic Scavenging in the ORB

My analyses of ORB lithic assemblages focused on movement constraints and distance from raw material sources as two primary variables influencing lithic assemblages; however, other researchers (e.g., Beck and Jones 2015; Duke 2011; Page and Duke 2015; Surovell 2003, 2009) have considered the potential influence of additional factors (e.g., scavenging of lithic materials). Given the paucity of geologic sources of toolstone in the ORB delta, Archaic occupants may have scavenged toolstone discarded there by Pre-archaic groups, which could obscure my expected trends. Extensive weathering of later artifact types is one indication that scavenging may have occurred in the ORB (Page and Duke 2015). Beck and Jones (2015:65) suggest that scavenging was likely a significant strategy for occupants of the proximal ORB "during at least some period of time". The point forms bearing the most distinctive evidence of recycling in their analysis is the Dugway Stubby (Figure 5.1). Beck and Jones (2015) consider these points to be early Holocene in age and a seriation of stemmed bifaces from ORB sites places their use prior to 8,800 ^{14}C yr BP (Schmitt et al. 2007). If this temporal placement is correct, then even if Stubbies were manufactured using scavenged material, only Pre-archaic groups should be represented by their presence. In a toolstone-poor environment such as the ORB, scavenging likely did occur, and such behavior may have obscured any correlation between assemblage and artifact characteristics and distance from the proposed ORB delta entry point. It is important to note, however, as Duke (2011) points out, that relying on discarded tools and the ability to locate such tools would have been a risky, and therefore unlikely, raw material procurement strategy, especially as hunter-gatherers moved farther into the basin away from toolstone sources.

Stockpiling lithic material for future use is a second toolstone provisioning strategy that could potentially affect my results. If raw material for stockpiling was transported into the ORB, its eventual use (and introduction into a sequence of production, maintenance and discard) would differ from that procured and transported for more immediate use, altering lithic reduction patterns across the landscape. As noted above, Duke (2011) suggests that the risk of not locating caches makes the dependence upon such a strategy unlikely. Duke and Young (2007) conclude that the large size of the ORB wetland would have allowed for extended spans of occupation by otherwise mobile groups. They contend that prolonged episodes of occupation during this period prompted groups to provision the ORB (i.e., the *place*; *sensu* Kuhn 1995) with toolstone acquired via logistical forays. Surovell (2009) shows that amounts of surplus toolstone increase

Figure 5.1. Dugway Stubby projectile point showing extensive weathering and reworking, approximately 3 cm in length; after Page (2008).

with longer occupation spans; however, stockpiling toolstone requires a potentially costly initial procurement investment (Surovell 2003) and Duke (2011) suggests that the considerable distances between the distal ORB and sources of toolstone (at least 60 km) should have caused groups to focus primarily on efficient toolstone transport by procuring and carrying the least amount of raw material necessary. Although Duke's (2011; Duke and Young 2007) research focuses on the more northern ORB, his observations are likely also applicable to the proximal ORB, where raw material sources are located at distances great enough (~50-400 km) to conceivably increase the costs of employing a scavenging or stockpiling strategy.

Site and Projectile Point Locations

As noted, researchers have hypothesized that Pre-archaic sites in the ORB are clustered along the basin's inverted gravel and sand channels (Madsen et al. 2015b; Oviatt et al. 2003; Schmitt et al. 2007). To test this hypothesis, I evaluated the distance of sites and projectile points from the ORB's channels, expecting to find a significant difference between those dating to the Pre-archaic period (when movement should have been largely confined to the channel system) and those dating to the Archaic (when movement should have been less constrained). Student's *t*-tests show that projectile points and archaeological sites from the two periods exhibit no significant differences in their location relative the ORB's channels (projectile points $p = 0.077$; sites $p = 0.1$). Instead, the mean distances of sites from their nearest channel (Pre-archaic $\mu = 243$ m;

Archaic $\mu = 463$ m) suggest that sites from both periods are not closely tied to the inverted ORB channels.

Nearest neighbor analysis (NNA) shows that Pre-archaic sites exhibit significant clustering relative to one another (NNR = 0.56; $p = <0.001$). Considered singularly, these results meet the expectation that a lack of dry ground during this interval would produce a pattern of site clustering where habitable living surfaces could be found (e.g., the raised channel system). The results of NNA using the Archaic site sample, however, also show significant clustering at the $\alpha = .05$ level. Without the presence of a wetland to influence the placement of later sites, a pattern of clustering was not expected. It is possible that the efforts researchers have devoted to mapping the basin's channel system introduces bias to the results of this analysis; however, several parcels of ORB land that cannot be reasonably associated with the channel system have undergone survey for cultural material (Figure 5.2), suggesting that such a bias is unlikely.

Considering the results of NNA in tandem with those of the Student's *t*-tests and the mean distances of sites to channels, it appears that the dry ground offered by the inverted channels may not be the only explanation for the clustering of Pre-archaic sites.

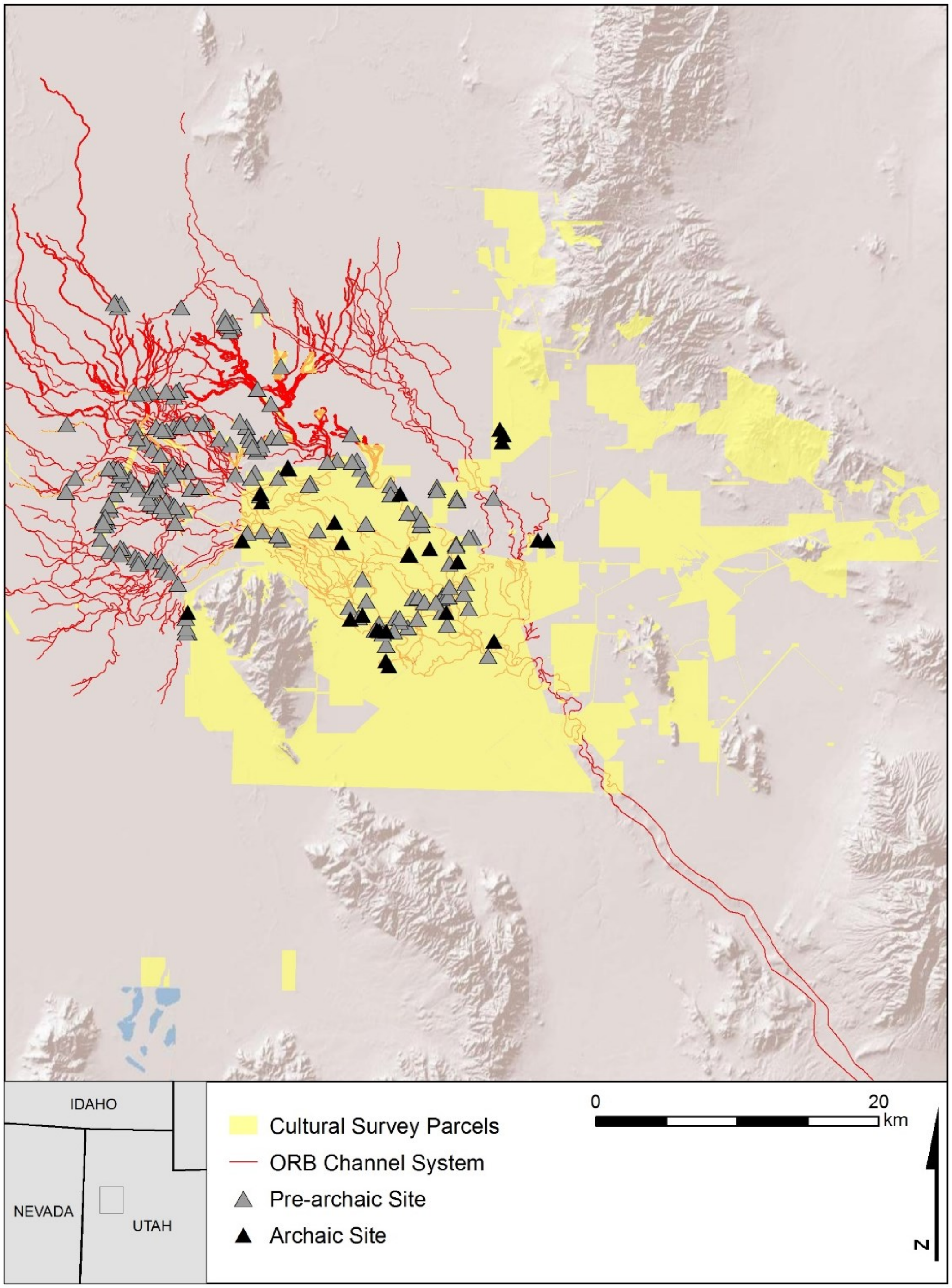

Figure 5.2. Map of the ORB showing cultural survey parcels in relation to the ORB's channel system and archaeological sites. Data source: David Page, DRI and Rachel Quist, DPG. Image source: ESRI.

Instead, some other variable(s) may have influenced both Pre-archaic and Archaic site location. Additional analysis incorporating the specific locations where site clustering and dispersal are statistically significant may aid in further conceptualizing the relationship between site placement and the variables of the ORB landscape.

Pre-archaic and Archaic Toolstone Procurement

Recent research has generated a considerable amount of geochemical sourcing data for the ORB and the surrounding areas (Arkush and Pitblado 2000; Duke 2011; Hughes 2014; Jones et al. 2003, 2012; Page 2008; Page and Duke 2015). These studies have frequently been concerned with explaining Pre-archaic mobility patterns at a regional scale. For this study, I employed sourcing data from the proximal ORB to test the hypothesis that the relative frequencies of raw material sources at sites should change as a result of differential access to toolstone sources by wetland-constrained Pre-archaic populations and less constrained Archaic populations. As I outline below, the results of my analyses fail to support this hypothesis.

Travel Costs for Obsidian Procurement

The disappearance of a formidable geographic barrier such as the ORB wetland should have altered the frequencies of northern and southern toolstone sources in part because of changes in the travel costs incurred when traveling to them. For example, Page and Duke (2015) suggest that the ORB wetland likely required groups to deviate from direct routes to toolstone sources and forced them in some cases (e.g., when traveling to northern sources such as Browns Bench) to follow more circuitous routes. In Chapter 4, I employed a LCP analysis to consider if, as Page and Duke (2015) suggested, northern raw material sources were more costly to procure when the ORB wetland was present and less costly to procure when it disappeared. As expected, LCP travel distance (and in turn, cost) to the commonly-used northern obsidian source, Browns Bench, decreased substantially in the absence of the wetland (353.5 km vs. 250.3 km), whereas the southern commonly-used Topaz Mountain source experienced a less dramatic decrease (95.6 km vs. 72.1 km). The results of my LCP analysis support Page and Duke's (2015) suggestion that the ORB wetland would have posed a substantial obstacle to pedestrian travelers traveling to toolstone sources.

The modeled travel distances indicate that the diminution of the wetland would have decreased the cost of procuring Browns Bench obsidian. As such, I expected it to become more common in Archaic assemblages. The results do not meet this expectation: Browns Bench obsidian (relative to the entire sourced obsidian sample) actually decreases across time, dropping from 20.8% during the Pre-archaic period to 13.3% during the Archaic period. A possible explanation for these results is that the inhospitable conditions of the Archaic ORB made travel across the basin's northern mudflats an unappealing option. However, while Archaic groups did not likely follow the exact routes modeled here, the results do suggest that the absence of a wetland decreased access restrictions to Browns Bench obsidian during the Archaic period making its decreased use during this interval unexpected. Topaz Mountain obsidian shows an expected increase in the Archaic period but it is difficult to gauge whether or not the increase from 64.8% to 73.3% between the Pre-archaic and Archaic periods is significant given the minimal difference in modeled travel distances between periods. Page and Duke (2015:46) also show that Topaz Mountain obsidian increases over time along with a synchronous decrease in the representation of all other sources of obsidian present in the ORB, concluding that "lithic transport into the ORB delta increased in intensity into the Early Holocene". It is possible that the increase in Topaz Mountain obsidian seen in my study is not a function of decreased travel distances associated with the decline of the ORB wetland but instead reflects continued and increased exploitation of the nearest obsidian source during a period when other, smaller lacustrine resource patches had declined even further. This could be the case if, as environmental conditions deteriorated in the eastern Great Basin, the few resource patches large enough to remain productive experienced increased visitation. An increase in the Archaic use of Topaz Mountain obsidian related to higher levels of human occupation is unlikely, however, given Louderback et al.'s (2010) evidence for decreased population density in the Bonneville Basin between 8,000 and 4,000 ^{14}C yr BP. I consider regional patterns of obsidian procurement to develop other potential explanations for the shifts seen in the ORB below.

Direction of Procurement

A Fisher's exact test comparing the frequencies of northern (Browns Bench, Malad, Owyhee, Paradise Valley) and southern (Black Rock, Kane Springs, Topaz Mountain, Wild Horse Canyon) obsidian sources in Pre-archaic and Archaic assemblages indicates that they are not significantly different (*p* = 0.370). As outlined earlier, the presence of a wetland increased the cost of pedestrian travel to northern toolstone sources. Researchers have pointed out that numerous variables likely influenced technological organization strategies (Andrefsky 2010; Beck et al. 2002; Jones et al. 2003). Page (2008) and Duke (2011) both suggest that the mechanical properties of raw material (e.g., knappability and durability) were likely influences on toolstone selection, but together, they demonstrate that "toolstone representation in the [ORB] delta fits a general distance decay model" in which closer sources are better represented than farther sources (Page and Duke 2015:35). That trend suggests that accessibility was an important consideration in the toolstone-poor ORB. Their comparison of frequencies of Browns Bench and Topaz Mountain obsidian frequencies for both the proximal and the distal ORB show increased amounts of the southern Topaz Mountain source and decreased amounts of the northern Browns Bench source between the Pre-archaic and Archaic periods (Page and Duke 2015) – exactly the opposite of my prediction that a TP/EH wetland may have dissuaded Pre-archaic groups from exploiting northern raw material sources. At Danger Cave, located on the western edge of the Bonneville basin, Page and Skinner (2008) observed a continued preference for Browns Bench obsidian throughout the cave's occupation, despite the fact that the Ferguson Wash and Topaz Mountain obsidian sources are located closer to the cave. Page and Skinner (2008) suggest that geographic barriers such as the Gilbert highstand of Lake Bonneville may explain the limited use of southern sources by the site's early occupants. The results of Hughes' (2014) study of obsidian projectile points also at Danger Cave show the same continuity in the use of Browns Bench obsidian between the Pre-archaic and Archaic periods. The continued preference for Browns Bench obsidian during the cave's later occupation suggests that the Archaic desiccation of an ORB wetland had little effect on toolstone procurement decisions. Alternatively, the reduction in Browns Bench obsidian across time in the ORB may simply reflect broader shifts in prehistoric mobility and/or toolstone procurement ranges unrelated to the presence/absence of a wetland. For example, at Bonneville Estates Rockshelter on the western edge of the Bonneville Basin, Goebel (2007) reports a shift in obsidian procurement between the Pre-archaic and early Archaic periods. Browns Bench obsidian constitutes over 70% of the Pre-archaic assemblage, while closer Ferguson Wash and Topaz Mountain obsidian each make up less than 10% of the Pre-Archaic assemblage. The opposite trend occurs in the early Archaic assemblage, which is dominated (66%) by obsidian from the closer sources (Ferguson Wash and Topaz Mountain). Goebel (2007) suggests that Pre-archaic groups had more expansive procurement ranges than Archaic groups, and that movement appears to have become restricted to the southern Bonneville basin during the later period. If these observations are correct, then the decreased frequency of Browns Bench obsidian and the increased frequency in Topaz Mountain obsidian observed in the ORB could reflect a regional shift in lithic procurement unrelated to the presence/absence of the ORB wetland. The fact that similar reductions in lithic procurement ranges have been noted elsewhere suggests that this may be the case. For example, Jones et al. (2003) conclude that lithic conveyance zones in the eastern Great Basin become smaller at the end of the early Holocene; Smith (2007, 2010) noted a similar reduction in procurement ranges in northwest Nevada. Those studies provide support for the possibility that my ORB results may simply reflect broader changes that occurred across the Great Basin.

Summary

In this chapter I placed the results of my analyses within a broader context of Bonneville basin archaeology and considered how they related to current models of mobility and land-use in the ORB. By and large, my evaluation of artifact- and assemblage-level lithic attributes, site and projectile point locations, and raw material frequencies has failed to provide support for the hypothesis that Pre-archaic travel was restricted by an extensive wetland to an elevated channel system, whereas Archaic travel was not. I have considered alternate explanations for the patterns revealed by my analyses, including that the ORB wetland was less restricting than researchers have suggested. I also discussed additional regional studies (Goebel 2007; Page and Skinner 2008; Smith 2007, 2010) to place the trends identified in this study within regional shifts in land-use and lithic procurement practices across the Pre-archaic/Archaic transition. In the next chapter, I present some concluding thoughts and point the direction towards future research that may help further refine the ideas developed in this thesis.

CHAPTER 6

Conclusion

In this study, I combined the use of lithic- and GIS-based analyses to evaluate current models of Pre-archaic mobility and land-use in the ORB of western Utah. I developed expectations from established lithic studies focused on raw material availability and use. I tested the hypothesis that pedestrian travel into and within the ORB during the Pre-archaic period (pre-8,000 ^{14}C yr BP) was restricted to the basin's inverted, elevated channels due to the presence of an expansive wetland, whereas movement during the more xeric Archaic period (post-8,000 ^{14}C yr BP) was not.

In Chapter 1, I highlighted differences in climate and environment in the Great Basin between the TP/EH and the middle Holocene. I also provided a broad overview of Great Basin prehistory and the adaptive shifts that occurred near the end of the early Holocene. I reviewed some pertinent lithic studies that highlight the relationship between mobility, raw material availability, and occupation span, and discussed relevant applications of GIS for spatial analysis. These reviews demonstrated the effectiveness of both approaches to the study of prehistoric movement and land-use to evaluate current models of human occupation of the ORB.

Chapter 2 described the materials used in this study, which consist of data collected on 226 archaeological sites and 303 projectile points compiled over eight field seasons of survey by DRI. I described the ORB's geomorphology, history of lake level fluctuation in the Bonneville basin, and the effects of middle Holocene climate change on the once prosperous ORB wetlands and related changes in human adaptation. I also provided an overview of the archaeological record of the area, focusing on lithic technology and projectile point chronology. The latter focus is critical because such artifacts allow sites containing them to be assigned to either the Pre-archaic or the Archaic periods.

In Chapter 3 I detailed the methods of analysis employed for this study. I emphasized an integrative approach by employing several statistical tests and GIS-based spatial analyses to evaluate attributes and locations of ORB lithic assemblages and projectile points. Attributes were chosen because researchers commonly argue that they reflect prehistoric mobility and land-use. I also utilized geochemical sourcing data for 250 ORB sites to compare toolstone frequencies between Pre-archaic and Archaic sites. I examined these frequencies relative to changes in the cost and direction of obsidian procurement between the two periods. These methods allowed me to test the hypothesis using quantitative data and statistical tests.

In Chapter 4 I presented my results. They do not support the hypothesis that pedestrian travel was largely confined to inverted channels (i.e., dry land) when humans first used the proximal ORB delta. Lithic data show few differences between the Pre-archaic (i.e., wetland) and Archaic (i.e., dry) periods. Expectations regarding the relationships between the ORB channel system and tool-to-debitage ratios, biface reduction stages, and projectile point weights were not met. With the exception of a weak positive correlation between Pre-archaic biface reduction and distance into the ORB basin, and a positive association between Pre-archaic tool-to-debitage ratios and increased distance from the delta margin, the tests I implemented failed to identify statistically significant differences between the Pre-archaic and Archaic periods.

In Chapter 5 I considered lithic scavenging and/or stockpiling as possible explanations for my results but ultimately I agree with Duke (2011) and his observations in the distal ORB that dependence on those practices as primary raw material procurement strategies is unlikely. Instead, my results may be best explained by a Pre-archaic occupation of the ORB in which groups were not closely tethered to the basin's channel system.

My evaluation of the spatial relationships between ORB channels and site and projectile point locations also indicate no apparent changes between the Pre-archaic and Archaic periods. While researchers have suggested that Pre-archaic sites are clustered along the basin's channels (Madsen et al. 2015b; Oviatt et al. 2003: Schmitt et al. 2007), results of Student's *t*-tests and nearest neighbor analysis suggest that Pre-Archaic sites and/or projectile points are no more associated with the channels than later Archaic sites. Furthermore, both Pre-archaic and Archaic sites are significantly clustered despite my expectation that if only the former groups were restricted to the dry ground offered by the raised channels, then only their sites should exhibit significant clustering. Because several survey parcels around the ORB lie well beyond the channel system, these results are probably not simply a function of sampling bias due to research being focused primarily on the channels.

Finally, my analysis of obsidian toolstone procurement in the ORB identified unexpected changes in raw material representation between the Pre-archaic and Archaic periods. Despite a substantial decrease in travel distance and, in turn, cost from the proximal ORB to the northern Browns Bench obsidian source following the diminution of the ORB wetland, that raw material is represented less during the Archaic period than the Pre-archaic period. Conversely, Topaz Mountain obsidian, which experienced only a slight decrease in travel distance/cost as the wetlands disappeared, increases by 8.5% during the Archaic period.

The results of a Fisher's exact test indicate that differences in the procurement of northern versus southern obsidians between the Pre-archaic and Archaic intervals are not significant but, as discussed in Chapter 5, other researchers (e.g., Page and Duke 2015) have observed similar patterns of decreased northern and increased southern obsidian procurement between the two periods in the ORB. I also discussed the relatively consistent preference for the more distant Browns Bench obsidian over the more local Topaz Mountain obsidian during both the Pre-archaic and Archaic periods at Danger Cave (Page and Skinner 2008). The Danger Cave data suggests that the desiccation of an ORB wetland during the Archaic interval had little effect on toolstone procurement decisions. Goebel (2007) showed that at Bonneville Estates Rockshelter, a shift from Browns Bench to Topaz Mountain and Ferguson Wash obsidian occurred between the Pre-archaic and early Archaic periods. Like Danger Cave, this decreased reliance on Browns Bench obsidian cannot be attributed to a presence/absence of an ORB wetland. Instead, the shift likely reflects a regional transition towards reduced procurement ranges and preference for more local raw materials during the Archaic period. Broader studies suggest that decreases in procurement range size in the eastern Great Basin between the Pre-archaic and Archaic periods (Jones et al. 2003) and in northwest Nevada (Smith 2007, 2010) occurred. Given these findings, it is possible that changes in the size of procurement ranges, rather than the presence/absence of the ORB wetland, may best explain the patterns observed in obsidian toolstone frequencies in proximal ORB assemblages.

My study provides significant contributions to the ongoing study of prehistoric land-use, mobility, and raw material procurement in the ORB and, more generally, the Great Basin in two ways. First, in terms of the specific environmental and cultural history of the ORB, I have shown that existing models of Pre-archaic movement and land-use there may need to be refined to better account for patterns of lithic reduction, site and artifact location, and raw material procurement highlighted by my analyses. Second, from a methodological standpoint, I demonstrated the utility of integrating lithic- and GIS-based methods to analyze technological and spatial data and test hypotheses about prehistoric mobility, land-use, and possible geographic/environmental constraints.

Future Research

While informative, the results of my study reveal opportunities for future research. As I noted in Chapter 4, the results of my nearest neighbor analysis could be further refined by the use of additional spatial analyses to pinpoint areas where site clustering occurs. This study showed that both Pre-archaic and Archaic sites exhibit significant clustering but the methods I employed were not suited to identify whether sites were clustered in similar or disparate locations. This information may provide insight into the settlement and land-use practices of prehistoric ORB populations. Also, continued cultural survey of the ORB, including areas not related to the channel system, will help to insure the accuracy of these results and those of other spatial analyses.

My suggestion that raw material frequencies in the ORB may reflect broader regional shifts towards use of local toolstone may be further explored through additional lithic analyses. For example, Goebel (2007) shows that the early Archaic assemblage from nearby Bonneville Estates Rockshelter contains more primary reduction flakes than the Pre-archaic assemblage. This observation supports his conclusion that Archaic groups traveled shorter distances with their raw material before manufacturing tools at the rockshelter than their predecessors. Discovery of a similar pattern in ORB assemblages would support a regional model of reduced procurement ranges and increased dependence on local toolstone sources during the Archaic period.

Additionally, the potential to refine models of lithic procurement and mobility has been demonstrated by recent revisions to Jones et al.'s (2003) Eastern Conveyance Zone by Jones et al. (2012). The importance of geochemical sourcing data and its continued collection throughout the Great Basin has been heralded by several researchers (Carey 2013; Page 2008; Jones et al. 2003; Smith et al. 2013). My evaluation of raw material frequencies and toolstone procurement patterns demonstrates that the value of ongoing provenance studies holds true in the ORB. Future work in the region should include the geochemical characterization of both obsidian and FGV artifacts to allow for the growth of the current lithic source distribution dataset and to increase researchers' ability to identify patterns of lithic procurement activities. If followed, the above avenues of future research can contribute to our knowledge of prehistoric ORB occupation and help to conceptualize changes in adaptive strategies that occurred between the Pre-archaic and Archaic periods.

Lastly, as stated in Chapter 1, the unique geomorphology of the ORB, its well-documented environmental past, and the quality of the archaeological record contained there provide a study area particularly well-suited for the study of prehistoric activity. However, the methods that I employed in this study are useful in any number of locations within and beyond the Great Basin. Using GIS-based analyses to evaluate trends in lithic data provides a platform from which powerful, quantitative arguments can be made. Any study containing elements of both technological and spatial data stands to benefit from a research design that promotes the use of such a platform.

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