HUNTER-GATHERERS, MOBILITY, AND OBSIDIAN PROCUREMENT:

A VIEW FROM THE MALHEUR HEADWATERS, NORTHEAST OREGON

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DEDICATION

This thesis is dedicated to my parents. Thank you for all your support.

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by

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The purpose of this thesis is to determine if there was shift in hunter-gatherer mobility strategies in the Malheur Headwaters, Oregon during the Middle and Late Holocene. It will be proposed that changes in mobility are linked to shifts in resource productivity and the intensification of root plant resources. Hunter-gatherer movement will be measured by examining changes in source-to-site distance, source variability, and procurement range size. Principles of human behavioral ecology will be used to connect changes in hunter-gatherer mobility to the intensification of root plant resources.

The intensification process is constructed by environmental variability, demographic packing, and technological changes. Signs of intensification are, "the reduction of food procurement areas, increased labor in the form of technological aids, and reduced mobility" (Binford 2001:189). A reduction in mobility that does not imply sedentism but a reduction in residential mobility, "where people would return to a central base point rather than establishing short stay residences" (Wingard 2001:5).

Mobility strategies like residential mobility create distinctive patterns of movement. It is assumed that as hunter-gatherers moved within the environment, the procurement of lithic raw material would be scheduled during the acquisition of food resources (Binford 1979; Shackley 1989). The location of raw material used for the manufacturing of stone tools, determined by x-ray fluorescence (XRF) analysis, depicts the extent of hunter-gatherer movement

through the landscape. Obsidian hydration dating (OHD) and projectile point typology will allow the projectile point itself to be used as a chronological marker. Obsidian projectile points will be used as an index of mobility and therefore can detect shifts in hunter-gatherer mobility strategies.

The results of this study show a significant decrease in hunter-gatherer mobility beginning in the late Middle Holocene and persisting into the Late Holocene. Differences in source-to-site distance, source variability, and obsidian procurement range size suggest that there was a reduction in residential mobility during the Late Holocene. A reduction in residential mobility and foraging area are signs of intensification. In addition, the frequency of hopper mortar bases suggests an increase in labor to process root plant resources.

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CHAPTER ONE: INTRODUCTION

The purpose of this thesis is to use obsidian stone tools from the Malheur Headwaters, Oregon, to examine changes in hunter-gatherer mobility during the Middle and Late Holocene. Specifically, if a decrease in residential mobility occurred during the Late Holocene. A decrease in hunter-gatherer mobility will be addressed within an ecological framework. It will be proposed that changes in mobility are linked to resource productivity and the intensification of root plant resources.

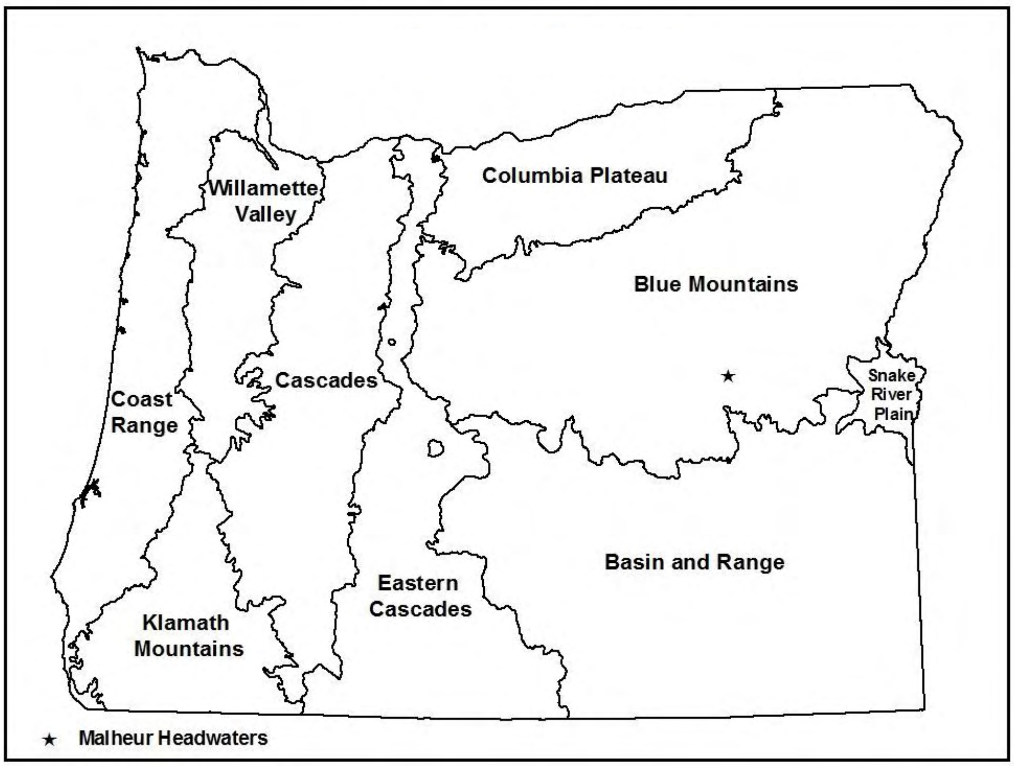


Figure 1-1. Location of the Malheur Headwaters.

The Malheur Headwaters contains 14 archaeological sites located in an upland valley between the Northern Great Basin and Southern Columbia Plateau (Figure 1-1). The complex of sites is situated within the Blue Mountain ecological region. These sites can be described as dense surface assemblages containing a variety of formed stone tools and debitage. In addition, the archaeological assemblage contains approximately 201 hopper mortars. In the Columbia Plateau, the presence of hopper mortars is attributed to root plant processing (Warren et al 1963; Ames 1998; Davis and Scott 1991; Ice 1962).

The Southern Columbia Plateau (Chatters 1995; Prentiss et al. 2005) and Northern Great Basin (Grayson 1993; Minckley et al. 2004) experienced shifts in climate and resource distribution during the Middle and Late Holocene. In both regions, during the latter half of the Middle Holocene plant resources (i.e., seeds and roots) are exploited more (Ames et al. 1998; Andrefsky 2004; Jenkins, Connolly and Aikens 2004; Moessner 2004). The Late Holocene is characterized by a series of short climatic shifts and changes in hunter-gatherer organization and food procurement. In the Northern Great Basin, a greater dependence on upland root crops emerged and a dual seasonal settlement pattern was adopted (Aikens and Jenkins 1994; Wingard 2001). A greater reliance on aquatic resources (i.e., salmon) with an emphasis on root plants emerged in the Southern Columbia Plateau and villages form near optimal fishing localities (Prentiss et al. 2005).

The Holocene was a period of shifting mobility strategies as hunter-gatherers adjusted to varying components of the environment. While there are general patterns of mobility observed during the Holocene, there is variation within each of these trends. Mobility is one aspect of hunter-gatherer organization that can be evaluated from the archaeological assemblage. This study uses 88 obsidian projectile points to examine patterns in hunter-gatherer mobility. The sample came from an archaeological collection managed by the U.S. Forest Service, located at the Malheur National Forest, Oregon. The projectile points were sent to the Northwest Research Obsidian Studies Laboratory for x-ray fluorescence (XRF) and obsidian hydration (OH) analysis.

In the Great Basin, XRF analysis and OH dating has allowed obsidian stone tools to be used as an index of mobility (Beck 1999; Beck and Jones 1990; Jones et al. 2003; Lyons et al. 2001; Shackley 1989; Skinner et al. 2004). The assumption is that raw material is embedded into subsistence tasks (Binford 1979) and trade is not a factor in the movement of obsidian. XRF analysis compares the chemical characteristics of obsidian artifacts to known geological sources. By determining where an artifact originated from it is possible to establish where a person has traveled. Previous studies referenced above have used XRF data to examine changes in source-to-site distance, source diversity, source directionality, and procurement range size. OH dating and projectile point typology allows the projectile point itself to be used as a chronological marker.

Once mobility patterns are determined, the question becomes why did hunter-gatherers choose certain mobility strategies? This question may be addressed through human behavioral ecology (HBE) which, "has devoted attention to interactions between people and their natural environments, including foraging group size, food selection, and group movements" (Kelly 1999:112). HBE follows the premise that hunter-gatherers will act optimally and will make rational decisions under specific conditions to maximize some goal (e.g., food intake). HBE can link hunter-gatherer mobility to issues of intensification.

This thesis (1) examines patterns in source-to-site distance, source variability, and procurement range size during the Middle and Late Holocene, (2) associates these patterns to the frequency of movement and residence time, and (3) uses principles of human behavioral ecology to connect changes in hunter-gatherer mobility to the intensification of root plant resources.

Thesis Organization

Chapter two is divided into three sections human behavioral ecology, mobility, and intensification. The goal of the chapter is to establish a theoretical framework that will connect mobility to intensification. Chapter three is an overview of the ecological and cultural setting. The intent is to illustrate how dynamic the upland valley is compared to the surrounding regional environment. Also, the cultural history of the Northern Great Basin and Southern Columbia Plateau are reviewed. This provides a point of reference that places the Malheur Headwaters within a larger regional and temporal context. Chapter four provides a summary of research conducted at the Malheur Headwaters and a description of all 14 sites. The site descriptions show the spatial and material relationships between all 14 localities. This information is pertinent to the sampling method. Chapter five explains how artifacts were typed and chosen for x-ray fluorescence and obsidian hydration analysis. A review of obsidian hydration dating and geochemical source characterization demonstrates the use of obsidian projectile points as an index of hunter-gatherer mobility. Chapter six uses hydration rim data, as a measure of time, to examine changes in source-to-site distance, source variability, and procurement range size. The patterns observed allow inferences about hunter-gatherer mobility. In chapter seven these inferences are then tied back to issues of intensification and root plant resources.

CHAPTER TWO: ECOLOGY, MOBILIY, AND INTENSIFICATION

Traditionally, archaeological research in the Great Basin has been focused on the relationship between humans and the environment. According to Kelly (1999) this ecological focus may have been the result of the pioneering work of Julian Steward. Steward (1955) developed an approach known as cultural ecology that focused on the relationships between society, technology, and the environment. While cultural ecology significantly contributed to hunter-gatherer research it did not account for change in hunter-gatherer societies (Kelly 1995: 45). Great Basin studies began utilizing theory and models drawn from human behavioral ecology to answer questions of hunter-gatherer variability. Human behavioral ecology has the ability to connect issues of subsistence and mobility. This chapter is divided into three sections. The first section discusses human behavioral ecology and its use in the Great Basin. A section focused on hunter-gatherer mobility follows summarizing differences between residential and logistical mobility. The last section discusses the process of intensification. The intent of this chapter is to link mobility to issues of intensification and construct a framework that will be used to interpret mobility patterns illustrated in Chapter Six.

Human Behavioral Ecology

Human behavior ecology (HBE) uses principles of evolutionary theory and optimization to understand why certain behaviors emerge and prevail. The variability seen in human behavior is viewed within a socio-ecological context. HBE argues that hunter-gatherers will act optimally or efficiently when acquiring food resources allowing more time for other fitness-related activities. HBE uses microeconomic concepts such as marginal valuation, opportunity costs, discounting, and risk sensitivity to assess the cost and benefit of differing responses to environmental conditions (Bird and O'Connell 2006; Kelly 1995; Shennan 2008; Winterhalder and Kennett 2006).

HBE uses the evolutionary process of natural selection to connect human behavior to the environment. Natural selection acts directly on the phenotype eventually changing a population's genetic composition. The phenotype is the observable traits of an organism determined by the genotype and influenced by environmental factors. Organisms with phenotypes or traits better suited for their environment will have greater reproductive success and over time the more advantageous trait will become more common in the population.

The phenotype includes human behavior. People will select those behaviors that will increase their individual and inclusive fitness. The problem that arises is that human behavior is variable and behavioral differences between populations are usually not genetically founded. HBE follows a "weak sociobiological thesis" to resolve this issue.

> Variation in human behavior are seen as expressions of a human genotype that is essentially similar across the human population but has endowed our species with psychological predisposition, mental capabilities and physical abilities that have tended to be adaptive in the environments of human evolution with, 'environment' to include individuals cultural and social situation (Cronk 1985:27).

The weak-thesis does not claim behavior is genetically controlled. Instead, humans subconsciously assess the reproductive consequences of their behavior (Kelly 1995:52).

HBE is not concerned with the specific mode of inheritance but with the, "fitness related trade-offs an individual faces in a particular socio-ecological context" (Bird and O'Connell

2006:146). Fitness is an organism's ability to survive and reproduce in a specific environment and population. HBE is examining the mean fitness of particular behaviors rather than the potential number of descendents or individual fitness. The reason being, behavior is culturally rather than genetically transmitted. HBE accepts that people evaluate the fitness-related costs and benefits of each course of action (behavior) and adopt those with the greatest fitness payoffs (Smith and Winterhalder 1992).

HBE works under two assumptions: methodological individualism and optimization. Methodological individualism argues that people are capable of comprehending the relationship between their actions and goals. In addition, the goals people make are biologically (to reproduce) and culturally (like spend time with offspring, acquire prestige, and acquire wealth) influenced. Individuals will maximize opportunities to achieve their goal, but the goal may not be the same for all individuals (Kelly 1995:53).

The main assumption that HBE follows is optimization. The biological concept of optimization is the expected outcome of natural selection. In addition, optimization borrows principles of microeconomics, "specifically the part that attends to the rational decision making of individual under a set of specified conditions that include limited resources and means and unlimited needs" (Bettinger 1987:131). Resources like food, space, and mates are limited and natural selection favors those organisms whose behavior and morphology enhances their access to those resources (Foley 1985:223). This does not mean that hunter-gatherers will achieve optimality; there is only a tendency toward optimization (Kelly 1995:54).

Optimality models follow a basic set of characteristics (1) a currency (energy) in which cost and benefit may be evaluated, (2) a phenotypic set, the available set of behaviors to be considered, (3) a goal, (4) a set of constraints that determines the options and their benefits, and

(5) competition, defined as the interaction between individuals for access to resources (Foley 1985:230; Kelly 1995:53). The model most used by anthropology is optimal foraging theory. It focuses on the ability of the individual to make rational decisions under certain constraints to maximize the net rate of energy gain (food intake). Optimal foraging theory is further divide into several models like diet breadth, patch choice, marginal value theorem, foraging group size, central place, and ideal free distribution.

Diet Breadth. The diet breadth model predicts if a resource will be taken when it is encountered. The model assumes that resources are evenly distributed within the foraging area and are randomly encountered. Resource acquisition is divided into search costs and handling costs. "Search cost is the time it takes to locate a resource; the handling cost is the time it takes to harvest and process" (Kelly 1995:78). However, following the random-encounter assumption, hunter-gatherers will search for all resources simultaneously and the decision to pursue is based on the cost of handling. The cost of handling is measured by the return per unit of time (cal/hr). Based on this measurement resource are then ranked. It is predicted that hunter-gatherers will select higher ranked resources over lower items when encountered (Kelly 1995; Smith 1983).

Bettinger and Baumhoff (1982) used a diet breadth approach to analyze the rapid spread of Numic people into the Great basin. It is argued that Numic groups adopted a high-cost processor strategy that maximized both large game and small seed procurement, with a greater dependence on small seeds. While Prenumic groups used a low-cost traveler strategy, that maximized large game procurement and minimized small seed procurement. Bettinger and Baumhoff explain that while adaptive strategies are strongly influenced by subsistence there are other contributing systems (e.g., sociopolitical organization, demography, and ideology) as well. Both traveler and collector strategies are adaptive peaks, meaning they are the most optimal local solution. Once the peak is established subsistence change is possible but dependent of other contributing variables that will cause the short-run lag time to vary. As populations began to increase a high-cost processor strategy allowed Numic groups to outcompete Prenumic groups. The reason being Prenumic groups did not have an adequate labor force for the high-cost of small seed procurement.

Simms (1985) used the diet-breadth model to predict the timing of pine nut use in three archaeological cases Reese River Valley, Nevada; Grouse Creek, Utah; Owens Valley, California. The model used experimental data to determine that pine nut procurement was highly efficient compared to other plant resources. Simms predicted that, "pine nuts should have been exploited as soon as they were available in sufficient quantity to fill a niche in the diet, possibly as winter storage resource" (1985:167). The archaeological evidence supports the appearance of settlements or settlement shifts in the Reese River and Grouse Creek region about the time pinyon became available. In Owens Valley, procurement of pine nuts did not follow the prediction and use occurred much later. Simms suspects that the high transportation cost of pinyon to the valley was not advantageous to the semi-sedentary strategy being used.

According to Madsen and Schmitt (1998) confusion between the terms "prey types" with "food types" has allowed for frequent misuse of the diet breadth model. A prey type is a class of prey items with the same return rate. The prey type can be as diverse as oranges, armadillos, and beehives but must have the same cost/benefit tradeoff. Madsen defines two return-rate-altering changes that allow a single food type to have numerous prey types (1) abundance of food type and (2) change in technology. At Lakeside Cave, Utah the archaeological record suggests that at times grasshopper collecting was almost entirely preferred over the hunting of large mammals. Madsen explains grasshoppers blown into the Great Salt Lake would wash up into large windrows (a long heap) along the shore. These windrows (prey type) at times would exceed the return rate of individually hunted large mammals and when encountered they were collected. The study shows that abundance of lower ranked resources (like grasshoppers) is relevant in determining diet breadth and that prey items of larger body size are not always the most optimal choice.

Patch Choice. The patch choice model calculates which resource patch (not resource) will be foraged. The model assumes that sets of resources (patches) are distributed across the landscape and are randomly encountered. Patches differ from each other by the amount of energy they contain and the time required extracting resources. Similar to diet breadth, patches are measured by the energetic return per unit of time. The difference is the net return rate includes the time spent searching for resources within the unit (Bettinger 1991; Kelly 1995; Smith 1983).

Raven and Elston (1989) created a patch choice model and applied it to the Stillwater Wildlife Management Area, Carson Desert, Nevada. They began by dividing the area into 34 habitat types based on soil, hydrologic, and biotic variables. A set of locally available resources possibly used by prehistoric foragers was applied to the habitat types by seasons. In addition, ethnographic literature was used to determine which resources would have been taken by men or women. The information was used to rank habitat types by energetic return rates. Based on the rankings, Raven and Elston predicted the archaeological material expected for each habitat type. Raven (1990) tested the model against the archaeological record and many of the predictions were met.

Marginal Value Theorem. The marginal value theorem asks how much time should be allotted per resource patch. It is expected that when the capture rate within the patch is equal to the overall rate available in the environment the forager should move on. In addition, an increase in habitat productivity will result in a decrease in foraging time within patches. Conversely, a decrease in habitat productivity will increase patch stay (Bettinger 1991; Kelly 1995; Smith 1983).

The marginal value theorem was used to address why a decrease in residential mobility occurred in Carson Sink, Nevada around 1500 B.P (Kelly 1990). It is assumed that marshes are isolated, diverse resource patches that maintain a constant food supply year around. Kelly (1990) explains that a decrease in effective moisture made the western Great Basin more heterogeneous. However, marshes are not directly dependent on local precipitation and would have provided a larger return rate compared to other patches (valley floors, alluvial slopes, and uplands). It is predicted that this shift, "would have encouraged longer occupations of the marsh "patch" (1990:272). In addition, a shift from summer to winter precipitation, after 1500 B.P., caused an increase winter severity. This increase in severity forced people to invest more effort into resource storage. According to Kelly (1990), no single resource could be reliably stored, so people positioned themselves near marshes to combat winter storage problems, resulting in decreased residential mobility.

Central Place. The central place foraging model examines the round trip travel costs from a central location. Foragers may position themselves near certain critical resources (like water or near a dense valuable food source). It is assumed that foragers may have to leave, this central place, and travel a certain distance to retrieve other food or nonfood resources. The central place foraging model predicts (1) that as travel cost increase the forager will become more selective of resources being harvest and (2) only the most valuable resource loads justify the costs associated with long distances (Winterhalder and Kennett 2006).

Zeanah (2002) used a central place approach to examine the variability of mobility strategies in the Great Basin. Initially, a transport cost model was developed to predict where hunter-gatherers would reside when presented with two spatially discrete resource patches, that is to camp at one site and logistically use the other. The model predicted that a winter camp would be established in the woodlands if the pinyon harvest was adequate and if not the camp would shift elsewhere and pinyon would be logistically procured. According to Zeanah (2002) the model (1) concurred with winter village locations described by Steward, (2) showed the influence of portability on net return rates, and (3) a central place approach links the forager-collector model with issues of diet breadth and intensification.

Zeanah applied insights obtained from the central place model to explain the rarity of milling stones in some areas of Great Basin, which does not correspond with the ethnographic importance of pinyon. He argues that the differential variability of milling stones reflects the decision to either reside in pinyon zones or logistically procure pinyon. This decision may have been influenced by the local variability in the amount of harvested nuts (2002:242). In addition, Zeanah found a "strong significant correlation between the proportion of pinyon and the number of ground stone tools per hectare (kendall's tau = .74, p = 0.133)" (2002:247). He believes this to be consistent with predictions made by the central place foraging model. Areas of high pinyon productivity encouraged the formation of residential base camps in pinyon-juniper woodlands; this is evident in the high number of milling stones.

In Owens Valley, pinyon camps did not develop until 1350 BP, despite being near some of the richest pinyon forests. Zeanah (2002) argues that prior to 1350 BP hunter-gatherers had access to a larger area and logistically transported pinyon. He explains that after 1350 BP an increase in demographic packing forced populations to shift from logistical to residential procurement of pinyon.

Mobility

Human behavioral ecology provides a conceptual framework on "how hunter-gatherers make decisions about interacting with their environment" (Kelly 1995:63). The basic assumption is that hunter-gatherers will act optimally and make decisions by examining the cost and benefit of certain activities. The amount of time and energy (cost) invested in various activities allows insight into how hunter-gatherers organize themselves. Binford believes, "mobility is a positioning strategy" (1980:14). It is one aspect of how hunter-gatherers organize themselves to manage issues of food procurement. Binford (1980) and Kelly (1983) suggest hunter-gatherer mobility is influenced by structural components of the environment that relate to resource (food) distribution and abundance.

Binford (1980) defined two subsistence-settlement systems, foragers and collectors. He explains that foragers use residential mobility to move consumers to resources while collectors use logistical mobility to move resources to consumers. Foragers usually do not store resources and have high residential mobility moving the group from one resource patch to another, as encountered. In resource patches that are large or homogeneous the number of residential moves may increase while the distance between them decreases. However, when resources are scarce and dispersed the group should reduce in size and spread over a larger area. The bulk of subsistence activities, such as processing, manufacturing and maintenance, occur at the residential base. Residential mobility requires that most of the group leave the residential base for some period of time. However, a degree of redundancy may occur which is dependent on the distribution of critical resources.

The forager and collector subsistence-settlement systems are part of a continuum of simple to complex. A collector system adds new organizational properties (i.e., field camps, stations, and caches) to those associated with a foraging system (i.e., residential bases and locations). Adjustments are made to those foraging components and residential mobility becomes less important. Instead, individuals or small task groups will move "logistically" from the residential location to procure specific resources. These logistical forays can vary in duration depending on the resource being targeted. A logistical strategy usually occurs when resources are heterogeneously distributed or when certain conditions restrict mobility.

As hunter-gatherers residentially move through the landscape raw materials used to manufacture tools are obtained. It is rare for either foragers or collectors to, " go out into the environment for the express and exclusive purpose of obtaining raw material for tools" (Binford 1979:259). The assumption is that the procurement of lithic raw material is embedded into subsistence tasks. However, as mobility decreases and hunter-gatherers shift toward more permanent residential settlements, the formation of ancillary sites becomes fixed in the surrounding habitat. That is, highly mobile systems will incidentally procure lithic material while more sedentary systems will habitually procure lithic resources from specific locations (Binford 1982:20). The variability and proportion of lithic material at a site is an index of mobility and the habitat exploited.

It was not the intention of Binford (1980) to place hunter-gatherers into one of two settlement types, forager or collector. The descriptions were extremes of a graded series in which hunter-gatherers fall within, that corresponds to seasonal variability. Binford examined the relationship between ethnographic hunter-gatherers and effective temperature (ET). ET, the total amount and yearly distribution of solar radiation, was used to measure the duration of the growing season. It is expected that as the growing season decreases there should be a reduction in residential mobility and an increase in both logistical mobility and seasonal sedentism

(1980:15-16). As a point of reference, Northern Great Basin and Columbia Plateau ethnographic hunter-gatherers and their associated effective temperatures (ET) are provided: Modoc (13.3), Umatilla (13.3), Harney Valley Paiute (13), Tenino (12.4), and Klamath (12.2) (Binford 1990:142-143). The research area was known to be used by the Umatilla, Harney Valley Paiute, and Tenino (Couture 1996:17).

Kelly (1983) agrees that mobility is related to certain environmental components. He used ET and primary biomass to measure environmental differences. As ET decreases the spatial distribution of resources becomes more segregated and the distance between residential moves will increase. This is especially true in settings with an ET between 8 -15 (Kelly 1983:295). Kelly defines, "primary biomass as the total amount of standing plant material in an environment" (Kelly 1995:121). According to Kelly (1983) there is an inverse relationship between primary biomass and resource accessibility, the time and effort required to extract faunal and plant remains. In areas with high primary biomass and little resource accessibility high residential mobility is expected. Reduced residential mobility is only feasible in settings with high primary biomass when storable resources are available.

Binford (1990) argues that there is a correlation between logistical organization and storage. However, he believes storage is largely a function of the length of the growing season. As ET decreases storage becomes important because it extends food availability and can be used as a safety tactic. As hunter-gatherers become more storage dependant there should be an increase in logistical mobility. That is while storage decreases "incongruous temporal phasing" it increases "spatial incongruity", hunter gatherers should then stay near stored resources and logistical obtain other critical resources (Binford 1980:15).

Binford (1982) believes mobility allows hunter-gatherers to "position" themselves in geographic space while providing stability within the current system. Mobility is one way in which hunter-gatherers can make a place (site) economically beneficial. The economic potential of a site is dependent on the scale of hunter-gatherer movement. That is the distance between residential moves influences the usage of sites in the surrounding habitat. For example, a site may be used as a hunting camp at one time, a transient camp at another time, and a short-term observation stand at still another. When residential mobility decreases, "the economic potential of fixed places in the surrounding habitat will remain basically the same" (Binford 1982:20).

Ames (1991) argues that sedentism is not a stable condition among hunter-gatherers but one class of variation in residential patterns. He believes sedentism and semisedentism are, "artificially constructed landscapes in which residential patterns and associated social and cultural patterns become fixed and maintained at certain places for some period of time" (Ames 1991:109-110). Residential sites of both sedentary and semisedentary systems are permanent features of the landscape. In addition, sedentary and semisedentary hunter-gatherers can operate in the same region and participate in the same social, economic, and subsistence system. Also, within the same region there can be variation among semisedentary groups.

Mobility allows hunter-gatherers to adjust to varying components of the environment. As the growing season decreases there should be a reduction in residential mobility and an increase in seasonal sedentism and storage dependence. While storage extends resource availability pass the growing season, it creates spatial incongruity and logistical mobility is used to obtain other critical resources. In setting with high primary biomass, the distance between residential moves should increase. Mobility is a positioning strategy that allows hunter-gatherers to increase site productivity.

Intensification

Intensification occurs when mobility is no longer a reliable option to meeting subsistence needs. Intensification is a process in which hunter-gatherers are pushed into extracting more food resources from a given area. It is a dynamic process constructed by environmental variability, demographic packing, and technological innovation. Binford (2001) developed an intensification model. The model predicts that as hunter-gatherer populations approach the packing threshold, 9.098 persons per 100 square kilometers, a greater dependence on a specific food resource will occur. As packing increases mobility decreases and is no longer an option to combat subsistence pressures. Intensification will result in increased investments of labor, sedentism, the development of new technological aids, and storage.

The intensification model is attempting to understand hunter-gatherer behavior through an ecological perspective. Binford has adopted the ecological concept of hyperspace to help build his model of intensification. Hyperspace is defined as an analytical domain occupied by a population. A domain constructed by varying responses to forces being monitored. Hyperspace is divided into three sets of variables: habitat, niche, and population (2001:32).

Habitat or environmental variables are properties of the environment that can be measured independent of organisms occupying a specific habitat. Examples of environmental variables are temperature, rainfall, and biomass. Niche is how a species lives within an ecosystem. It is a complex and multidimensional interaction between a population and their habitat. Examples of niche variables are prey size, potential plant food, and species density. Niche variables speak to ecological variability and are understood by linking environmental variables together. Binford explains that within hyperspace a population never occupies one location but is distributed in varying densities. Each population will occupy a semi-independent hyperspace that is still part of the larger-scale hyperspace. According to Binford it is only when habitat, niche, and population variables are used collectively that, “the world of dynamic open systems become accessible and the investigation of organizational change and evolution becomes possible” (2001:33).

Binford argues for a scientific learning strategy as a method of understanding variability among human organization systems. He uses an inductive strategy that relies on prior knowledge to build a causal argument addressing why hunter-gatherer groups differ. He explains that by constructing frames of reference the researcher can then articulate one well known domain of knowledge to a lesser known domain. The two frames of reference used by Binford are environmental variables and documented hunter-gatherer groups. This known source information is then linked by using pattern recognition tactics. Binford has produce generalizations and propositions concerning the phenomena known as intensification. By understanding the process of intensification the archaeologist can then articulate the unknown properties of the archaeological record to the known properties of intensification.

The concept of packing is essential to understanding the intensification process. Packing measures the relationship between the number of individuals in a group and the geological space they occupy. This variable determines the likelihood that mobility is a viable component of the food-getting strategy. It is assumed that hunter-gatherer movement is organized according to the occurrence and availability of needed resources. Packing begins as movement into new foraging areas decreases and population density increases. When the population density reaches 9.098 persons per 100 square kilometer the packing threshold is reached and subsistence oriented mobility becomes obsolete (2001:373-376). Once mobility is no longer a feasible food getting strategy, new tactics of ensuring subsistence security are required. “Sedentism is not expected until a nearly exclusive investment of labor has been made in a single venue for the production of non-mobile food resources" (Binford 2001:438).

Binford established the packing threshold by first determining a standard measurement for group size (COHAB) and foraging area (FORAD) based on ethnographic cases (2001:229-238). COHAB represents 20.47 persons, the minimal number of people in a foraging group needed to maintain subsistence procurement tasks. FORAD represents a circular area of 225.33 square kilometers, the foraging area that a COHAB operates within. The packing threshold was determined by, "dividing the COHAB (20.47) value by the number of 100 square kilometer units in a FORAD (2.2533) which yields a value of 9.098 persons living in a 100 square kilometer unit" (2001:374).

As hunter-gatherers become packed, there is a decrease in the procurement of large terrestrial animals and a greater dependence on fewer animals of smaller body size. Once the packing threshold is reached the primary food source should be either terrestrial plants or aquatic resources depending on the environmental setting (2001:383). In cool or cold environments that prohibit plant-based subsistence a greater dependence on aquatic resources should occur (2001:210). In well watered forest settings some groups dependent on terrestrial plants may tap into aquatic resources to stabilize niche breadth before reaching the packing threshold (2001:444). As food resources traditionally obtained by males contributes less to the group diet the sexual division of labor begins to change. Female contribution to food labor costs increases as greater dependence on new food resources or those previously obtained by females occurs (2001:376).

Intensification is not simply a greater dependence on a new resource but the ability to extract more food resources from a given geological space. As demographic packing increases the procurement range is reduced, there is a corresponding reduction in both the species exploited and their seasonal production schedules. The packed population must exploit fewer species in greater quantities. The ability to expand food production is accomplished by greater investments in technology. Tools used to increase food production can vary from simple digging sticks to tended facilities (game blinds, fish weirs, fish nets, and fish hooks). Tool variability and complexity is dependent on the resource being extracted (2001:388-391). It is the innovation of storage that allows hunter-gatherers to extend the time a resource can be consumed (2001:256). This allows the population to maintain a level of subsistence during periods of low productivity. "As intensification increases, the dependence upon storage should also increase" (Binford 2001:370).

Resources obtained in bulk require both male and female labor to simultaneously procure and process the same resource for storage and consumption (2001:303). The labor party usually tasks males with procurement and females with processing. In warmer setting were meaty foods can spoil easily the size and skill of the female labor force is critical to the quantity of food delivered to storage. The processing rate cannot fall behind the rate of procurement (2001:430).

Intensification tactics require a greater investment of labor. The increase in labor costs are divided into four categories (1) labor invested in technology to increase the amount of food procured; (2) labor invested in building habitats to yield higher returns from key species; (3) labor invested in making resources edible, like acorn leaching; (4) labor invested in preparing resources for storage and in storage facilities (2001:420). Binford explains that the greater investment of labor in extracting resources the more limited procurement rights become. This is especially true of hunter-gatherers dependent on aquatic resources which will result institutionalized ownership (2001:369).

Ownership is defined as a monopoly of resources. It is an exclusion of one's kin from food producing venues that were shared prior to packing. Exclusion is achieved by changing the mechanisms of kin inclusiveness or by dividing kinspeople into smaller units with more restricted functions (2001:371). These changes in social organization are variable and resource dependent. In hunter-gatherers dependent on terrestrial plants there is no evidence of wealth or social ranking prior to packing. Once the packing threshold is passed differences in wealth are displayed. Increased organizational complexity is represented by secret societies and social differentiation based on age (2001:406). The method of exchange also varies according to social organization. There is social storage, a transfer of goods that incurs some type of debt by the recipient, and bidirectional exchange, the even trade of craft goods (like beads) for food. Craft items become an investment of labor that allows families to buy food when experiencing short falls (2001:371).

Intensification is a dynamic process that results in increased investment of labor, technological innovation, storage, and sedentism. As demographic packing increases hunter-gatherer mobility decreases and eventually is no longer a suitable subsistence strategy. Investments in technology and storage allow the population to extract more food resources from a given area. This will lead to changes in the division of labor and social organization. According to Binford, archaeological evidence of intensification are (1) a reduction in the size of food procurement areas; (2) increased labor in technological aids used for food procurement; (3) reduced mobility both in the number of annual residential moves and in the distance traveled in the course of a seasonal round; (4) increased exploitation of resources that require greater labor to procure or process (2001:189).

CHAPTER THREE: ECOLOGICAL AND CULTURAL OVERVIEW

Ecological Setting

The Malheur Headwaters archaeological complex contains 14 archaeological sites located on small dry ridges distributed across an upland valley. At an elevation of 5,100 feet, the valley lies between the Strawberry Mountain range to the north and the Malheur River to the south. The small ridges are surrounded by a seasonally wet meadow/grassland and the valley is circumscribed by a warm dry forest. A fen complex and large tree stand composed of ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and aspen (*Populus tremuloides*) is situated in the northern extent of the valley. Five perennial streams flow through the valley draining into the Malheur River. The valley represents an area of converging ecological communities that has created a dynamic environment rich in ungulate, plant, and aquatic resources.

Regional Geology

The Blue Mountain region extends east to northeast from the Cascade Mountain range dividing the Columbia Plateau to the north and the Northern Great Basin to the south. The valley lies within the western Blue Mountain region which is defined as the area west of the Dixie Mountain summit. The variable relief of the region is the result of intensive volcanic, tectonic, and erosional events that occurred during the Cenozoic era. Prior to the Tertiary period, the general elevation of the Blue Mountain region was similar to the present Columbia Plateau. It was during the Tertiary period that the Clarno, John Day, Columbia River Basalts, Mascall, and Rattlesnake formations began to build the western Blue Mountain region, Table 2-1 provides a description of each geological formation (Baldwin 1981; Robyn 1977).

Table 3-1. Description of Geological Formations.

Geological Formations	Chronology	Description
Clarno	Late Eocene to early Oligocene	The Clarno Formation is composed of thick basalt, rhyolite, and andesite flows, waterlaid conglomerate, breccias and varicolored tuffs, and tuffaceous sedimentary rocks.
John Day	Middle to late Oligocene	The John Day Formation was not as widespread as the Clarno formation. The unit is composed of waterlaid tuffaceous siltstone and rhyolitic tuff to the west; air fallen tuff and one prominent welded tuff to the east. The formation is divided into three distinguishing colors: an older basal red member, a middle blue green member and an upper buff member.
Columbia River Basalt	Middle Miocene	The Columbia River Basalts are divided into two subgroups. The older Picture Gorge Basalt contains more olivine, less silica, and is less continuous. Yakima Basalt is usually found along the Columbia River and in the northeastern corner of Oregon. It is thicker and more resistant to erosion.
Mascall	Middle to late Miocene	The Mascall Formation is described as white to buff sedimentary rocks which contains ash and tuff, with sand and conglomerate. The formation was laid down as alluvium originating from a volcano near Strawberry Mountain.
Rattlesnake	Middle Pliocene	The Rattlesnake Formation contains gravel, tuff, silt and a prominent middle member of welded tuff. Gravels were created when bending, folding, and breaking along faults caused the Strawberry Mountain range to rise a mile and half to two miles. It lies on folded and eroded Mascall beds.

The term Strawberry Volcanics is used to describe the varied lithologies created by Miocene and Pliocene volcanoes near Strawberry Mountain which contain basalitic and andesitic flows, basaltic cinder cones, rhyolite tuff, rhyolite, vent breccias, and micronorite (Robyn 1977:10). Strawberry Volcanics lie on top of the Clarno formation to create the Strawberry Mountain Range. The valley south of the mountain range, where the archaeological complex is located is a graben created by two south-southeast trending faults coming from Strawberry Mountain. The valley is underlain with Strawberry Volcanics and filled with tuffaceous sedimentary rocks and Quaternary alluvium (Personius 2002; USDA Forest Service 2000).

The small ridges within the valley were probably formed during the Pleistocene, elongated depressions or holes in the ice formed when Pleistocene glaciers began to melt. Over time, as the glaciers continued to recede, glacial debris collected in the holes and created small ridges or hills (Anderson et al. 1998).

It was during the Pleistocene that Mount Mazama began to form in southwestern Oregon and would eventually erupt during the Holocene. The climatic eruption of Mount Mazama about 7,600 cal. BP deposited ash over 1,000,000 km^2 of western North America (Oetelaar and Beaudoin 2005) forming a clear stratigraphic boundary. Mazama ash deposited in the Blue Mountain region over time eroded from many ridges and south facing slopes to valley bottoms (USDA Forest Service 2000).

Soil

The numerous geological formations, volcanic debris and ash have formed a variety of soil types across the Blue Mountain region. Xeric or dry soils are usually found in lower elevations and are generally formed from local geologic parent material. These soils tend to have rock fragments that reduce the amount of soil needed for rooting and have low water storage capacity. The productivity of the soil is dependent on thin organic surface layers and periodic fires which release nutrients from woody debris and grasses back into the soil. Higher elevation soils are udic or moist and tend to be more productive. The most productive soils are composed of aerially deposited ash and are found in mesic forests. Soils formed from volcanic ash have a high rate of infiltration and water storage capacity (Bryce and Omernik 1997).

The soil composition of the archaeological complex is a mixture of volcanic ash and glacial till. Excavations throughout the valley have shown soil depth to range from 30 to 90 centimeters. Areas that reach a soil depth of 90 centimeters tend to have darker and wetter soils. These areas are usually associated with wet meadows that have high water tables. On the central valley floor, the soil is lighter and drier for much of the summer (USDA Forest Service 2000).

Climate

The Blue Mountain region has a continental climate that varies both longitudinally and latitudinally. As elevations increase throughout the Blue Mountain region, there is an increase in moisture and decrease in temperature. The majority of precipitation in the region usually falls in the form of snow during the winter and early spring. The warmest and driest months of the year are July and August.

The western portion of the Blue Mountain region lies in a rain shadow created by the Cascade Mountains and is defined by light precipitation, high evapotranspiration, and wide temperature fluctuations (Bryce and Omernik 1997). The average annual precipitation is 13.3 inches, with 28 percent occurring between April and June and 53 percent occurring between November and March. The average maximum and minimum temperatures for January are 38.9° and 18.4° F. The average maximum and minimum temperatures for April through June are 68.1 and 36.2°F (Anderson et al. 1998).

The northeast portion of the region is defined by increased cloudiness, higher humidity, and increased precipitation coming from the Columbia River Gorge (Bryce and Omernik 1997). The average annual precipitation is 22.4 inches, with 32 percent occurring between April and June and 54% occurring between November and March. The average maximum and minimum temperatures for January are 33.8° and 15.1° F. The average maximum and minimum temperatures for April through June are 70.2° and 38°F (Anderson et al. 1998).

The proximity of the Strawberry Mountains to the research area provides a greater degree of precipitation than normal for the region. The average annual precipitation in the valley is 25 to 30 inches with 70 percent coming in the form of snow, falling between October and March. Snow pack can persist into the early spring. The average maximum and minimum snow pack depths are 50 and 20 inches, respectively. The average winter temperature ranges between 20° to 30°F. The average summer temperature ranges between 40° to 60°F (Anderson et al. 1998; USDA Forest Service 2000).

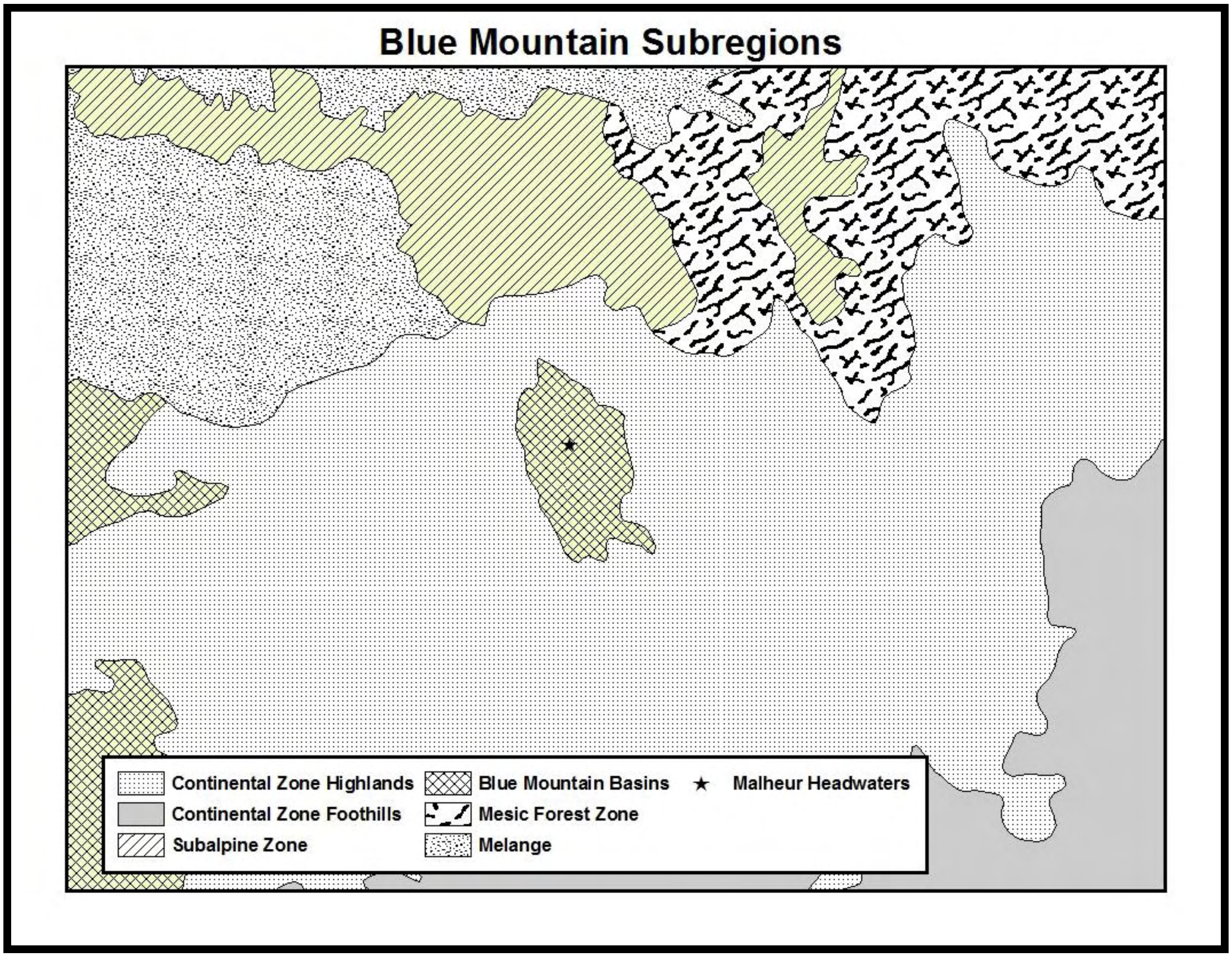


Figure 3-1. Map of Blue Mountain ecological subregions.

Vegetation

The ecological subregions that surround the upland valley are the Continental Zone Highlands, Melange Zone, Subalpine Zone, and Mesic Forest Zone (Figure 2-1). The Continental Zone Highlands is a hot dry forest constituted by a ponderosa pine/elk sedge (*Carex geyei*) and ponderosa pine/pinegrass (*Calamagrostis rubescens*) plant associations. The Melange Zone is a warm dry forest represented by ponderosa pine and Douglas fir (*Pseudotsuga menziesii* var.

glauca). The Mesic Forest Zone is a cool moist forest. The ash mantel retains soil moisture and allows for the growth of grand fir (*Abies grandis*)/ twinflower (*Linnaea borealis*) and grand fir/grouse huckleberry (*Vaccinium scoparium*) plant associations. The cold moist Subalpine Zone is composed of subalpine fir (*Abies lasiocarpa*), subalpine fir/elk sedge, and subalpine fir-Englemann spruce (*Picea englemannii*) plant associations (Bryce and Omernik 1997; U.S. Forest Service 2000).

While the upland valley is broadly placed within the Blue Mountain Basins subregion, it encompasses a variety of habitats and a diverse collection of vegetation. Sagebrush (*Artemisia tridentate*) communities reside along the valleys edge marking the transition from ponderosa pine and Douglas fir plant associations to valley grasslands (U.S. Forest Service 2000). The grasslands located in the northern half of valley are divided into a series of wet and dry meadows. The southern half of the valley contains several narrow dry ridges surrounded by seasonally wet meadows.

The wet meadows provide a suitable habitat for the growth of elephant head (*Pedicularis groenlandica*), bog saxifrage (*Micranthes oregano*), white bog orchid (*Platanthera dilatata var. albiflora*), American bistort (*Polygonum bistortoides*), paintbrushes (*Castilleja sp.*), western polemonium (*Polemonium occidentale*), and camas (*Camassia sp.*) (WildFlower USFS). Camas bulbs were widely traded and represent one of the most culturally significant plants in the Northwest region. The process of gathering and preparing camas bulbs was labor intensive. A digging stick was used to harvest the bulbs and then they were pit-cooked for 24 to 36 hours (Couture 1978; Hunn and French 1981). There is currently no evidence of camas ovens in the archaeological complex. However, a cluster of camas ovens were discovered in an upland valley similar to the research area in the Malheur National Forest (Hann 1997).

The dry meadows and ridges support the growth of balsam root (*Balsamorhiza sp.*), yampa (*Perideridia gairdneri*), larkspur (*Delphinium sp.*), bighead clover (*Trifolium macrocephalum*), biscuit root (*Lomatium sp.*), and other lomatium species (U.S. Forest Service 2010). Lomatiums, like camas, were an important food resource for hunter-gatherers in the region. The roots could be eaten raw, boiled, baked or ground into flour to make small transportable cakes. Lomatiums are a high caloric resource offering more carbohydrates per 100 edible grams than the common white potato (Couture et al. 1986). At a rate of 4 kg/hr, an individual could harvest an annual supply of lomatiums for themselves and their family within 50, eight hour days (Hunn and French 1981). In addition, lomatiums are high in vitamin C and were used to treat colds and respiratory ailments.

Other plants occasionally found within the valley are heartleaf arnica (*Arnica sp.*), strawberry (*Fragaria sp.*), yarrow (*Achillea millefolium*), lupine (*Lupinus sp.*), rabbit brush (*Chrysothamnus sp*.), and sego lily (*Calochortus nuttallii*) (U.S. Forest Service 2010). An aspen stand sits between the meadow and the fen complex in the north central portion of the valley. The aspen stand is flanked on either side by a mixed tree stand of ponderosa pine and lodgepole pine. Wild onion (*Allium sp.*), columbine (*Aquilegia formosa*), and sweet cicely (*Osmorhiza chilensis*) reside within the aspen stand. The fen complex north of the tree stand, is an alkaline wetland dominated by a variety of grasses, sedges and rushes. The fen along with riparian zones in the valley allow for the growth of willows (*Salix sp*).

Wildlife

Riparian zones add to species richness by creating microclimates, seasonal travel corridors, feeding and roosting areas, and perching and nesting sites. The riparian zones located in the research area provide suitable habitats for a variety of animals such as neotropical migratory birds, ospreys (*Pandion haliactus*), spotted frogs (*Rana pretiosa*) and other amphibians, water birds such as common loons (*Gravis immer*), sandhill cranes (*Gus Canadensis labida*), and upland sandpipers (*Bartramia longicauda*). The travel corridors created by riparian zones bring ungulates such as Rocky Mountain elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and antelope (*Antilocapridae sp.*) to feed on the valley grasslands. Other terrestrial animals observed in the valley are coyotes (*Canis latrans*), badgers (*Taxidea taxus*), raccoons (*Procyon lortor*), striped skunks (*Mephitis mephitis*), porcupines (*Erethizon dorsatum*), snowshoe hares (*Lepus americanus*), bats, chipmunks, pocket gophers, shrews, and other rodents. The cool streams that flow through the valley are suitable habitats for redband trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and brook trout (*Salvelinus fontinalis*) (U.S. Forest Service 2000).

Historic Impacts

Prior to the construction of dams along the Snake River and lower Malheur River, the valley streams supported a population of anadromous fish such as chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) (U.S. Forest Service 2000). According to Couture (1996), the valley represented a major salmon fishery site for the Burns Paiute. A Paiute born in 1916 recalls going to the valley as a child to fish for both salmon and steelhead (36).

Another animal rarely seen in the present valley environment is the beaver (*Castor canadensis*). It is assumed that the occurrence of beaver along the Malheur drainage was higher prior to contact. The journals of Peter Skene Ogden and John Work, fur trappers for the Hudson Bay Fur Company, recorded the number of beavers trapped per drainage system. Between 1827 and 1828, the journals recorded that 327 beavers were caught in the Malheur drainage which included the valley streams (Hann 2004). The presence of beaver may have formed valley streams into a series of shallow ponds with steps. Water distribution would have been shifted to more overland flow creating wetter meadows and increasing both plant and animal diversity within the valley.

The most significant impacts to the valley are those activities related to grazing. According to a 1937 forest service report the valley environment was depleted by the, "cumulative effect of misuse extending back a number of years before the national forests were created". Little vegetation was left after years of overgrazing by sheep, horses, and cattle which lead to erosion and soil loss in many areas. The report argued that the valley was once very productive based on local accounts and material evidence.

> The presence of old stone mortars and pestles, arrow heads and other stone implements lead us to believe that valley was inhabited at least part of the year by Indians, probably as a hunting ground, indicating that forage for deer, and antelope was plentiful (U.S. Forest Service 1937).
>
> Old timers tell of Indian camps in the valley and places where horse races were held. Also white men going to the valley in the late 70's to hunt antelope (U.S. Forest Service 1937).

Cultural History

The Malheur Headwaters is located on the Great Basin-Columbia Plateau border. The archaeological and ethnographic literature of both regions implies a long term transregional relationship woven together by a number of social and economic pursuits. Ethnographically the Malheur Headwaters were used by the Northern Paiute, Umatilla, Cayuse, Walla Walla and Tenino tribes (Couture 1996:17). The archaeological assemblage of the site implies a greater influence by the Northern Great Basin. However, the presence and number of hopper mortar bases may reflect a Southern Columbia Plateau component. It becomes important then to understand the cultural patterns that emerged in both the Northern Great Basin and Southern

Columbia Plateau. These two regions both experienced fluctuating climates during the Holocene that created shift in resource productivity. Hunter-gatherer survival depended on the ability to use numerous strategies to endure periods of low productivity and increased population densities. The cultural history is presented within an ecological framework.

Ethnographic Record

Northern Paiute

The Northern Paiute are part of the Numic language group a branch of Uto-Aztecan language family. The Harney Valley Paiute or Wada'tika (Wada seed eaters) was a Northern Paiute band that occupied 6000 square miles in southeastern Oregon. The Wada'tika wintered around the Malheur and Harney Lakes and would disperse into smaller groups in the summer to procure a wide range of resources. They frequently interacted with the other Paiute bands like the Hu'nipwi'tika (root eaters), Pa'tihichi'tika (elk eaters), and Agai'tika (salmon eaters) and shared no feelings of ownership over hunting and gathering grounds. Intermarriage between these groups often occurred, creating strong inter-band ties. The following summary of the Wada'tika seasonal round is based on the ethnographic Burns Paiute, descendents of the Harney Valley Pauite (Couture 1978, 1996; Couture et al. 1986).

The Wada'tika seasonal round began in the early spring with root digging. The women would harvest roots and prepare them for storage (sego lily, bitterroot, camas, biscuitroot, Canby lomatium, bigseed lomatium, desert parsley, wild onion, and desert celery). A digging stick would be used to extract the roots and then they would be washed, peeled and dried. At this time the men would prepare and install fish traps along the Malheur River. Fishing devices used included nets, weirs, willow bundles, harpoons, and hooks. When the runs began, the women would join the men and dry the fish for storage. It was not uncommon for groups to move upstream to the Malheur Headwaters to fish. According to the Burns Paiute, the following groups including predecessors would come to the spring root grounds: Warm Springs Indians, Bannocks, Yakima, Northern Nevada Paiute, Shoshone, Umatilla, and Surprise Valley Paiutes. This provided an opportunity to socialize, trade, and arrange marriages (Couture 1978, 1996; Couture et al. 1986).

Once the salmon run was over the large assemblage would disperse pursuing resources like game, seeds, roots, berries, and crickets. The Wada'tika would move back toward the marshes and wetlands of the Harney Basin in the fall to collect wada, Indian rice grass, saltbrush, and wild rye. The men would participate in antelope drives using brush enclosures and in the winter rabbit drives. Winter subsistence relied on stored foods and hunting. The end of the winter and the emergence of spring brought migratory birds (mudhens, ducks, and geese) to the wetlands. The hunting of these birds required group effort and the use of nets, decoys, and bows (Couture 1978, 1996; Couture et al. 1986).

Sahaptin

The Sahaptin language group resided along the Columbia River and its tributaries relying heavily on anadromous fisheries. Hunn and French (1981) argue that while fishing was an important pursuit, so was the acquisition of lomatiums. It is estimated that the precontact Sahaptin population density was one person per five square kilometers (Hunn and French 1981:88). The population was large enough that several seasonal pursuits could occur simultaneously. Lomatiums were a high energy resource that provided balance to the high protein yield of salmon (Hunn and French 1981:93). The Sahaptin participated in an extensive trade system. They traded with the Klamath to the south (for California baskets, beads, eagle feathers, and slaves), the Chinook to the west (for dentalia and other shells), the Umatilla to the east (for horses, buffalo hides, and parfleches), and the Wishram to the north (for coiled baskets, slaves, and shells) (Murdock 1980:132).

The Tenino, or Warm Spring Sahaptin, include the Dalles Tenino, Tygh, Celilo, and John Day dialect groups. Their seasonal round began in March as they moved from protected interior winter sites to summer localities along the Columbia River. Each family constructed a rectangular structure made of poles and mats which was used as a living space and area to dry salmon. In April, a “First Fruits” ceremony featuring roots and salmon brought the Tenino to The Dalles Tenino village. After the ceremony, half of the families departed for the mountain hinterlands, women gathered roots and men hunted. The remaining population continued to catch and dry salmon. In late summer, the families returned to the summer village to celebrate a second food ceremony featuring berries and venison. Families divided once again to hunt and collect berries and nuts. Berry season ended in September and a long hunting expedition along the John Day and Deschutes rivers would occur. Women continued to dry salmon and gather roots. Families began returning to winter villages in October. Each family constructed an elliptical semi-subterranean earth covered lodged used for sleeping and a rectangular frame house used for cooking and daytime activities (Murdock 1980).

Archaeological Record

Northern Great Basin

Terminal Pleistocene (15,500-12,000 cal. BP [13,000-10,000 RCYBP]). The Laurentide ice sheet split the polar jet stream increasing the frequency of Pacific storms that reached the Great Basin during the last glacial maximum between 21,000 and 16,000 cal. BP (18,000 to 13,4000 RCYBP). This increase in precipitation, along with a decrease in temperature and evaporation, created many pluvial lakes in the Great Basin (Mehringer 1986:32). The increase in moisture and lower temperatures expanded the woodlands. The jet stream began to flow northward between 16,000 and 14,000 cal. BP (13,400 and 12,000 RCYBP) during the late glacial resulting in less effective moisture. The pluvial lakes began to drop sometime after 18,000 cal. BP (Grayson 1993; Minckley et al. 2004).

Humans were present in the Northern Great Basin at least by 15,500 cal. BP during the Terminal Pleistocene. This is based on the earliest radiocarbon date from Fort Rock Cave (Jenkins, Connolly and Aikens 2004:9). The productive and most intensively occupied areas in the Great Basin were the terraces near pluvial lakes. This assumption is based on the occurrence of Great Basin Western Stemmed and fluted points within these lowland areas (Bedwell 1973). Fluted points are usually found as isolates throughout the Great Basin but there are a few locations were multiple fluted points are represented such as the Dietz Site in the Alkali Lake Basin, central Oregon (Willig 1989), Sunshine Well Locality (Beck and Jones 2009), eastern Nevada, and China Lake, southeastern California (Davis and Richard Shutler 1969). Occupants at this time seem to be engaged in a hunting based system. Although there is no clear evidence for the hunting of megafauna (Beck and Jones 1997).

At Paisley Cave 5 a radiocarbon date of ca. 14,300 cal. BP (12,300±40 RCYBP) was obtained from a large camelid bone and a mean age of 13,270 cal. BP (n=4) from a partially charred horse bone. There was a strong correlation between these faunal remains and five obsidian artifacts recovered nearby and dated by obsidian hydration. However, three tightly twisted threads from the same unit and level dated to 12,750 cal. BP (10,550±40 RCYBP) making the findings inconclusive (Jenkins 2007). More recent investigations have recovered and dated horse (13,670 to 14,640 cal. BP), camelid (13,700 to 14,730 cal. BP), modified bear bone

(14,230 cal. BP) and large mammal (13,690 to 14,420 cal. BP) in association with artifacts and human coprolites (12,900 to 14,620 cal. BP) (Gilbert et al. 2008; Jenkins 2007).

According to Bedwell (1970), areas of the Great Basin and Columbia Plateau shared a similar environmental composition during the Terminal Pleistocene. At this time, the area would have been highly productive and people were less dependent on lake and river systems. This allowed for more fluid movement between the Great Basin and Columbia Plateau possibly creating a similar hunting and gathering culture. As these regions began to experience increased aridity during the Early Holocene, regional cultural diversification increased. Bedwell believes that "although the two areas eventually developed along two distinctive lines probably more than a casual contact continued between the inhabitants" (1970:233).

Early Holocene (12,000-7600 cal. BP [11,000-7000 RCYBP]). Greater summer insolation began during the Early Holocene creating warmer conditions and a decrease in effective moisture. Pluvial lakes continued to shrink transitioning into shallow marshes. In the northern Great Basin pluvial lakes were lower than those located in the south. This difference was due to an increase in monsoonal moisture in the south from the eastern subtropical North Pacific. The increase in aridity occurring in the Northern Great Basin caused pine, spruce, and fir to shift northward and upslope, while juniper dominated lower and middle mountain slopes. Sagebrush and grasses expanded across basin floors (Minckley et al. 2004).

According to Bedwell (1970), as aridity increases there is an increase in the intensity of cave sites. He argues that the proximity of caves to water sources and grasslands attracted a number of small to large animals and water fowl. The increased number of resources would have supported a larger human population than before. He referred to this increase in population and exploitation of lacustrine settings as the Western Pluvial Lakes Tradition (WPLT). It is during this period that Bedwell (1970) observed similarities in stemmed projectile point forms and flaking techniques with artifacts found in the Columbia River drainage (Bedwell 1970:222-223). These similarities suggest a continued relationship with people of the Columbia Plateau despite diverging cultural patterns.

In the Northern Great Basin, sites like the Connley Caves, Fort Rock Cave, Paisley Caves, and Cougar Mountain Cave contain assemblages associated with the WPLT. These Early Holocene assemblages contain Western Stemmed, Windust, lanceolate, and foliate projectile points, crescents, scrapers, bifaces, choppers, cobblestone tools, manos, and bone awls. The Connley Caves, located near Pauline Marsh, represents a winter residential base camp. The faunal assemblage contained a large number of waterfowl bones and terrestrial animal (rabbit, pika, small mammals, deer, elk, pronghorn, mountain sheep, and bison) remains (Jenkins, Connolly, and Aikens 2004).

These larger Early Holocene populations participated in broad subsistence patterns dependent on a variety of wild game resources. In addition to the variety of resources represented, obsidian sourcing suggests that a high degree of mobility was maintained. For example, a significant amount of exotic stone material, mostly from Fort Rock Basin, was transported to the Paulina Lake site, located in Newberry Caldera, on the Basin-Plateau border. This summer residential base camp contains three components. Component 1 (11,000 cal. BP) and Component 2 (10,500 to 8500 cal. BP) both contained pre-Mazama features (Connolly and Jenkins 1999:100-103). A pit feature from Component 1 (Feature 9) may have been used to store grass seeds, based on pollen and phytolith analysis (Cummings 1999:209). Macrobotanical analysis of remains collected within and around a hearth (Feature 7) from Component 2 yielded evidence of a variety of berries, herbs, and nutlets (Stenholm 1999:194). Blood residue analysis on chipped stone tools indicated the processing of rabbit, bison, bear, and deer (Connolly 1999:228). The lithic assemblage contained Western Stemmed and unstemmed foliate/lanceolate projectile points, abraders, hammerstones, mauls, girdled stones, plummet stone, handstones, and grinding slabs. There is no evidence of structures or hearths in Component 3 (8500 to 7500 cal BP). The assemblage is sparse suggesting a decrease in residential permanence. This change may reflect an increase in local aridity prior to the eruption of Mount Mazama (Connolly 1999:232).

The archaeological record suggests that Early Holocene hunter-gatherers participated in large scale procurement and processing activities. In Buffalo Flat, Christmas Lake Valley, Oregon, two large rabbit processing sites were identified, 35LK1881 and 35LK2076 (Oetting 1994, 2004). Both localities contained pits with several hundred grams of charcoal and 14,000 burned and unburned rabbit bones. Charcoal samples produced a range of radiocarbon dates between 8080±120 RCYBP to 9120±120 RCYBP (Oetting 1994:160). Both sites contained numerous flakes and chipped stone tools including Great Basin Stemmed points. Obsidian sourcing identified a variety of sources that ranged from 30 to 220 km away from the sites reflecting a high degree of mobility (Oetting 2004:239). Site 35LK1881 and 35LK2076 may represent one massive rabbit drive or several smaller drives occurring intermittently over several hundred years (Oetting 1994:167).

As basins continued to dry, a pattern of short-term foraging or hunting sites emerges near seasonally wet playas. By 10,800 cal. BP (9600 RCYBP) there was no permanent body of water in the Dietz Basin. Instead the basin had become a seasonally wet playa with patches of wet meadow. The Tucker Site, located in the Dietz Basin dated 10,700 cal. BP (9500±30 RCYBP), consisted of two possible hearths and two possible shelter floors. The features contain charcoal, animal bones, lithic debitage, and ground stone fragments. The identified faunal remains are mostly of small mammals and large birds, probably waterfowl or grouse (Pinson 2004).

The Locality III site in Fort Rock Valley was occupied intermittently for short periods between 8600 and 6300 cal. BP (7880 to 5550 RCYBP). The site contains a number of hearths with associated assemblages. The Early Holocene assemblages include a thin scatter of lithic debitage and bone. In addition, charred roots, fruity tissues, juniper, chenopodium, and sagebrush were identified (Jenkins, Droz, and Conolly 2004). An increase in short-term foraging and hunting sites like the Tucker site and Locality III persisted after 9000 cal. BP.

Middle Holocene (7600-3000 cal. BP [7000-2000 RCYBP]). The Middle Holocene begins with the climactic eruption of Mount Mazama (6850 RCYBP or 7600 cal. BP). The effects of Mount Mazama varied across the region. Areas like the Newberry Caldera and the Deschutes and Klamath River basin saw reduced biotic productivity due to the amount and depth of Mount Mazama tephra. While areas like Fort Rock basin and Harney basin maintained a degree of biotic diversity and productivity.

A warm dry trend persisted during the first half of the Middle Holocene (7600 to 6000 cal. BP). The Great Basin pluvial lakes were at their lowest levels and shadscale expanded replacing sagebrush (Wigand 1987). These changes reflected an increase in aridity and a decrease in effective moisture (Minckley et al. 2004). Macrobotanical evidence from the Locality III, DJ Ranch, Bowling Dune, Sage, and GP-2 sites in the Fort Rock Basin lowlands were used to identify subsistence and settlement strategies during the Middle Holocene. Small highly mobile bands continued to exploit marshes and surrounding grasslands but Early Holocene cave sites, like the Connolly Caves, were hardly occupied. A variety of lowland plant and animal resources with similar return rates were procured. Hunter-gatherers moved frequently between resource patches forming short-term occupation sites (Prouty 2004).

A gradual increase in effective moisture began during the latter half of the Middle Holocene (6000 to 3000 cal. BP). This increase in moisture expanded and stabilized marshes and allowed sagebrush to dominate basin floors. The southern portion of the Great Basin did not respond to this increase in effective moisture until about 2300 cal. BP (Minckley et al. 2004). In the Northern Great Basin there was an increase in human population, sedentism, and resource intensification. A greater dependence on seeds and fish in combination with increased sedentism may have been a response to large populations seeking dependable resources during times of climatic and ecological change (Jenkins, Aikens, and Connolly 2004). Prouty (2004) argues that storage was the key to adaptive success by serving as a, “buffer against resource stress during seasons of scarcity” (165).

The Bergen (6000 to 4000 cal. BP), DJ Ranch (5600 to 3700 cal. BP) and Dunn (3472 cal. BP) sites provided evidence of long term residential occupation during the Late-Middle Holocene (Helzner 2004; Moessner 2004; Musil 1995). These lowland sites contained built houses, hearths and storage pits. The Bergen and DJ Ranch sites are located in the Fort Rock Basin and the Dunn site is located in the Harney Basin. Macrobotanical analysis and the presence of groundstone, primarily metates and manos, suggested an increased dependence on seed processing. Upland roots begin to be exploited more after 4000 cal. BP. For example, at the DJ Ranch Site, Period 1 (5600 cal. BP) contained some unidentified root material but by Period 3 (3700 cal. BP) there is camas, biscuit root, and upland fruit material present in the assemblage which corresponds with the most intense period of occupation (Moessner 2004).

A variety of animal resources were procured, but a greater dependence on tui chub (fish) is clearly represented. Over 40 percent of the Bergen and DJ Ranch faunal assemblages consisted of tui chub bones. Both sites contained evidence of fishing technology in the form of net weights or sinkers and fish gorges. While fish remains were present in the Dunn assemblage, there seems to be a greater reliance on medium to large size mammals (Greenspan 1995:249). This is not true for other Harney Basin sites, where fish resources were a significant contribution to the diet. Initially the Bergen site was reported to have a low percentage of fish remains but flotation samples used for macrobotanical analysis produced a large number of fish bones (Helzner 2004:91).

Late Holocene (3000 cal. BP [2000 RCYBP] to Historic Contact). According to Grayson (1995) the Late Holocene climate was moister and cooler than the Middle Holocene. However, the Northern Great Basin experienced frequent wet-dry fluctuations which lead to less dependable lowland resources. While lowland resources continued to be used increasing Late Holocene populations began to shift toward greater dependence on upland root crop resources. Upland and lowland assemblages suggest more complex cultural systems by the presence of elite goods and varying house types (Aikens and Jenkins 1994; Wingard 2001).

At Carlon Village, eight stone ring houses were constructed on a peninsula located at the southern end of Silver Lake in Fort Rock Basin. Shallow earthen house floors surround these eight stone units. This lowland site was occupied between 2300 to 230 RCYBP with the most intensive periods of occupation being 2100 to 1500 RCYBP and 700 to 500 RCYBP (Wingard 2001:149). The faunal and plant assemblages suggest that marsh resources (fish, waterfowl, wada, bulrush, grasses, and chenopodia) and upland resources (fruity tissues, processed edible tissues, charred roots, and imported fuel wood and structural materials) were both highly utilized. Residents of Carlon Village maintained a complex tool kit, participated in a west and southwest trade network, and produced labor intensive nonessential objects (e.g. decorative bone beads and pendants). It is argued that residents of the village site may have been Penutian speakers like the Klamath-Modoc (Wingard 2001:151-153). The display of elite goods and labor intensive semi-subterranean structures is similar to behavior reported in Klamath-Modoc ethnography. Obsidian source data has linked inhabitants of Carlon Village with an upland root ground known as Boulder Village (Wingard 2001:137).

Boulder Village was occupied between 1500 and 200 RCYBP and is located east of Silver Lake near an upland root ground. The site contains 120 stone ring structures and 50 large cache pits. There are other upland root sites in the region but not as large as Boulder Village. The larger stone structures and cache pits were constructed between 1500 and 900 RCYBP. Similar in design but smaller structures and storage pits were built around the original village between 600 and 500 RCYBP. Like Carlon Village the structures in both periods resemble Klamath/Modoc design. Light built wickiups were erected by 200 RCYBP marking a change in dwelling type and possibly populations. The size of the cache pits (4 m in diameter and 1 to 1.5 meters deep) and botanical evidence suggests that large quantities of roots were being processed and stored. Boulder Village would have been occupied during the spring and summer in order to harvest and process the roots. Warmer lowland sites, like Carlon Village, would have been occupied during the winter. This dual seasonal settlement pattern is similar to the ethnographic Klamath/Modoc. However, the presences of lowland resources, like chenopodium and waada seeds, suggest that at times it was beneficial to winter at Boulder Village (Aikens and Jenkins 1994; Jenkins 1994).

The investment in building stone ring houses is not seen in the Harney Basin. However, winter villages like the Blitzen Marsh Site (2350 to 170 RCYBP) and McCoy Creek sites (1900 to 900 RCYBP) did occur (Fagan 1973; Musil 1995). Both sites contained a clay lined floor, deep storage pits, and large groundstone items. The faunal and botanical assemblages suggest greater dependence on plant (goosefoot, juniper, bunchgrass, and knotweed) and aquatic resources (tui chub, suckers, trout, and freshwater mussels). Labor intensive craft goods like tubular bone beads, bone flutes, and polished bone tubes were present. The presence of a single dentalium shell bead at both sites may suggest participation in a trade system (Musil 1995). It is argued by O'Grady (2006) that other sites like Hoyt, Laurie, and Broken arrow were not winter villages but centrally placed residences. These residential sites allowed foraging populations to store a variety of resources extracted from surrounding areas. These populations would assemble and travel to upland root grounds like the RJ Site (O'Grady 2006:48). So while there is a decrease in mobility, Harney Basin populations are still focusing on marsh/lake settings but are periodically moving great distances to hunting and root ground sites.

Southern Columbia Plateau

Early Holocene. The Columbia Plateau like the Northern Great Basin experienced greater summer radiation and a shift toward increased aridity (Whitlock 1992). Ames (1988) defines sparse Early Holocene populations as midlatitude foragers. They utilized a large area to procure high-yield low-cost seasonal resources but occasionally focused on one or two resources. This pattern of high mobility and broad subsistence would continue until the late Middle Holocene and throughout the Columbia Plateau.

There are two cultural phases identified during the Early Holocene the Windust phase (10,800-8000 BP) and the Early Cascade phase (8000-7000 BP) (Ames 1988; Leonhardy and Rice 1970). The Windust phase is defined by the presence of stemmed and unstemmed lanceolate shaped dart point. Windust points are widely distributed (observed in the Great Basin) and coincide with the Western Pluvial Lakes Tradition defined by Bedwell (1970:223). Cascade points are a small laurel leaf or willow leaf shaped biface or bipoint. The cultural material from both phases consisted of edge ground cobbles, large cobble spalls, pounding stones, scrapers, gravers, burins, bone needles, bone awls, and olivella beads (Ames et al. 1998; Andrefsky 2004). The only major difference between the two cultural phases other than the projectile point styles is the increased frequency of cobbles tools during the Early Cascade phase. According to Andrefsky (2007), the cobble tool industry has been linked by some researchers to the procurement and processing of anadromous fish but others suggest that hammers and cobble choppers found in the interior Columbia Plateau were used for the production of bone grease (Andrefsky 2007:256). Andrefsky believes that these artifacts can be placed into several tool types and each type can have more than one function.

Cobble tools are part of the basic Early Holocene assemblage but abraders, fishing tackle, anvils, and milling stones (hopper mortars) were specialized tools occasionally used, also. The use of milling stones represents a major investment in processing that is rarely seen during this time (Ames 1988). One of the best examples of an early processing locality is the Goldendale site located two miles north of the Columbia River (Warren et al. 1963). The assemblage contains 32 edge ground cobbles, 4 hand stones, and 19 milling stones. One milling stone had three small impressions of basket in dried mud stuck to the sides and edge of the stone. This root gathering and processing site was occupied some time during the Cascade phase (8000-4500 BP). The original report dates the Goldendale site between 6000-9000 years ago by presence of Cascade projectile points and oval knives (Warren et al. 1963:9).

Middle Holocene. The Late Cascade phase (7000-4500 BP) persisted into the early Middle Holocene with little changes in climate and cultural patterns. Population remained small mapping on to a variety of seasonally available resources (Ames 1988; Leonhardy and Rice 1970). It is during the Late Cascade that Northern Side Notched or Cold Springs Side Notched projectile points appear in post-Mazama assemblages (Andrefsky 2004).

In the late Middle Holocene, a gradual decrease in temperature began around 5500/4500 BP followed by an increase in moisture persisting into the Late Holocene ending around 2400 BP. The temperature dropped precipitously at 3900 BP, which coincides with a population decline and a 400 year hiatus between cultural phases Pithouse I and Pithouse II (Chatters 1995).

Pithouse I (5100-3900 RCYBP) is defined by the appearance of small semisubterranean pit houses. Hunter-gatherers populations adopted a low mobility foraging pattern placing sites a few hours from a number of seasonal resources. This allowed them to remain at one locality almost year around without the use of storage (Chatters 1995; Prentiss et al. 2005). There was a greater occurrence of hopper mortars, anvils, and pestles in the cultural material as edge ground cobbles disappeared. The southeastern Plateau sites like Alpowai, Hatwai, and Hatiuhpuh contained clusters of large hopper mortars suggesting an increase root processing but a broad spectrum diet still persisted (Ames et al. 1998).

Between 3900 and 3500 RCYBP pit houses were absent from the archaeological record. It was during this period that hunter-gatherer populations substantially decreased and returned to a more mobile lifestyle. A dramatic drop in temperature occurring at 3900 BP caused a shift in seasonality, resource availability and seasonal stream flow (Chatters 1995:357). Chatters (1995) suggest that a return to greater mobility occurred because hunter-gatherers did not have a strategy like storage to extend the seasonality of resources. In additions changes in seasonal stream flow impacted the timing and concentration of salmon and steelhead correlating with an increase in fish remains in the archaeological record.

The major difference between Pithouse I and Pithouse II is the addition of storage in the form of cache pits. Pithouse II (Chatters 1995) or Classic Collectors (Prentiss et al. 2005) (3500-2400 RCYBP [3600-2500 cal. BP]) begins with the reappearance of pit houses in greater numbers and distribution and an increase in population. People at this time were logistically organized collectors. A broad range of resources were procured but there was an emphasis on salmon and medium to large mammals. Andrefsky (2004) suggest that there is an increase in camas exploitation that concurs with the increase in salmon availability. Settlement patterns included residential base camps (small pit house villages) and field camps (shellfish gathering camps, root gathering camps, and hunting camps). Lava Butte located within the Great Basin-Columbia Plateau borderlands was occupied during the late Middle Holocene and Late Holocene based on presence of Elko, Rosegate, and Desert Side Notched projectile points. This field camp contained 13 hopper mortars and 6 possible metates or grinding stones. It is not clear if the hopper mortar bases are associated with Elko (Middle Holocene) or Rosegate/Desert Side Notched (Late Holocene) component but does suggest the processing of root plant resources (Davis and Scott 1991; Ice 1962).

Late Holocene. Between 3500 BP and 200 BP (3600-250 cal. BP) the Columbia Plateau encountered a series of short climatic shifts. Initially, a cool wet period occurred corresponding to the Pithouse II or Classic Collectors cultural phase. Previously, the described Classic Collectors phase is defined by the addition of storage to small pit house villages. Starting at 2400 BP (2500 cal. BP), a new cultural pattern emerged termed Complex Collectors. The distinguishing property between Classic and Complex Collectors is the emergence of corporate group households which originated from the Northwest Coast. A corporate group household contained multiple family units conducting a number of activities related to food preparation and tool production. The development of corporate groups allowed people to control access to resources while simultaneously increasing procurement of other resources. In general, Complex Collectors like Classic Collectors relied heavily on salmon but there was an emphasis on medium to large mammals and root plants. Another attribute of Complex Collectors is status inequality at the inter-individual and inter-household level (Prentiss et al. 2005).

Classic and Complex Collectors expanded and contracted across the Columbia Plateau corresponding to climatic shifts. Between 2400-1700 BP (2500-1800 cal. BP), a warm dry climate persisted and Classic Collector populations decreased in the Columbia Plateau but increased in the north in the Canadian Plateau. This increased aridity caused a decline in wet meadow geophytes like camas but an increase in dry meadow geophytes like *Lomatium sp*. Geophytes were important to the collector population because they provided a critical nutrient to a lean protein diet that ensured winter survival. This is one reason why populations may have fluctuated between the Columbia and Canadian Plateau as shift in climates allowed certain geophytes to flourish. Subsistence stress may have caused populations to aggregate and form large villages (like Umatilla, Wildcat Canyon, and Mack Canyon) near optimal fishing spots and fortified encampment with hidden food caches to protect resources from competing groups. The emergence of the bow and arrow at this time may imply an increase in violence caused by economic stress (Prentiss et al. 2005).

A warm moist climate occurred between 1700-1200 BP (1800-1250 cal. BP) and Classic Collector populations increased in the Columbia Plateau and decreased in the Canadian Plateau. A large number of pit house sites emerged along the Lower Columbia River and Lower Snake River. Complex Collector sites like Umatilla and Wildcat Canyon, contain a variety of prestige items like nephrite adze, elaborately carved digging stick handles, and exotic objects made of obsidian. A surplus in labor is suggested by the manufacturing of stone sculptures at The Dalles (Prentiss et al. 2005).

Between 1200-700 BP (1250-650 cal. BP), a warm dry climate occurred and Classic Collector populations decrease in the Columbia Plateau and increase in the Canadian Plateau. Beginning at 950 cal. BP, Wildcat Canyon and Umatilla contained small mat lodges suggesting a shift from residential to temporary camp sites. Complex Collector sites emerge along the Middle and Upper Columbia River as suggested by the presence of larger circular, subrectangular, and rectangular houses. Upper Columbia sites like Ferry Canyon A, Alpowai, and 45PO137, suggest a greater emphasis on medium to large mammals (Prentiss et al. 2005).

The climate was defined by cool temperatures and greater effective moisture between 700-200 BP (650-250 cal. BP). There is a general decrease in both Classic and Complex Collector populations. Around 500 cal. BP, rectangular plank houses and above ground ossuaries appeared at The Dalles suggesting a Chinookan presence. This would represent the last Complex Collector expansion (Prentiss et al. 2005).

CHAPTER FOUR: HISTORY OF RESEARCH

The Malheur Headwaters archaeological complex is managed by the USDA Forest Service (USFS) and is located in the Malheur National Forest, Grant County, Oregon. Since 1978, the USFS has conducted several cultural resource surveys of the valley for various undertakings. These preliminary surveys began identifying artifact concentrations. Beginning in 2001, more extensive testing established the range of cultural material and number of sites presented in the valley.

The archaeological complex contains 14 multicomponent sites and encompasses an area of 6,523 acres (2640 hectares). The archaeological sites represent those areas with the highest artifact density. A lower density of artifacts (mostly debitage) is observed between sites. The sites are located on small dry ridges within an upland valley and are adjacent to several water sources. The valley is defined as a seasonally wet meadow with a number of culturally significant plants such as, camas, wild onion, yampa, sego lily, and variety of *Lomatium sp* (Figure 4-1). The soil composition is described as light brown gravelly loam made from volcanic tuff and glacial till. The upland valley continues to be a well used resource for both cattle grazing and recreational use. These activities have caused some degree of disturbance but overall the sites are in good condition. The following is a summary of the archaeological work conducted in the Malheur Headwaters and a description of all 14 sites.

Archaeological Work Conducted

Janice Peterson (1978) completed the first report detailing the findings of a 140 acre pedestrian survey in the northern portion of the valley. The area surveyed was described as a single site containing intermittent clusters of artifacts consisting of debitage, projectile points, knives, scrapers, mullers and metates. She noted that the metates may actually be hopper mortar bases. Given that only one metate has been recorded in the valley it is assumed that they were hopper mortar bases. Peterson acknowledged that cultural material extended past the 140 acres surveyed and believed the valley contained multiple sites (1978:44).

As other portions of the valley were surveyed for various undertakings (Bibb 1984, 1985; Duncan 1994; Stegell and Tousant 1992; Zilverberg and Bibb 1982a), it would be confirmed that the extent of human occupation in the valley was larger than initially recorded. The pedestrian surveys were usually conducted at 30 to 50 meter transect intervals. The valley seemed to contain discrete clusters of stone tools and debitage. Initial site boundaries were influenced by survey project limits.

Beginning in 2001, the USFS completed more extensive pedestrian surveys at five meter transect intervals. The surveys were designed to systematically determine the distribution and types of artifacts present in the valley. Initially, surveys began with previously recorded sites to determine the extent of the surface assemblage. Once this was accomplished, the areas between known sites were surveyed. A Trimble GPS device was used to map all cultural material observed, excluding debitage. A sample of the bifaces in addition to all projectile points and stone tools rarely observed, were collected. The GPS data revealed a pattern in the distribution of artifacts. Distinct lithic clusters, on small ridges, within the valley were recognized. A lithic cluster was defined as a concentration of debitage, chipped stone tools, and/ or hopper mortars. Attention was then focused on those areas identified as lithic clusters (U.S. Forest Service 2001-2009). In 2009, after several years of surveying, more accurate site boundaries were created. The site boundaries were defined by the spatial distribution of chipped stone tools and/or hopper mortars. The density of debitage is greater within these site boundaries but a light scatter of debitage can be observed outside of these margins.

In addition to surveys, a number of excavation projects have been conducted (Table 4-1). The purpose was to examine the range and context of the possible subsurface components. The testing has shown little to no stratigraphy and usually the cultural material is concentrated within the first 30 to 50 cm (U.S. Forest Service 2001-2009). The lack of stratigraphy is probably the result of both natural and human activity. A history of gravitational and fluvial erosion in the area may be one reason for the lack of stratigraphy (U.S. Forest Service 2000:4). Also, a great deal of bioturbation and cryoturbation occurs throughout the valley. Historically, large portions of the valley were plowed and reseeded to create livestock fodder (U.S. Forest Service 1937).

Table 4-1. Summary of Excavations Completed.

Date	Site	Survey Description	Number
June1996	646-3003	1x1 meter excavation unit	5
July 2001	*646-3000	1x1 meter excavation unit	5
July 2001	*646-3004	50x50 cm shovel probe	7
August 2001	*646-3004	2x2 meter shovel scrape	2
August 2002	*646-3000	1x1 meter surface sample	30
August 2002	*646-3000	2x2 meter surface scrape	2
June 2003	*646-3001	50x50 cm shovel probe	4
August 2003	*646-3010	50x50 cm shovel probe	2
September 2003	*646-3000	50x50 cm shovel probe	4
October 2003	*646-3010	50x50 cm shovel probe	7
July 2008	*646-3001	1x1 meter excavation unit	4
July 2008	*646-3004	1x1 meter excavation unit	3
July 2008	646-3012	1x1 meter excavation unit	1
August 2009	*646-3000	2x2 meter excavation unit	1
August 2009	646-3013	50x50 cm shovel probe	4

***** Sites sampled.

Malheur Headwaters Archaeological Sites

All 14 archaeological sites are eligible for inclusion into the National Register of Historic Places (NRHP) under the 1984 Lithic Scatter Programmatic Memorandum of Agreement (USDA Forest Service 1984). In addition, this collection of sites has the potential to be listed as an archaeological district on the NRHP. The sites can be described as dense lithic scatters all containing debitage, bifaces, and projectile points. Other stone tools represented in lesser numbers are unifaces, knifes, drills, scrapers, abraders, edge modified flakes, hammer-stones, cores, cobble tools, manos, and a metate (Table 4-2). The majority of the stone tools are manufactured from obsidian. However, a small number of tools have been manufactured from cryptocrystalline silicates (CCS), basalt, dacite, andesite, and rhyolite. In addition, the Malheur Headwaters contains approximately 201 hopper mortar bases made of vesicular basalt, vesicular andesite, basalt, or andesite. Sites 646-3006 and 646-3007 are the only two sites that do not contain hopper mortars.

Figure 4-1 is a map of the Malheur Headwaters. The map illustrates site locations, perennial streams, the fen (an alkaline wetland), and the modern distribution of plant resources. The distribution of root plant resources like *Lomatium sp.* and camas was based on field notes, topography, and habitat (Hann 2010). *Lomatium sp.* (e.g., biscuit root) thrive in dry open scabby ridges (Johnson 1998) similar to the small dry ridges seen in the valley. Snow melt has created a seasonally wet meadow among these ridges. Camas grows well in moist meadows and seepages (Johnson 1998).

Sites 646-3006 and 646-3007 located on the southwestern edge of the valley are the only sites not surrounded by these root plant resources. This may explain the lack of hopper mortar bases and low artifact density at the two sites. In comparison, sites 646-3000 (n = 29), 646-3001 (n = 21), 646-3002 (n = 23), and 646-3010 (n = 41) contain twenty or more hopper mortar bases and are located in the northeast section of the valley with equal access to both camas and *Lomatium* species. In addition, three of the four largest artifact densities are located in this section of the valley: 646-3000 (n = 399), 646-3008 (n = 260), and 646-3010 (n = 127). The following section provides a more detailed discussion of all fourteen sites.

Site Descriptions

Site 646-3000. The 90,300 square meter site is located 695 meters west of a perennial stream, and just west of an unpaved forest service road. The site is located on the most prominent ridge in the valley surrounded by an open meadow. An unnamed spring is located on the northern portion of the 90,300 square meter site. The spring attracts cattle grazing which causes a degree of disturbance. In 2003, an exclosure was constructed around a portion of the site as a method of protection and the spring was redirected outside the site boundary. Site 646-3000 has the largest chipped stone tool assemblage (n = 370) and the third largest sample of hopper mortar bases (n = 29) in the Malheur Headwaters. Excavations conducted have shown cultural deposits reach 90 cm. Artifacts collected during excavations were projectile points (n = 4), bifaces (n = 37), scrapers (n = 2), edge modified flakes (n = 12), cores (3), a uniface (n = 1), a drill (n =1), and debitage.

Site 646-3001. The site is located 645 meters west of a perennial stream and just south of a paved road. It is situated between several intermittent drainages within an open meadow and is centrally located within the area of occupation. Site 646-3001 is one of the smallest sites in the valley with an area of 26,278 square meters. A holding pen located east of the site was repositioned in 2009 creating a spatial buffer between the site and grazing activity. The site contains the second largest sample of hopper mortar bases (n = 31) in the valley. The number of hopper mortars contributes to almost half of the total site assemblage (n = 67). Excavations conducted have shown cultural deposits to reach 70 cm. Artifacts collected during excavations were bifaces (n = 8), unifaces (n = 2), edge modified flakes (n = 5), and debitage.

Site 646-3002. The site is centrally located in the valley in an open meadow and is 198 meters east of a perennial stream. An intermittent drainage runs along the eastern extent of the site. Site 646-3002 is one of the smallest sites in the valley with an area of 30,235 square meters but contains the fourth largest sample of hopper mortar bases (n = 23). The number of hopper mortars contributes to almost half of the total assemblage (n = 58).

Site 646-3003. The site covers an area of 63, 657 square meters and is located in an open meadow. A perennial stream is located 168 meters west of the site. The northern portion of the site is bisected by a paved road and two drainages flank the eastern and western site boundaries. Site 646-3003 has only one hopper mortar base recorded. Also, the majority of projectile points recorded are Northern Side Notched dart points (n = 8), no arrow points have been found on the site. Excavations conducted have shown cultural deposit to reach 100 cm. Artifacts collected during excavations were bifaces (n = 5), a uniface (n = 1), an edge modified flakes (n = 1), and debitage.

Site 646-3004. The site is located on the eastern side of the Malheur Headwaters archaeological complex in an open meadow with less than five percent tree cover (ponderosa pine and lodgepole pine). A perennial stream divides site 646-3004 from site 646-3003. The site covers an area of 51,653 square meters. The only heat altered rock (HAR) feature observed in the valley is present on this site. In 2008, the northwest corner of the HAR feature was excavated and a hopper mortar with two bowl-like depressions was recovered. Two associated charcoal samples were sent to Beta Analytic Inc. for radiocarbon dating. Sample 646-1895-CH1 was

Table 4-2. Surface Artifacts Recorded by Site (646-3###).

Artifact Type	*3000	*3001	3002	3003	*3004	3005	3006	3007	3008	3009	*3010	3011	3012	3013	Adj.	Total
Hopper Mortars	29	31	23	1	2	2	0	0	7	3	41	2	13	7	40	201
Projectile Points	97	6	2	10	33	3	1	2	25	11	26	4	6	3	26	255
Bifaces	241	28	27	59	83	18	8	20	213	54	59	28	57	25	119	1039
Unifaces	8	0	0	0	2	0	1	1	2	1	1	0	0	1	0	17
Knifes	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	3
Drills	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6
Scrapers	5	0	0	0	1	0	0	2	0	0	0	0	0	0	0	8
Abraders	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
EMF	6	1	4	3	7	0	0	0	7	7	0	0	5	0	1	41
Hammer-stones	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Core	3	0	1	3	1	0	0	0	4	1	0	0	0	0	1	14
Cobble	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Mano	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Metate	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Ground Stone	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	3
HAR	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	3
Total	399	68	58	78	134	23	11	25	260	77	127	34	81	36	188	1600

Adj. = Adjacent areas, those areas within the archaeological complex not associated with a site.
EMF = Edge Modified Flakes.
HAR = Heat Altered Rock.
* Sites sampled.

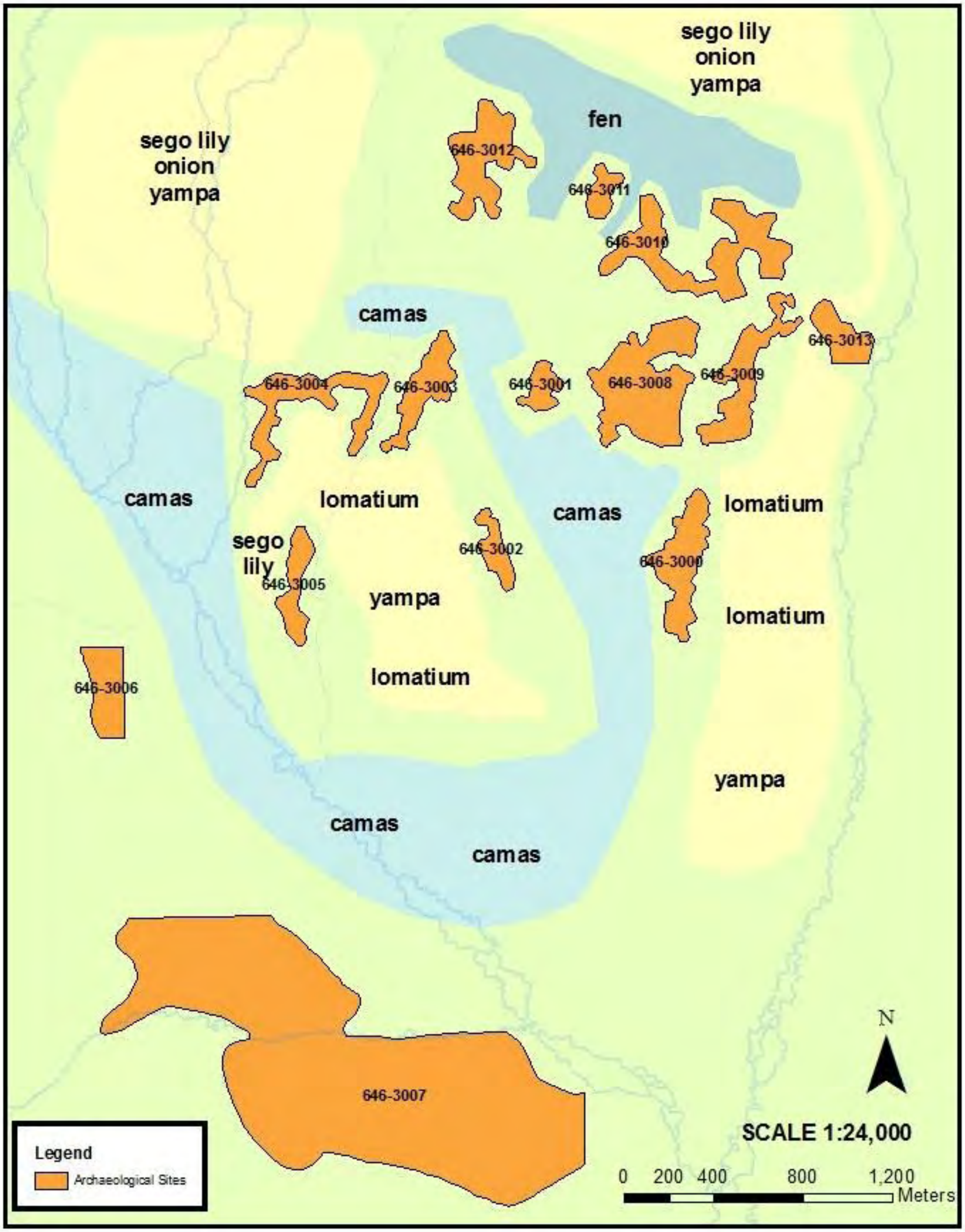


Figure 4-1. Map of the Malheur Headwaters.

dated 600 +/- 40 BP (660 to 530 cal. BP; Beta-246899) and Sample 646-1895-CH2 was dated 310 +/- 40 BP (490 to 290 cal. BP; Beta-246900) (Tamers and Hood 2008).

Site 646-3004 has the third largest chipped stone tool assemblage (n=134) but only two hopper mortar bases. Also, there is a significant difference between the number of dart (n = 27) and arrow (n = 6) projectile points recorded. Excavations conducted have shown cultural deposit to reach 60 cm. Artifacts collected during excavations, in addition to the hopper mortar, were projectile points (n = 3), bifaces (n = 3), edge modified flakes (n =3) and debitage.

Site 646-3005. The site covers an area of 44,245 square meters and is located south of site 646-3004. It is situated in an open meadow between two perennial drainages. The site is bisected by an unpaved road. Site 646-3005 has one of the smallest archaeological assemblages (n = 23) in the Malheur Headwaters. The majority of the assemblage consist of bifaces (n = 18).

Site 646-3006. The site area is 60,937 square meters and is located on the south east side of the Malheur Headwaters archaeological complex. An unpaved road is located 230 meters to the west and a perennial stream is located 402 meters east of the site. Site 646-3006 sits on three small ridges bisected by intermittent drainages. A large portion of the site includes a lodgepole pine tree stand. The site contains the smallest archaeological assemblage (n = 11) in the valley. Of the two manos found in the archaeological complex, one was found on this site.

Site 646-3007. The site covers an area of 1,345,634 square meters and is located at the confluence of two perennial streams. An unpaved road flanks the western edge of the site. The site is situated on two ridges bisected by a perennial stream. The ridge north of the drainage is an open sagebrush prairie and south of the drainage there is a lodgepole pine tree stand.

Site 646-3007 is an obsidian quarry. Obsidian is observed throughout the site but the preponderance of raw material is found on the northern ridge. The site contains obsidian cobbles that range from small to medium (no larger than 4 inches in diameter) in size and of low grade quality (Zilverberg and Bibb 1982b). Most of the cobbles contain phenocrysts and/or bubbles. These inclusions have created a dull surface luster and earthy surface texture. Zilverberg and Bibb stated that people probably, “carried off cobbles and flakes, but that the area was not an important lithic source” (1982b:1). The obsidian cobbles have been identified as a secondary deposit of Whitewater Ridge obsidian by the Northwest Research Obsidian Studies Laboratory. Higher grade Whitewater Ridge obsidian is located four miles away. This higher grade material was preferred when manufacturing formed stone tools (Hann, personal communication 2010). The site contains an estimated 2000 obsidian flakes and has the third smallest archaeological assemblage (n = 25).

Site 646-3008. The site is located 115 meters east of site 646-3001, 225 meters north of site 646-3000, and 789 meters west of a perennial stream. A paved road bisects the site and two intermittent drainages flank the eastern and western site boundaries. Site 646-3008 is the second largest site in the archaeological complex, with an area of 177,815 square meters, and contains the second largest archaeological assemblage (n = 260). The majority of the assemblage is composed of bifaces (n =213). Compared to other sites with large archaeological assemblages site 646-3008 has a small sample of hopper mortar bases (n = 7). Also, there is a significant difference between the number of dart (n = 22) and arrow (n = 3) projectile points recorded. There is a range of dart points represented.

Site 646-3009. The site covers an area of 90,438 square meters and is located 571 meters west of a perennial stream. An intermittent drainage separates site 646-3009 from site 646- 3008. The site is transversely bisected by a paved road and is flanked by two intermittent drainages. The archaeological assemblage is mostly composed of bifaces (n = 54). There is a significant difference between dart (n = 10) and arrow (n =1) projectile points, the majority of the typed points are Elko (n =7).

Site 646-3010. The site is located on the northern portion of the archaeological complex and is 964 meters west of a perennial stream. The 160,181 square meter site is on a seasonally wet meadow and a large aspen, ponderosa pine, and lodgepole pine tree stand lies along its northern edge. Site 646-3010 has the largest sample of hopper mortar bases (n=41) and the fourth largest chipped stone tool assemblage (n = 86) in the valley. The site contains a range dart point types but no arrow points. The majority of the hopper mortar bases are located within the tree line. Excavations conducted have shown cultural deposit to reach 50 cm. Artifacts collected during excavations were a projectile point (n = 1), bifaces (n =6), and debitage.

Site 646-3011. The site is located 114 meters west of site 646-3010 and is 950 meters east of a perennial stream. It is situated in a seasonally wet meadow with several intermittent drainages. A lodgepole pine tree stand is located along the site's northern border. The 23,940 square meter site is the smallest site in the archaeological complex and contains the least amount of cultural material (n = 34). The archaeological assemblage is largely composed of bifaces (n = 28).

Site 646-3012. The site is located on the northwest portion of the archaeological complex, covering an area of 101,536 square meters. It is 423 meters east of a perennial stream and is surrounded by several intermittent drainages. The site is on a semi-open meadow with a ponderosa pine and lodgepole pine tree stand situated on the northern end of the site. The archaeological assemblage (n = 81) is composed mostly of bifaces (n = 57) and hopper mortar bases (n = 13). Excavations conducted have shown cultural deposit to reach 40 cm. Artifacts collected during excavations were a biface (n =1) and debitage.

Site 646-3013. The site covers an area of 44,294 square meters and is located on the eastern side of the Malheur Headwaters archaeological complex. It is 140 meters west of a perennial stream. The western portion of the site contains a lodgepole pine tree stand surrounded by a dry open meadow and sagebrush. The eastern extent of the site is a riparian area with associated willows. The archaeological assemblage (n = 36) is composed mostly of bifaces (n = 25) and hopper mortar bases (n = 7). Excavations conducted have shown cultural deposit to reach 80 cm. Artifacts collected during excavations were bifaces (n = 5), an edge modified flake (n =1), a graver (n = 1), and debitage.

The Malheur Headwaters archaeological complex is located in a dynamic ecological setting. The upland valley is an ecotone that allows for a number of different habitats to be exploited at once, this may have attracted hunter-gatherers to the area. Human occupation within the upland valley is focused on those areas adjacent to present camas and *Lomatium* resources. The fourteen archaeological sites within the valley contain a mixed assemblage of chipped stone tools, debitage, and hopper mortars. There are a range of projectile point types represented that include Large Stemmed, Willow Leaf, Northern Side Notched, Gatecliff Contracting Stem, Gatecliff Split Stem, Elko Series, Rosegate Series, Small Corner Notched, and Desert Side Notched (Table 4-3).

Of the 255 projectile points recorded in the Malheur Headwaters, there are 199 dart points (i.e., Large Stemmed, Willow Leaf, Northern Side Notched, Gatecliff Contracting Stem, Gatecliff Split Stem, and Elko Series) and 56 arrow points (i.e., Rosegate Series, Small Corner Notched, and Desert Side Notched). The projectile point types most represented are the Northern Side Notched dart point (n = 86), Elko series dart point (n = 53), Rosegate series arrow point (n = 28), and Small Corner Notched arrow point (n = 25). These four point types represent 75 percent of the projectile points recorded at the Malheur Headwaters.

The projectile point types are distributed across the archaeological complex. However, there are parallels between hopper mortar bases, projectile point types, and artifact densities. The following site assemblages contain 20 or more hopper mortar bases: 646-3000 (n = 29), 646-3001 (n = 31), 646-3002 (n = 23), and 646-3010 (n = 41). These four sites contain 62 percent (n = 124) of the hopper mortars recorded in the valley. As seen in Figure 4-1, all four sites are located within the northeast portion of the archaeological complex. This area also contains three of the largest site assemblages in the Malheur Headwaters: 646-3000 (n = 399), 646-3008 (n = 260), and 646-3010 (n = 127). These five assemblages (646-3000, 646-3001, 646-3002, 646-3008, and 646-3010) contain 57 percent of the dart points (n = 113) and 77 percent of the arrow points (n = 43) recorded in the archaeological complex. This may suggest an association between arrow points and hopper mortar bases. Specifically, Rosegate series and Small Corner Notched arrow points, an assumption based on the small number of Desert Side Notched arrow points (n = 2). Two factors may influence the strength of this correlation (1) site 646-3000 contains the majority of the arrow points (n = 34) and (2) there are no arrow points recorded within site 646-3010.

The number of hopper mortars and stone tools suggest greater occupation over time in the northeast portion of the Malheur Headwaters archaeological complex. In Figure 4-1, this area extends south of the fen to sites 646-3000 and 646-3002. The area contains more than half of the hopper mortars bases in the valley. Three hopper mortars bases and adhering soil were sent for pollen, starch, phytolith and protein residue analysis (Varney et al. 2003). The elevated *Lomatium* pollen frequencies concluded that the hopper mortars were probably used to process biscuit root. There was some evidence that fruits or hips of members of the rose family were processed. Also, two of the hopper mortar bases may have been used to grind cool-season grass seeds. There was no evidence of animal or fish processing.

The Malheur Headwaters archaeological complex is located in a dynamic ecological setting. The upland valley provided access to numerous resources. Analysis of the three hopper mortars suggests that people were processing plant resources like *Lomatiums*. In addition, the density of chipped stone tools and hopper mortar bases suggests occupation was greatest within the northeast portion of the archaeological complex.

Table 4-3. Projectile Point Types Recorded by Site (646-3###).

Projectile Point Type	*3000	*3001	3002	3003	*3004	3005	3006	3007	3008	3009	*3010	3011	3012	3013	Adj. Area	Total
Large Stemmed	5	0	0	0	2	0	0	1	2	1	2	0	1	0	0	14
Willow Leaf	1	0	0	0	0	0	0	0	1	1	1	0	0	0	1	5
Northern Side Notched	39	1	0	8	10	2	0	1	5	0	10	2	1	1	6	86
Gatecliff SS	2	1	0	0	2	0	0	0	4	1	6	0	0	0	1	17
Gatecliff CS	2	0	0	0	0	0	0	0	1	0	1	0	0	1	1	6
Elko	9	0	0	1	9	1	1	0	8	7	4	2	2	1	8	53
Rosegate	16	0	1	0	2	0	0	0	3	1	0	0	1	0	4	28
Small Corner Notched	16	4	1	0	4	0	0	0	0	0	0	0	0	0	1	25
Desert Side Notched	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Dart Point	5	0	0	1	4	0	0	0	1	0	2	0	1	0	4	18
Arrow Point	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total	97	7	2	10	33	3	1	2	25	11	26	4	6	3	26	255

Adj. = Adjacent areas, those areas within the archaeological complex not associated with a site.

* Sites sampled.

CHAPTER FIVE: METHODS

The intent of the research design is to model the relationship between hunter-gatherer mobility and the conveyance of lithic raw material. It is assumed that as hunter-gatherers moved within the environment, the procurement of lithic raw material would be scheduled during the acquisition of food resources. The location of raw material used for the manufacturing of stone tools reflects the scale of hunter-gatherer movement across the landscape. The spatial and temporal data needed to trace hunter-gatherer movement can be obtained from one singular artifact type, obsidian projectile points. X-ray fluorescence (XRF) analysis can provide the geological location of the raw material used to create obsidian stone tools. Obsidian hydration dating (OHD) and projectile point typology allows the obsidian projectile point itself to be used as a chronological marker. A sample of 88 obsidian projectile points of different types from the Malheur Headwaters was used to create an index of mobility over time.

Sampling

The following factors were considered when deciding which sites to sample for this study: overall density of chipped stone tools, frequency of hopper mortars, test excavations, and a usable sample of obsidian projectile points. There are fourteen archaeological sites within the Malheur Headwaters. These sites contain a mixed surface assemblage composed of lithic material. Based on the density of chipped stone tools and hopper mortars, the hub of human occupation was south of the fen, between two perennial streams, surrounded by camas and *lomatium* root crop fields.

Sites 646-3006 and 646-3007 are located on the southeastern edge of archaeological complex, just outside the *Lomatium* and camas fields. Site 646-3007 is an obsidian quarry. There are no hopper mortar bases present at either site and they contain a low density of chipped stone tools. These two sites were eliminated from further consideration.

The remaining twelve sites were then evaluated. The two most important factors were (1) frequency of hopper mortar bases and (2) the density of chipped stone tools. Sites 646-3000, 646-3001, 646-3002, and 646-3010 contained 20 or more hopper mortars. Sites 646-3000, 646-3004, 646-2008, and 646-3010 contained the largest density of chipped stone tools (and the largest number of projectile points). Sites 646-3000 and 646-3010 were chosen because they contain both a high frequency of hopper mortars and a large density of stone tools. In addition, archaeological excavations have been conducted at both sites.

Sites 646-3000 and 646-3010 were located on the east side of the valley. A focus was then placed on those sites located in the western and central portions of the valley to ensure the sample represented the entire area of occupation. Site 646-3001 was chosen because it was centrally located and contained a high frequency of hopper mortars and a moderate number of chipped stone tools. Site 646-3004 was chosen because it had the largest density of stone tools on the east side of the valley. Also, archaeological excavations have been conducted at both sites.

The projectile point samples used for this study came from sites 646-3000, 646-3001, 646-3004, and 646-3010. These sites represent the area most used by hunter-gatherers based on the density of chipped stone tools and hopper mortars. The criterion for sampling was (1) projectile points manufactured from obsidian, (2) complete points or basal fragments, (3) diagnostic projectile points, and (4) surface artifacts. The sample was chosen from projectile points available at the time for x-ray fluorescence (XRF) analysis and obsidian hydration dating (OHD). The following is a brief summary of these four sites and the number of projectile points sampled. A more detailed site description is found in chapter four.

Site 646-3000 contains the largest and most diverse assemblage (n = 399) in the archaeological complex. A sample of 53 projectile points was chosen from the 97 points recorded. Of those 97 projectile points, six were non-diagnostic projectile points and seven were not made from obsidian. Of the remaining 84 projectile points, 53 points were chosen based on availability. Site 646-3001 is centrally located within the twelve archaeological sites and has the second largest sample of hopper mortars (n = 31). All seven projectile points found at the site were used. Site 646-3004 has the third largest chipped stone tool assemblage (n = 129) in the Malheur Headwaters. A sample of 13 projectile points was chosen from the 33 points recorded. It should be noted that since the sample was chosen the site area was expanded. Site 646-3010 contains the largest concentration of hopper mortar bases (n = 41) and the fourth largest chipped stone tool assemblage in the archaeological complex. A sample of 15 projectile points was chosen from the 26 points recorded. It should be noted that since the sample was chosen the site area was expanded.

A total of 88 obsidian projectile points was chosen. The sample came from the Malheur Headwaters collection, managed by the U.S. Forest Service, located at the Malheur National Forest, John Day, Oregon. The projectile points were collected and recorded during pedestrian survey discussed in chapter four. Once the sample was chosen, the projectile points were placed into a typology and sent to Northwest Research Obsidian Studies Laboratory for XRF and OH analysis. The following section discusses the method used to type the projectile points and the number of each point type represent in the sample.

Projectile Point Typology

Originally, the projectile points were typed by a number of Forest Service employees. In 2009, I also went through and typed the sample before submitting the specimen for XRF and OH analysis. Justice (2002) and Hann (2006) were used to define point typology. Hann (2006) provided a range of measurements (maximum length, maximum width, maximum thickness, and neck width) specific to point styles found in the Malheur National Forest, Oregon. Point morphology and measurements from Hann (2006) were used to determine point type. The age range for each point type was derived from Justice. The chronology was based on the projectile point's position within stratified sites, and their ages based on carbon-14 dates and obsidian hydration. The dates presented by Justice were in B.C. format and were converted to BP format to be consistent.

Large Stemmed (10,950-7950 BP). Five Large Stemmed dart points were identified in the sample. This Early Holocene dart point is also referred to as Great Basin Stemmed which includes a variety of stemmed and lanceolate shaped projectile points. Large Stemmed dart points tend to have straight or contracting stems with straight or convex bases (Figure 4-1). The point measurements are: maximum length (3.4-9.2 cm), maximum width (2.4-3.2 cm), maximum thickness (0.4-0.9 cm), and neck width (1.4-2.4 cm) (Hann 2006).

Northern Side Notched (7950-4950 BP). Thirty-five Northern Side Notched dart points were identified in the sample. The point type emerged during the early Middle Holocene and disappeared during the late Middle Holocene. This dart point exhibits U-shaped notches placed horizontal to the long axis. The stem is usually expanding but the range of variation includes straight and contracting stems. The base can be straight or concave, occasionally convex (Figure 4-1). The point measurements are: maximum length (1.5-5.4 cm), maximum width (1.4-2.9 cm), maximum thickness (0.2-0.7 cm), and neck width (1.0-2.0 cm) (Hann 2006).

Gatecliff Split Stem (4950-3250 BP). Ten Gatecliff Split Stem dart points were identified in the sample. This late Middle Holocene dart point exhibits a bifurcated base with slightly rounded to sharp basal ears. The base is notched and ranges between V-shape to an expanding U-shape. The stem is usually straight but the range in variation includes expanding and contracting stems (Figure 4-2). The point measurements are: maximum length (2.5-4.5 cm), maximum width (1.5-2.6 cm), maximum thickness (0.2-0.7 cm), and neck width (0.9-1.6 cm) (Hann 2006).

Gatecliff Contracting Stem (3950-2750 BP). Two Gatecliff Contracting Stem dart points were identified in the sample. The point type emerged during the late Middle Holocene and ended early during Late Holocene. The dart point is a variant of the Gypsum cluster. The dart point has a contracting stem and convex base (Figure 4-2). The point measurements are: maximum length (2.2-4.0 cm), maximum width (1.8-2.4 cm), maximum thickness (0.5-0.7 cm), and neck width (1.1-1.3 cm) (Hann 2006).

Elko Series (3450-1250 BP). Nine Elko dart points were identified in the sample. This late Middle Holocene dart point was gradually replaced by the Rosegate Series during the Late Holocene. The series is divided into three subtypes corner notched, side notched, and eared. It is argued that Elko Eared points evolved from Gatecliff Split Stem points and Elko Corner Notched point derived from Elko Eared. The Elko Corner Notched is prevalent in the Malheur National Forest. The base exhibits a range in variation that includes straight, concave, convex, and notched. The stem is usually expanding (Figure 4.2). The point measurements are: maximum length (1.1-5.1 cm), maximum width (1.4-3.3 cm), maximum thickness (0.2-0.7 cm), and neck width (0.7-1.8 cm) (Hann 2006).

Rosegate Series (1250-650 BP). Eight Rosegate arrow points were identified in the sample. The appearance of this Late Holocene point marks the transition to bow and arrow technology in the Great Basin. The Rosegate series is a combination of the Rose Spring Corner Notched and Eastgate Expanding Stem. The Rosegate series exhibits a narrow to wide triangular shape with corner or basal notching. The stem displays a range in variation that includes expanding, straight, and contracting (Figure 4-3). The point measurements are: maximum length (2.1-3.3 cm), maximum width (1.3-2.2 cm), maximum thickness (0.2-0.4 cm), and neck width (0.5-0.8 cm) (Hann 2006).

Small Corner Notched (750 BP-Historic). Seventeen Small Corner Notched arrow points were identified in the sample. The Malheur National Forest uses the descriptive term Small Corner Notched for this Late Holocene point type. This arrow point is a variant of the Gunther Barbed series. The Small Corner Notched type exhibits a triangular shape with corner notching; basal notching is occasionally seen. The stem varies between straight to expanding (Figure 4-3). The point measurements are: maximum length (1.0-2.6 cm), maximum width (0.9-1.8 cm), maximum thickness (0.1-0.4 cm), and neck width (0.2-0.5 cm) (Hann 2006).

Desert Side Notched Series (650 BP-Historic). Two Desert Side Notched arrow points were identified in the sample. The shape of this Late Holocene point varies from an isosceles to equilateral triangle with a straight, concave, or notched base. The side notches are usually narrow and deep. The stem varies from straight to expanding (Figure 4-3). The point measurements are: maximum length (0.8-2.7 cm), maximum width (0.9-1.5 cm), maximum thickness (0.2-0.4 cm), and neck width (0.5-0.9 cm) (Hann 2006).

Length: 2.7 cm
Width: 2.6 cm
Thickness: 0.7 cm
Neck Width: 2.1 cm
Artifact No. 950

Length: 3.7 cm
Width: 2.0 cm
Thickness: 0.8 cm
Neck Width: 1.8 cm
Artifact No. 1068

Length: 3.0 cm
Width: 2.8 cm
Thickness: 0.8
Neck Width: 2.1 cm
Artifact No. 1130

Length: 1.4 cm
Width: 2.5 cm
Thickness: 0.6 cm
Neck Width: 1.4 cm
Artifact No. 157

Length: 3.96 cm
Width: 2.03 cm
Thickness: 0.7 cm
Neck Width: 1.92 cm
Artifact No. 224

Length: 5.06 cm
Width: 1.87 cm
Thickness: 0.53 cm
Neck Width: 1.17 cm
Artifact No. 228

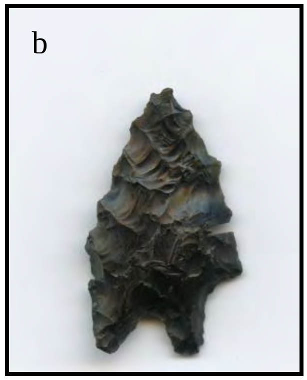
Length: 3.53 cm
Width: 2.02 cm
Thickness: 0.52 cm
Neck Width: 1.13 cm
Artifact No. 244

Length: 6.1 cm
Width: 3.0 cm
Thickness: 0.8 cm
Neck Width: 2.0 cm
Artifact No. 1069

Length: 3.9 cm
Width: 1.9 cm
Thickness: 0.6 cm
Neck Width: 1.4 cm
Artifact No. 1083

Figure 5-1. Projectile points: a - c Large Stemmed, d - i Northern Side Notched.

Length: 4.04 cm
Width: 2.11 cm
Thickness: 0.67 cm
Neck Width: 1.16 cm
Artifact No. 233



Length: 3.39 cm
Width: 1.96 cm
Thickness: 0.59 cm
Neck Width: 0.8 cm
Artifact No. 241

Length: 2.13 cm
Width: 1.76 cm
Thickness: .62 cm
Neck Width: 1.27 cm
Artifact No. 335

Length: 5.3 cm
Width: 2.6 cm
Thickness: 0.7 cm
Neck Width: 1.3 cm
Artifact No. 17

Length: 2.3 cm
Width: 3.1 cm
Thickness: 0.68 cm
Neck Width: 1.5 cm
Artifact No. 229

Length: 2.77 cm
Width: 1.54 cm
Thickness: 0.44 cm
Neck Width: 1.03 cm
Artifact No. 765

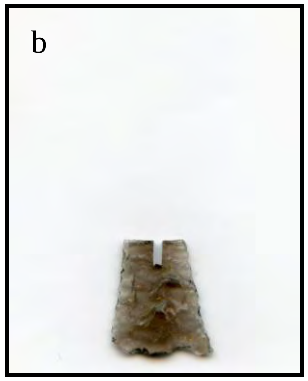
Length: 3.30 cm
Width: 2.40 cm
Thickness: 0.5 cm
Neck Width: 1.1 cm
Artifact No. 936

Length: 3.9 cm
Width: 2.6 cm
Thickness: 0.5 cm
Neck Width: 1.4 cm
Artifact No. 981

Figure 5-2. Projectile points: a - c Gatecliff Split Stem, d - e Gatecliff Contracting Stem, f – h Elko Series.

a

Length: 1.66 cm
Width: 1.6 cm
Thickness: 0.32 cm
Neck Width: 0.61 cm
Artifact No. 202



b

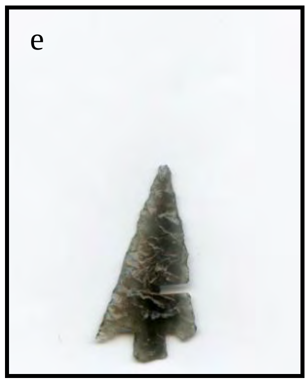
Length: 1.7 cm
Width: 1.6 cm
Thickness: 0.3 cm
Neck Width: 0.6 cm
Artifact No. 1076

c

Length: 2.8 cm
Width: 1.5 cm
Thickness: 0.4 cm
Neck Width: 0.7 cm
Artifact No. 1075

d

Length: 2.33 cm
Width: 1.21 cm
Thickness: 0.25 cm
Neck Width: 0.47 cm
Artifact No. 218



e

Length: 3.0 cm
Width: 1.5 cm
Thickness: 0.2 cm
Neck Width: 0.5 cm
Artifact No. 1077

f

Length: 1.69 cm
Width: 1.3 cm
Thickness: 0.28 cm
Neck Width: 0.4 cm
Artifact No. 200

g

Length: 1.58 cm
Width: 1.26 cm
Thickness: 0.39 cm
Neck Width: 0.73 cm
Artifact No. 209

h

Length: 1.2 cm
Width: 1.3 cm
Thickness: 0.3 cm
Neck Width: 0.8 cm
Artifact No. 677

Figure 5-3. Projectile points: a – c Rosegate Series, d – f Small Corner Notched, g – h Desert Side Notched.

Obsidian Hydration Dating

Friedman and Smith (1960) were the first to introduce the obsidian hydration dating (OHD) method. OHD follows the premise that obsidian absorbs water from the environment causing a chemical diffusion reaction which forms a hydration band or rind. The band or rind thickness increases with time. When a new surface is exposed on a piece of obsidian a new hydration band begins. The rind thickness should then be proportional to the time since the projectile point was manufactured. A microscope with polarizing light is used to view a thin section cut from the specimen to measure the rind (Friedman and Smith 1960; Michels and Tsong 1980; Michels 1973).

The OHD method was built upon observations reported by Ross and Smith (1955) about the water content of obsidian and perlite; acknowledging that perlite was actually hydrated obsidian. It was argued that during formation obsidian acquires less than 1% water from magma and that hydrated obsidian contained 3-5% water as a result of post-magmatic processes. This increase in water content in the outer layer increased the index of refraction and created a mechanical strain in the hydrated layer (1955:1088).

Friedman and Smith (1958) demonstrated that the deuterium (heavy hydrogen) content in water of hydrated obsidian was similar to the deuterium content in the ambient surface water. They concluded that obsidian hydrates under normal atmospheric temperatures and pressures on the earth's surface. In 1960, Friedman and Smith demonstrated how hydration rinds are measured and illustrated the potential of obsidian hydration as a dating method. They explained that several factors could affect the hydration rate such as temperature, chemical composition, burning, and mechanical erosion. At the time Friedman and Smith believed relative humidity was not a factor but this has proven to be a misconception (Friedman et al. 1994; Mazer et al.

1991). Beck and Jones (2000) have outlined trends in OHD since 1960. Trends such as the correct hydration rate equation, the effects of temperature, relative humidity, and chemical composition on the hydration rate; and experimental versus empirically derived hydration rates.

Beck and Jones argued that the value of OHD is not in its ability to provide precise dates but in its ability to date the artifact directly (2000:143). Great Basin researchers have assigned temporal periods to projectile point types based on stratigraphic evidence. Some researchers have challenged this assumption arguing that due to hafting, use, breakage, and rejuvenation the morphological types assigned may not concur with their true temporal types (Flenniken and Raymond 1986; Flenniken and Wilke 1989). The use of OHD on the actual artifact confirmed that Great Basin projectile points are adequate chronological markers (Beck and Jones 2000:146).

According to Beck (1999), surface assemblages are usually mixed making it difficult to use diagnostic points to establish a chronological sequence. Mixed surface assemblages are problematic for addressing many issues that require chronological control. The application of OHD to surface assemblages can create a serial order and assess contemporaneity. It allows the assemblage to be viewed as continuous. Beck demonstrated the validity of this method by using surface assemblages from the Steen Mountains and eastern Nevada. The mean hydration values of several projectile point types for three obsidian sources were plotted. The expected pattern was observed corresponding to the relative ages of projectile point series represented (1999:179).

For this study, a sample of 88 projectile points representing seven types was sent to the Northwest Research Obsidian Studies Laboratory for obsidian hydration analysis. Initially, the hydration band measurements were plotted against the projectile point series to examine band variability. Linear regression analysis can determine if the hydration values would be a reliable dating method. The obsidian hydration range (maximum – minimum band width) was plotted against the date range (inception- termination date) for each projectile point series. Also, the obsidian hydration mean was plotted against the mid-date for each projectile point type. The linear regression equation produced ($Y = bX + a$) where Y = years and x = hydration band thickness (μ) will be used as an empirical hydration rate.

X-Ray Fluorescence Analysis

X-ray fluorescence (XRF) analysis is a nondestructive method of sourcing obsidian artifacts by measuring trace elements quantities and comparing them to known obsidian sources. The chemical composition of most obsidian sources is homogeneous and each source is compositionally dissimilar. In XRF analysis, the specimen is bombarded with X-rays displacing electrons from the inner energy levels. As electrons from higher levels fill the vacancies created fluorescent X-rays are emitted. These X-rays have characteristic energies that identify elements. The intensity of x-rays is measured to determine the quantity of elements, in parts per million (ppm), present in the sample (Glascock et al. 1998).

XRF analysis has been applied to archaeological studies examining hunter-gatherer procurement ranges and changes in mobility (Beck and Jones 1990; Jones et al. 2003; Shackley 1989; Skinner et al. 2004; Wallace 2004). These studies follow the assumption that hunter-gatherers procured lithic raw material during annual foraging pursuits. The known provenience of the raw material represented in the archaeological assemblages corresponds to the foraging or procurement range of hunter-gatherers. In addition, patterns in source variability, source-to-site distance, and directionality were used to examine changes in mobility. Before discussing the application of XRF analysis to hunter-gatherer studies further, a brief review of earlier obsidian studies is provided.

According to Skinner (1983) and Glascock et al. (1998), there were several weaknesses with earlier obsidian source characterization studies (Bennett and D'Auria 1974; Cobean et al. 1971; Ericson and Berger 1974; Ericson 1977; Hughes 1978 ; Huntley and Bailey 1978; Pires-Ferreira 1973; Sappington 1981b; Sappington and Topel 1981). These problems included (1) incomplete surveys of all obsidian sources, (2) inadequate number of samples for each source, (3) locality of source samples not reported, (4) poor descriptions of source areas, (5) analysis of too few elements, (6) inability to identify crucial elements needed to discriminate between individual sources, and (7) quantitative data and analytical method of characterization often not reported.

A more systematic approach to obsidian source characterization was advocated (Glascock et al. 1998; Shackley 1998; Skinner 1983). This approach emphasized a more thorough survey in order to determine precise location and range of both primary and secondary sources. Also, an adequate number of samples, from several locations, should be obtained. The samples should be analyzed thoroughly to determine the number of chemical attributes that will “fingerprint” obsidian sources. In addition, Skinner (1983), Shackley(1998), and Glasscock et al. (1998) saw the importance of having all descriptive, physical and chemical information accessible in one comprehensive data base. There are currently two extensive obsidian source catalogs available the International Association of Obsidian Studies (IAOS) Obsidian Source Catalog and the Northwest Research Obsidian Studies Laboratory (NROSL) United States and Canada Obsidian Source Catalog. For this study the NROSL source catalog was used.

A better understanding of the geological distribution of obsidian sources has allowed successful studies of raw material procurement, mobility, and exchange in the Great Basin (Jones et al. 2003:9). Jones et al. (2003) explains there are many aspects of mobility (e.g., number of moves, distance of move, and residence time) that are difficult to examine using archaeological data. However, one aspect that has been studied with success is, “the size of the territory or foraging range that a group or set of related groups habitually occupied” (2003:8). Jones et al (2003) suggest, simply plotting source locations, represented in the archaeological assemblage, provides a course measure of the geographic area utilized by hunter-gatherers. This method can only be applied if (1) the locations of geological sources are known, (2) source provenance of artifacts can be identified unambiguously, and (3) exchange can be ruled out. Following this methodology, Jones et al. (2003) was able to identify five lithic conveyance zones in the Great Basin during the Terminal Pleistocene – Early Holocene. There was little movement of material outside these zones implying human interaction among these zones was limited (Jones et al. 2003:31).

The archaeological movement of lithic material may occur through exchange or direct procurement. The problem is distinguishing between the two modes of procurement. According to Meltzer (1989) and LeTourneau (2000), the archaeological “signatures” produced by exchange and by direct procurement are almost identical. Meltzer explains, to prove exchange you must first demonstrate territoriality (1989:5). According to Skinner et al, “the activities that led to the archaeological distribution of obsidian over a landscape may be poorly known or even unknowable, but provenance studies provide us with a relatively clear map of the procurement territory that was involved” (2004:227).

Following the assumption that raw material was procured directly, “extralocal source diversity may serve as a proxy for residence time” (Jones et al. 2003:25). As hunter-gatherers extend their stay at a site they will deplete their stone tool and raw material inventories. Artifacts should then originate from more proximate (local) sources. An increase in residence time should correspond to a decrease in source diversity. Also, if high quality knappable sources of stone are available throughout the foraging area, these sources should be proportional to the time spent adjacent to each source (Beck and Jones 1990:285).

Another measure of mobility and foraging range is source-to-site distance. The McCoy Creek and Lost Dune assemblages were divided into four periods (i.e., 3,500 to 2,000 BP, 2000 to 500 BP, 500 BP, and 330 BP) (Lyons et al. 2001:279). The distance to each site was measured from nearest known sampling location of each source represented in the assemblage. The mean site-to-source distances for each period were compared. At the Lost Dune site (3,500 to 500 BP) the mean source-to-site distance was 55 $\pm$ 17 km to 67 $\pm$ 25 km and at the McCoy Creek Site (500 BP) the mean distance was 60 $\pm$ 16 km. At the Lost Dune site, there was a significant increase in source-to-site distance (92 $\pm$ 27 km) observed at 330 BP (Lyon et al. 2001:284). This increase in source-to-site distance and the appearance of Shoshonean brown ware during this time (330 BP) suggested that site was occupied by people outside their usual foraging area (Lyons et al. 2001:282-285).

At Fort Rock Basin, source variability and directionality was used to examine foraging area and shifting settlement patterns. Local obsidian made up 38 percent of the basin wide total but varied substantially among subbasins (i.e., Fort Rock Valley, Silver Lake Subbasin, and Christmas Valley Subbasin) inferring that occupants within each basin utilized different foraging areas (Skinner et al. 2004:228). In addition, directionality of sources varied by subbasins. The directionality of sources used provided insight into shifting settlement patterns (Skinner et al. 2004:230).

In the central Great Basin, projectile point collected from the Eastern Nevada Project Area (i.e., Combs Creek Localities, Hunter Point Localities, John's Point, White Sage Well

Locality, and Sunshine Well locality) were used to show chronological differences in source use. The study showed that during the latter portion of the Early Holocene there was an eastward expansion of Paleoarchic foraging areas (Jones et al. 2003:20-21).

For this study it is assumed that obsidian was procured directly during the acquisition of food resources. It is acknowledged that a minimal amount of obsidian was probably acquired through local exchange. This assumption is based on the extensive amount of obsidian available in the region, making it a resource easily accessible and less of a commodity. Eighty-eight obsidian projectile points were sent to the Northwest Research Obsidian Studies Laboratory for x-ray fluorescence analysis. ArcMap was used to display the geological location of obsidian sources identified. A single obsidian source can be geographically widespread due to secondary depositional processes (Shackley 1998). It is for that reason a conservative measure was taken and the nearest known location for each source was used. The distance (km) from each source to the Malheur Headwaters archaeological complex was determined by using the ArcMap measuring tool. A central point was used to represent the entire archaeological complex. The relationships between source-to-site distance and hydration rim values were then examined. The projectile points were grouped into three temporal periods (i.e., early Middle Holocene, late Middle Holocene, and Late Holocene) and used to examine chronological differences in source variability. In addition, ArcMap was used to plot obsidian sources represent in these three temporal periods to determine the procurement range size. The purpose of examining source-to-site distance, source variability, and procurement range size is to determine if there was a change in hunter-gatherer mobility patterns over time.

CHAPTER SIX: RESULTS

X-ray fluorescence (XRF) analysis of 88 projectile points identified 18 geochemical sources and obsidian hydration (OH) measurements were obtained from 83 projectile points (Skinner and Thatcher 2009). Figure 6-1 illustrates the nearest known location of all 18 obsidian sources and Table 6-1 is a summary of artifact provenience and OH measurements. Hydration values range from 1.2 microns (µ) to 5.7µ. The sources are distributed from north to south within eastern Oregon. The only exception was the Obsidian Cliffs source located in the central High Cascades. Northeast Oregon obsidian sources represented in the assemblage are Bear Creek, Eldorado, Gregory Creek, Indian Creek, Van Gulch, Whitewater Ridge, and Wolf Creek. Southeast Oregon sources represented are Beatys Butte, Big Stick, Curtis Creek, Dog Hill, Glass Buttes 1, Indian Creek Buttes, Indian Creek Buttes (B), Rimrock Spring, Tule Spring, and Venator. A description of each source is located in Appendix A.

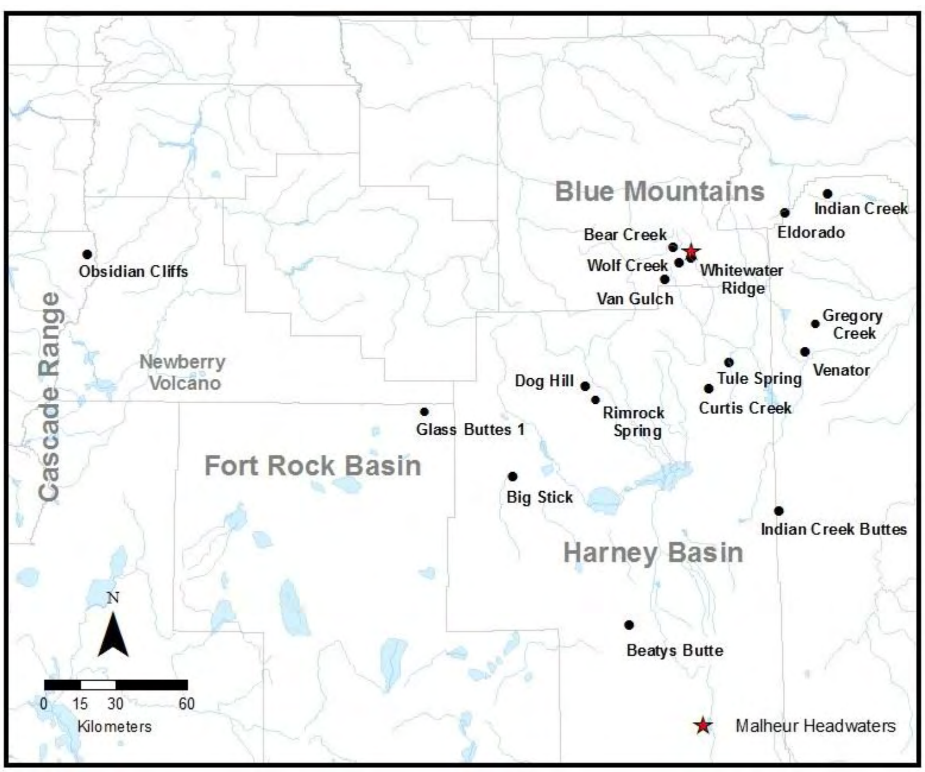


Figure 6-1. Trace element provenance of artifacts from the Malheur Headwaters.

Table 6-1. XRF and OH Data for the Malheur Headwaters.

Artifact No.	Artifact Type	Artifact Source	Hydration Rim (μ)	Artifact No.	Artifact Type	Artifact Source	Hydration Rim (μ)
5	Northern Side Notched	Wolf Creek	5.1	217	Northern Side Notched	Tule Springs	4.4
14	Northern Side Notched	Whitewater Ridge	4.1	218	Small Corner Notched	Gregory Creek	1.2
15	Northern Side Notched	Whitewater Ridge	3.4	224	Northern Side Notched	Whitewater Ridge	4.5
17	Gatecliff Contracting Stem	Wolf Creek	3.9	225	Small Corner Notched	Gregory Creek	1.3
28	Large Stemmed	Tule Springs	-	228	Northern Side Notched	Indian Creek Buttes	4.7
37	Northern Side Notched	Whitewater Ridge	5.7	229	Gatecliff Contracting Stem	Gregory Creek	2.2
66	Large Stemmed	Gregory Creek	2	233	Gatecliff Split Stem	Whitewater Ridge	4.4
103	Elko	Whitewater Ridge	4.1	234	Northern Side Notched	Eldorado	3
128	Small Corner Notched	Whitewater Ridge	2	241	Gatecliff Split Stem	Indian Creek	3.2
157	Northern Side Notched	Whitewater Ridge	4.8	244	Northern Side Notched	Curtis Creek	4.3
165	Northern Side Notched	Wolf Creek	4.2	246	Gatecliff Split Stem	Whitewater Ridge	4.1
197	Elko	Wolf Creek	1.9	256	Gatecliff Split Stem	Tule Springs	4.5
198	Gatecliff Split Stem	Wolf Creek	3.1	265	Gatecliff Split Stem	Whitewater Ridge	4.1
199	Rosegate	Whitewater Ridge	2.5	268	Northern Side Notched	Big Stick	2.1
200	Small Corner Notched	Whitewater Ridge	2.3	335	Gatecliff Split Stem	Indian Creek Buttes B	3.1
201	Small Corner Notched	Whitewater Ridge	2.6	340	Northern Side Notched	Whitewater Ridge	5.7
202	Rosegate	Rimrock Spring	2.7	354	Northern Side Notched	Whitewater Ridge	3.3
206	Rosegate	Whitewater Ridge	1.7	598	Northern Side Notched	Indian Creek Buttes B	-
207	Rosegate	Whitewater Ridge	2.8	677	Desert Side Notched	Whitewater Ridge	1.8
208	Small Corner Notched	Wolf Creek	1.8	687	Small Corner Notched	Wolf Creek	1.2
209	Desert Side Notched	Wolf Creek	1.9	734	Small Corner Notched	Whitewater Ridge	2.2
211	Small Corner Notched	Whitewater Ridge	2.4	765	Elko	Wolf Creek	4.1

Note: Data from Skinner and Thatcher (2009).

Table 6-1 continued. XRF and OH Data for the Malheur Headwaters.

Artifact No.	Artifact Type	Artifact Source	Hydration Rim (µ)	Artifact No.	Artifact Type	Artifact Source	Hydration Rim (µ)
785	Small Corner Notched	Wolf Creek	2.7	996	Northern Side Notched	Whitewater Ridge	3.2
790	Rosegate	Whitewater Ridge	4.1	1002	Northern Side Notched	Venator	2.3
818	Northern Side Notched	Whitewater Ridge	4.9	1015	Small Corner Notched	Whitewater Ridge	2.7
819	Northern Side Notched	Whitewater Ridge	1.5	1067	Elko	Wolf Creek	4.6
833	Gatecliff Split Stem	Beatys Butte	2.5	1068	Large Stemmed	Whitewater Ridge	5.1
845	Elko	Whitewater Ridge	2.6	1069	Northern Side Notched	Whitewater Ridge	4.1
854	Elko	Whitewater Ridge	1.6	1075	Rosegate	Whitewater Ridge	2.2
861	Northern Side Notched	Glass Buttes 1	3.1	1076	Rosegate	Wolf Creek	1.5
863	Small Corner Notched	Whitewater Ridge	1.7	1077	Small Corner Notched	Gregory Creek	1.5
877	Northern Side Notched	Bear Creek	-	1078	Small Corner Notched	Whitewater Ridge	1.6
883	Small Corner Notched	Whitewater Ridge	2	1079	Small Corner Notched	Whitewater Ridge	2.2
902	Northern Side Notched	Whitewater Ridge	2.2	1081	Small Corner Notched	Whitewater Ridge	2.2
912	Northern Side Notched	Whitewater Ridge	3.9	1083	Northern Side Notched	Whitewater Ridge	4.6
933	Northern Side Notched	Whitewater Ridge	4	1084	Northern Side Notched	Obsidian Cliffs	5
935	Northern Side Notched	Whitewater Ridge	4.9	1085	Northern Side Notched	Whitewater Ridge	4
936	Elko	Gregory Creek	2.7	1087	Gatecliff Split Stem	Whitewater Ridge	3.7
942	Northern Side Notched	Indian Creek	2.9	1088	Northern Side Notched	Dog Hill	3.3
950	Large Stemmed	Whitewater Ridge	-	1089	Elko	Wolf Creek	2.9
961	Northern Side Notched	Eldorado	2.8	1090	Gatecliff Split Stem	Whitewater Ridge	4
975	Northern Side Notched	Wolf Creek	5.2	1127	Northern Side Notched	Whitewater Ridge	4.8
980	Northern Side Notched	Whitewater Ridge	4.1	1130	Large Stemmed	Whitewater Ridge	1.7
981	Elko	Van Gulch	-	1132	Rosegate	Whitewater Ridge	2.9

Note: Data from Skinner and Thatcher (2009).

The majority of artifacts originated from sources located in northeast Oregon (84.1%, N = 74) and over half (54.6%, N=46) were manufactured from the Whitewater Ridge source. The source-to-site distance (Table 6-2) of northeast Oregon sources ranges from 4 to 63 km with Whitewater Ridge being the nearest source to the Malheur Headwaters. Thirteen (14.8%) artifacts were made from sources located in southeast Oregon and no one source dominated this group. The source-to-site distance of southeast Oregon sources ranges from 49 to 158 km. Obsidian Cliffs the most distant (258 km) source is represented by one artifact in the sample.

Table 6-2. Obsidian Sources and Source-To-Site Distances.

Obsidian Source	(N)	Distance (km)	Obsidian Source	Number	Distance (km)
Bear Creek	1	9	Indian Creek Buttes	1	115
Beatys Butte	1	158	Indian Creek Buttes (B)	2	115
Big Stick	1	124	Obsidian Cliffs	1	258
Curtis Creek	1	55	Rimrock Spring	1	76
Dog Hill	1	73	Tule Spring	3	49
Eldorado	2	44	Van Gulch	1	18
Glass Buttes 1	1	131	Venator	1	62
Gregory Creek	6	58	Whitewater Ridge	48	4
Indian Creek	2	63	Wolf Creek	14	9

As the source-to-site distance increases the number of artifacts decreases (Figure 6-2). Seventy-two percent (n = 63) of the sample was manufactured from sources 9 km or less from the Malheur Headwaters. Of the 63 artifacts manufactured from sources 9 km or less, sixty-six percent (n = 48) originated from a source 4 km away. The density of artifacts originating from sources 9 km or less infers that the Malheur Headwaters was highly utilized. At this point it would be difficult to determine if this increase in density was the product of reoccupation or an increase in residence time. Chronological control will be established next in order to examine changes in source-to-site distance. The purpose of the next section is to determine if OH measurements provide a reliable temporal marker.

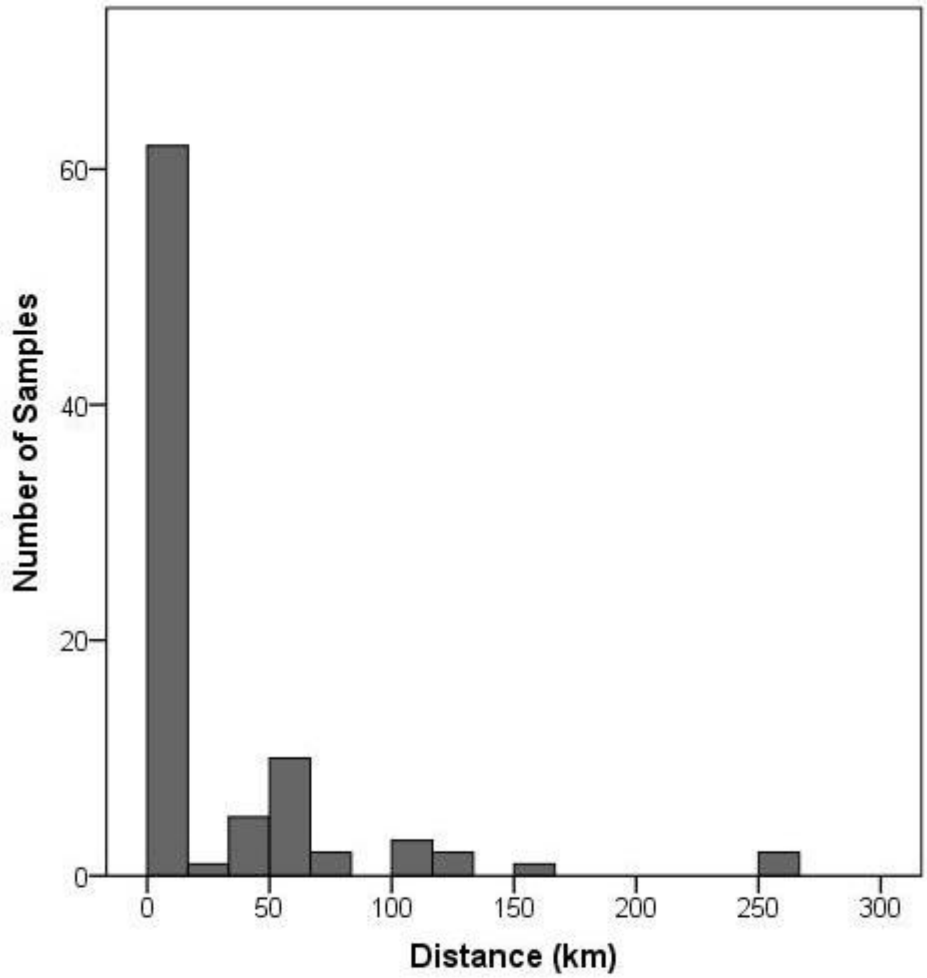


Figure 6-2. Distance decay.

Obsidian Hydration

All 88 projectile points were sent for obsidian hydration analysis but five artifacts could not be measured due to poor optical quality or the absence of a visible hydration rim (Skinner and Thatcher 2009). The distribution of 83 rim measurements is shown in Figure 6-3. The histogram illustrates a bimodal distribution, with a peak at 2.5µ and another at 4.4µ, perhaps indicating at least two periods of occupation. There is a significant reduction in rim thickness between 3.4 µ and 4.0µ implying a considerable decline in use of the region during this time period.

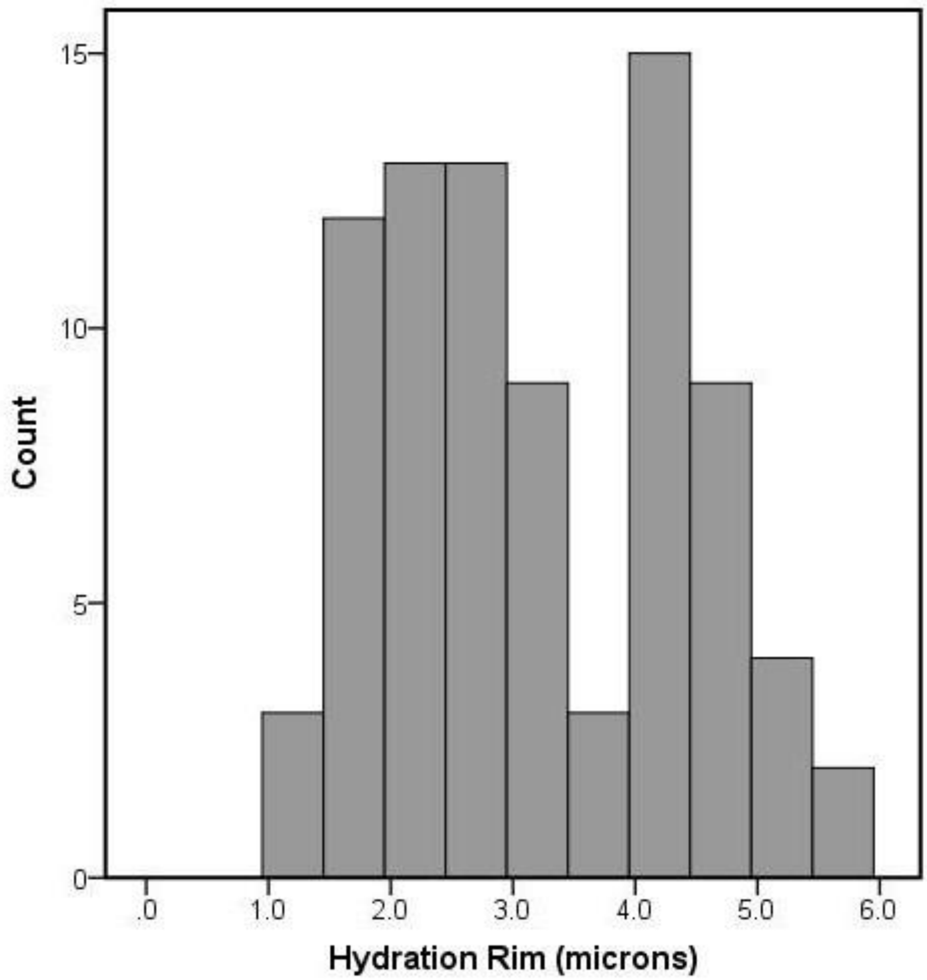


Figure 6-3. Hydration rim distribution of 83 projectile points.

There are eight projectile point types represented in the sample. It is accepted that Great Basin projectile points, "follow a regular sequential pattern" (Beck and Jones 2000:146). Hydration rim bands should increase with the expected age of the projectile point. Figure 6-4 uses boxplots to evaluate this relationship. Projectile point types are plotted from youngest on the left to oldest. The black line is the median hydration band thickness, the box is the interquartile range, and the whiskers are the upper and lower quartiles. The values are shown in Table 6-3. The trend is clear; hydration band thickness correlates with the expected age of projectile points.

Table 6-3. Data Used in Figure 6-4.

Projectile Point Type	(N)	Median (μ)	UQ (μ)	LQ (μ)	IQR (μ)
Large Stemmed (LS)	3	2	3.6	1.7	1.9
Northern Side Notched (NSN)	33	4.1	4.8	3.2	1.6
Gatecliff Split Stem (GSS)	10	3.85	4.1	3.1	1
Gatecliff Contracting Stem (GCS)	2	3.1	3.9	2.2	1.7
Elko	8	2.8	4.1	1.9	2.2
Rosegate (RG)	8	2.6	2.9	1.7	1.2
Small Corner Notched (SCN)	17	2	2.3	1.6	0.7
Desert Side Notched (DSN)	2	1.85	1.9	1.8	0.1

UQ= Upper Quartile, LQ = Lower Quartile, IQR = Interquartile Range

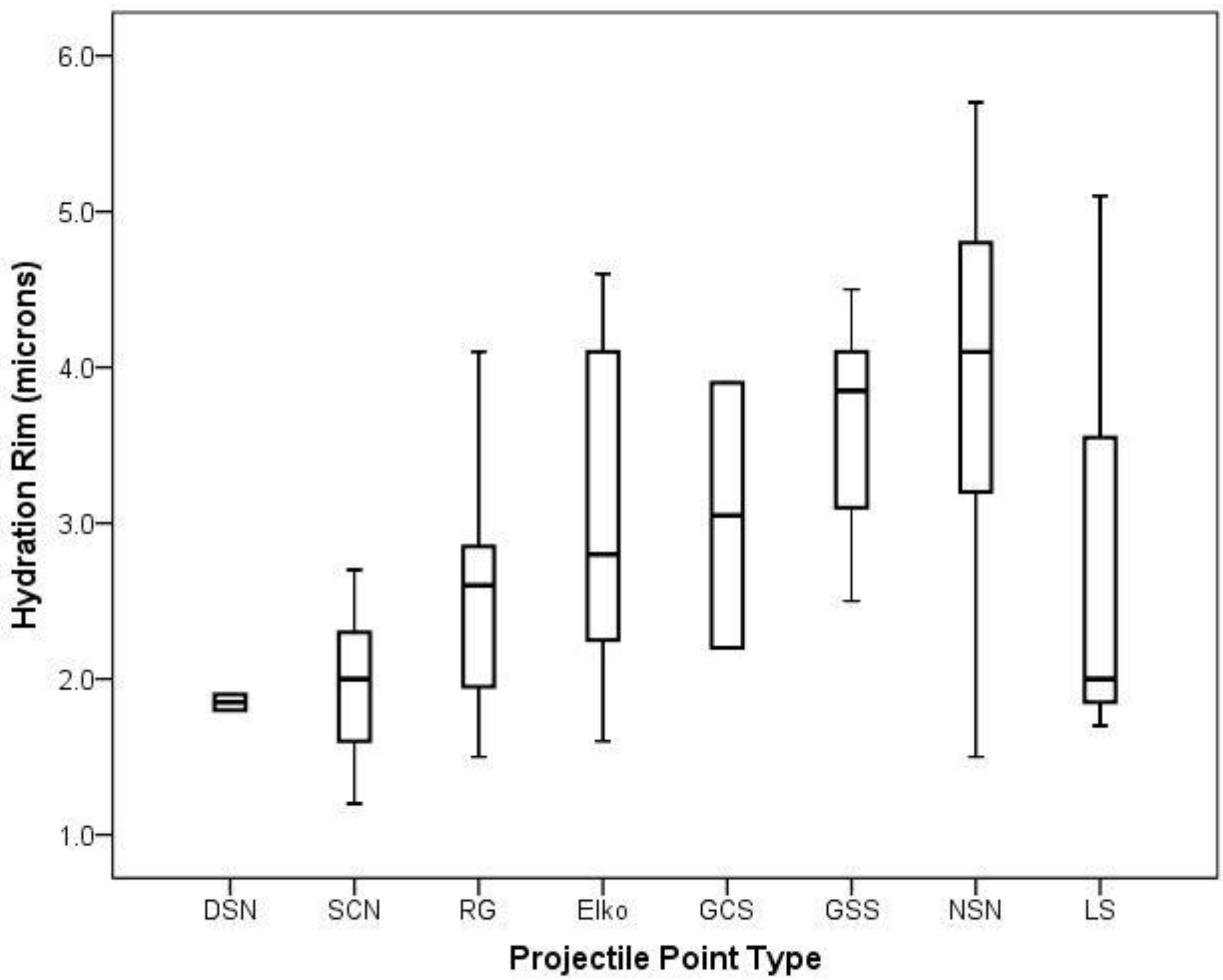


Figure 6-4. Hydration values grouped by projectile point type.
Note: Abbreviations listed in Table 6-3.

The range of hydration rim measurements for each projectile point type is broad. The wide range of values may represent multiple hydration rates operating on different obsidian sources or may correlate with the varying spans of particular projectile point types. For instance, the Harney Basin sources are known to hydrate at exceptionally fast rates (O'Grady 2006). This could cause points of the same age but different obsidian sources to exhibit substantially different hydration rim thicknesses. In order, to use hydration rim values as a measure of time, source variability must be evaluated, or if source is a significant variable, than a rate for each source would need to be established.

Despite the broad range in measurements, two patterns have emerged. First, the median corresponds to the relative age of each point type. The Large Stemmed dart point is the exception to this pattern. Of the five Large Stemmed dart points submitted for analysis, three had measurable rims. The rim measurements were 5.1µ, 2µ, and 1.7µ. The 5.1 value is within the expected range, while the other two values are substantially less than expected. It is not known at this time if the typological classification, the known age range of this type, or if the points were reused at a later date accounts for the inconsistency. For the purpose of this analysis Large Stemmed dart points will be removed from this analysis.

Second, there is a difference between earlier dart points (i.e., Northern Side Notched, Gatecliff Split Stem, and Gatecliff Contracting Stem, and Elko) and later arrow points (i.e., Rosegate, Small Corner Notched, and Desert Side Notched). In Figure 6-4, the box graphically depicts the central batch of hydration rim values (the interquartile range) for each point type. Arrow points tend to have smaller hydration band widths compared to dart points. There is a degree of overlap between the interquartile ranges but this would be expected if transition from one point type to the next is gradual. A Rosegate arrow point was trimmed from the sample as an outlier (artifact 790, 4.1µ).

Based on the median and interquartile range seen in Figure 6-4, there appears to be a correlation between the projectile point age and the associated rim width. The next step is to determine how strong the correlation is between these two variables. The strength of the relationship will demonstrate that the range of measurements is more the product of tool use and not differences in source composition. Regression analyses were used to examine the relationship between obsidian hydration rim thickness and the expected projectile point age. Specifically, two aspects were examined: (1) the relationship between hydration rim mean and projectile point mid-date, and (2) the relationship between hydration rim range and date range. Other factors that may affect the rate of hydration are temperature and other environmental variables (e.g., relative humidity, soil pH, and exposure time). The empirical approach utilized considers these variables implicit and constant. That is, the obsidian artifacts hydrated under generally similar environmental conditions.

Table 6-4. Data Used in Figure 6-5 and Figure 6-6.

Projectile Point Type	(N)	Mean (µ)	Median (µ)	Range (µ)	Mid-Date (BP)	Date Range
Large Stemmed (LS)	3	2.93	2	3.4	9450	3000
Northern Side Notched (NSN)	33	3.94	4.1	4.2	6450	3000
Gatecliff Split Stem (GSS)	10	3.67	3.85	2	4100	1700
Gatecliff Contracting Stem (GCS)	2	3.05	3.1	1.7	3350	1200
Elko	8	3.06	2.8	3	2350	2200
Rosegate (RG)	7	2.33	2.6	1.4	950	600
Small Corner Notched (SCN)	17	1.98	2	1.5	575	350
Desert Side Notched (DSN)	2	1.85	1.85	0.1	525	250

Note: Excludes artifact 790, 4.10µ.

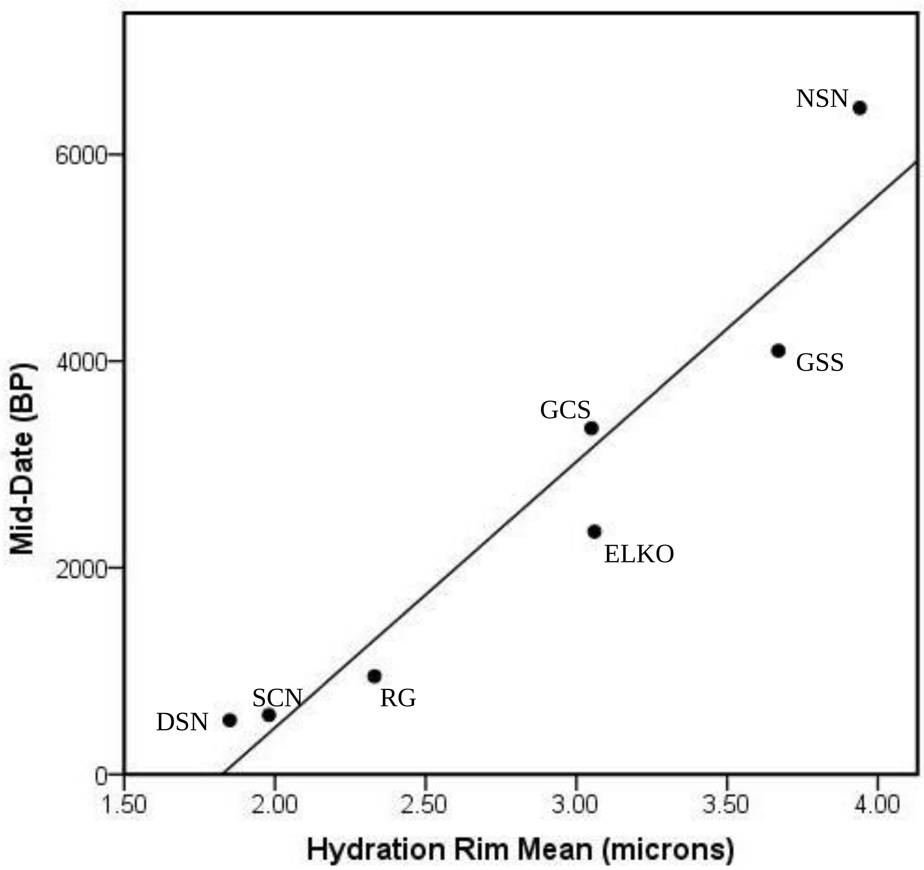


Figure 6-5. Scatter plot of hydration rim mean by projectile point mid-date.

The mean hydration width represents the center of the hydration measurements for each projectile point type. The mean is a more statistically robust measure to evaluate the relationship between the obsidian hydration data and projectile point ages. Histograms were run for each projectile point type and it was determined that the rims are normally distributed. In addition, when compared, the mean and median hydration values are similar (Table 6-4). It should be noted that the Gatecliff Contracting Stem and Desert Side Notch projectile point samples are small but the distribution of rim measurements are reasonable. It was concluded that the mean hydration values were valid and could be used to assess the relationship between the mean and projectile point mid-date.

The hydration rim mean is plotted against the projectile point mid-date in Figure 6-5. The pattern suggests there is an increase in mean rim thickness through time. There is a strong correlation and statistically significant relationship between the hydration rim mean and the projectile point mid-date ($r^2 = .912$, $p = .001$, $Y = 2573x - 4694$). The association between mean and mid-date strengthens the assumption that rim variability is due to age. The hydration readings are a reliable temporal marker without regard to source.

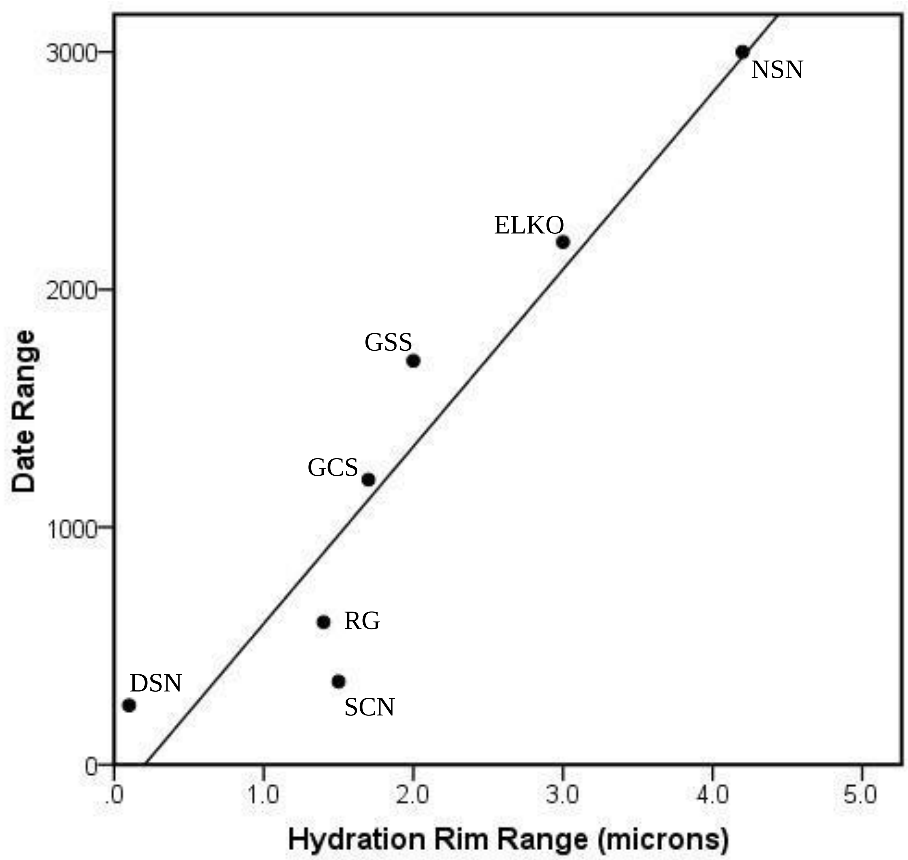


Figure 6-6. Scatter plot of hydration rim range by projectile point date range.

In Figure 6-6, the hydration rim range (maximum rim width – minimum rim width) is plotted against the date range (inception – termination date) for each projectile point type (Table 6-4). The pattern suggests there is an increase in rim thickness through time. There is a strong correlation and statistically significant relationship between the hydration rim range and date range ($r^2 = .886$, $p = .002$, $Y = 745x - 151$). The strong association between the two variables suggests that the distribution of rim measurements is largely due to age rather than environmental or intrinsic factors related to source type. The hydration values are valid chronological indicators.

Whitewater Ridge Hydration Rate

Only projectile points manufactured from Whitewater Ridge obsidian were used to determine an empirical hydration rate. The obsidian source was chosen for two reasons. First, by using one source issues surrounding the chemical composition of varying sources become less problematic. Second, more than half of the projectile points originated from the Whitewater Ridge source. Histograms were run for each projectile point type made from Whitewater Ridge obsidian and rim thicknesses are normally distributed. The mean value is a valid measure of central tendency. It should be noted that the Elko and Desert Side Notched sample size was small. Also, there were no Gatecliff Contracting Stem projectile points made from Whitewater Ridge obsidian.

Table 6-5. Whitewater Ridge Data Used in Figure 6-7

Projectile Point Type	Mean (µ)	Mid-Date (BP)
Northern Side Notched	4.09	6450
Elko	2.77	2350
Gatecliff Split Stem	4.06	4100
Rosegate	2.42	950
Small Corner Notched	2.17	575
Desert Side Notched	1.8	525

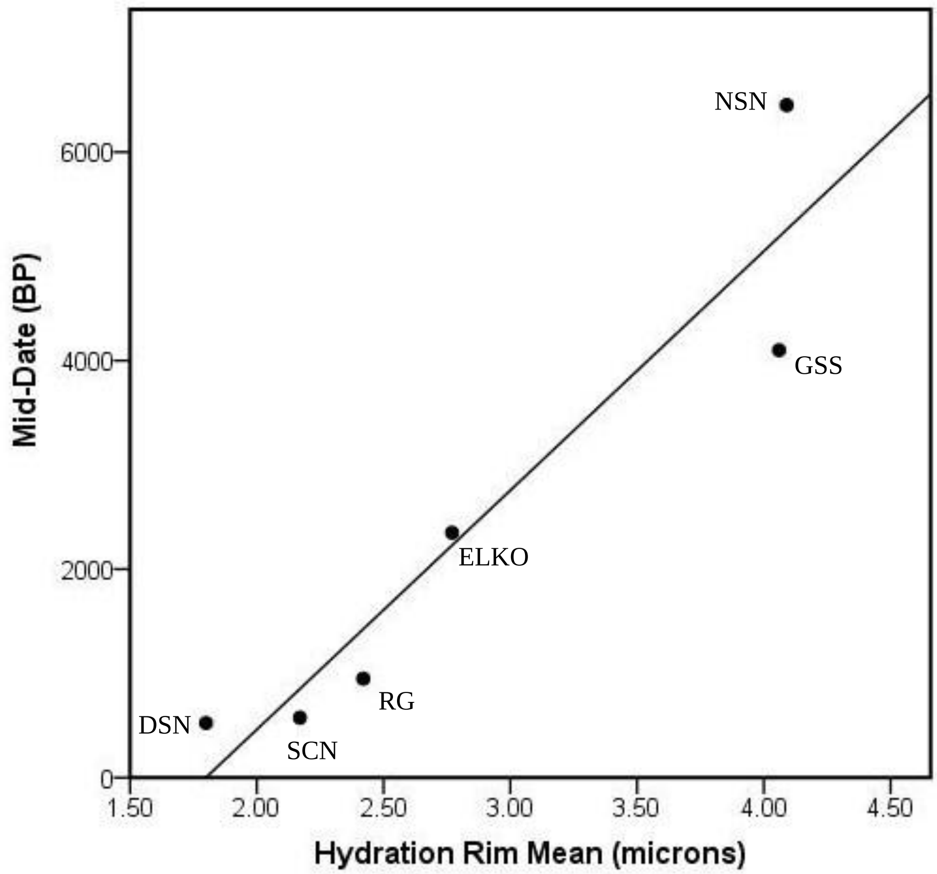


Figure 6-7. Regression analysis of Whitewater Ridge material.

The data and correlation results used to determine the hydration rate are shown in Table 6-5 and Figure 6-7. There is a strong positive correlation and statistically significant relationship between the hydration rim mean and the expected mid-date of Whitewater Ridge artifacts ($r^2 = .887$, $p = .005$, $Y = 2294x - 4126$). The strong correlation between these two variables allows for proposing the following hydration rate:

$$\text{Age BP} = 2294(\text{rim}) - 4126$$

The hydration rate must be used with a degree of caution since it includes many assumptions such as environmental conditions, intra-source chemical variability, and post-depositional artifact history.

Source-To-Site Distance

Hydration rim measurements appear to be a reliable measurement of age. It is now possible to examine changes in source-to-site distance. It is expected that as residential mobility decreases there should be a decrease in source-to-site distance. The relationship between source-to-site distances and hydration rim values is shown in Figure 6-8. Artifacts with hydration values ≤ 2μ do not originate from sources further than 58 km. In comparison, artifacts with hydration values between 2.1μ and 3.4μ are coming from sources ranging between 4 km and 158 km. Artifacts with rim widths ≥ 3.7μ are originating from sources between 4 km and 258 km. This pattern may imply a decrease in mobility over time. As expected the nearby 4 km distant

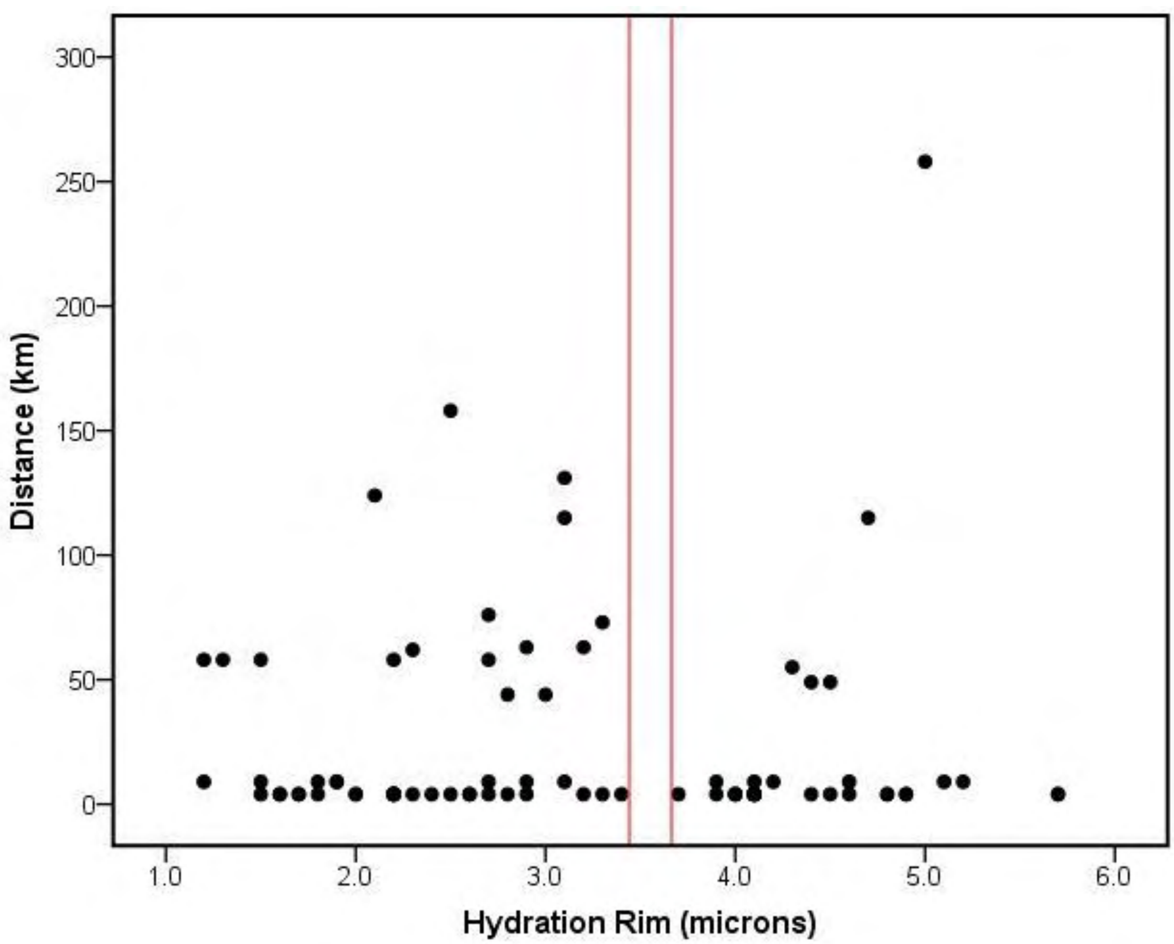


Figure 6-8. Scatter plot of hydration rim values and source-to-site distance.

Whitewater Ridge source predominates through time. It is assumed that a stable population would exploit local resources more heavily, though no obsidian sources including Whitewater Ridge occur with rims between 3.7µ and 3.4µ.

The break in hydration sequence may indicate a short period of absence of obsidian use during this period. Based on the hydration rate determined (Age BP = 2294[rim] − 4126), it is estimated that the break occurred between 4362 BP and 3674 BP during the late Middle Holocene. At this time, the Northern Great Basin was experiencing an increase in effective moisture and marshes expanded and stabilized (Minckley et al. 2004). In the Harney Basin marshes began expanding into areas previously dominated by alkaline greasewood flat by 4400 BP. In addition the water table was highest between 4000 and 2000 BP (Wigand 1987:452-453).

The Southern Columbia Plateau was experiencing a gradual decrease in temperature and increase in effective moisture (Chatters 1995). Hunter-gatherers at this time adopted a low mobility foraging pattern (Prentiss et al. 2005). A dramatic drop in temperature occurred at 3900 BP and hunter-gatherers returned to greater mobility to combat shifts in seasonality and resource productivity (Chatters 1995:357).

Based on the climatic and ecological changes occurring during the late Middle Holocene and the upland valley's proximity to the Strawberry Mountain range, the Malheur Headwaters may have had too much water or snow. A significant increase in moisture may have drowned out the valley or a dramatic drop in temperature may have stunted plant grown. Hunter-gatherers may have chosen to remain near more stable resources (e.g., reliable marsh resources) instead of traveling to the Malheur Headwaters which would explain the break in hydration sequence occurring between 4362 BP and 3674 BP.

Prior to and following the break in hydration sequence, there is an almost consistent use of the Whitewater Ridge obsidian source inferring that the Malheur Headwaters was habitually visited over time. This redundancy may be tethered to a number of critical resources in the local area. The frequency of artifacts originating from sources 9 km or less (n = 58), and the quantity of artifacts detailed in chapter four, suggests that the Malheur Headwaters served as a residential base.

Foragers will leave the residential base to procure resources daily and do not store food (Binford 1980). If it is assumed that procurement of lithic raw material is embedded into subsistence tasks, then the frequency of artifacts originating from local sources (9 km or less) is an index of the daily foraging radius. Forty-four percent (n = 44) of the artifacts originating from local sources were made from the 4 km distant Whitewater Ridge source. This pattern allows the following inferences (1) the maximum daily foraging radius was 9 km, and (2) hunter-gatherers traveled more often to foraging areas 4 km from the Malheur Headwaters.

In Figure 6-8, the following three periods were identified based on natural breaks in the distribution: Period 1 (5.7 μ to 3.7μ), Period 2 (3.4μ to 2.1μ), and Period 3 (2μ to 1μ). Table 6-6 provides the proportion of local and nonlocal obsidian sources within these three periods. Obsidian sources 9 km or less from the Malheur Headwaters are considered local and sources 40 km or greater are considered nonlocal.

Table 6-6. Proportion of Local and Nonlocal Obsidian Sources.

Period	(N)	Local (9 km or less)	Nonlocal (40 km or greater)
Period 1 (5.7 μ to 3.7μ)	31	84%	16%
Period 2 (3.4μ to 2.1μ)	32	59%	41%
Period 3 (2μ to 1μ)	16	81%	19%

At 40 km or greater, nonlocal obsidian sources are probably too far to be a product of logistical forays from the Malheur Headwaters. The nonlocal obsidian sources were more likely part of previous movement prior to arrival at the Malheur Headwaters and part of the maximal territory size. Period 1 and Period 3 have similar proportions of local versus nonlocal obsidian sources. In both periods, the proportion of local obsidian is over 80 percent and nonlocal just below 20 percent. The ratio between local and nonlocal sources seen in Period 1 and Period 3 may suggest that hunter-gatherers are moving great distances between residential moves, and the Malheur Headwaters is located in a highly utilized portion of the maximum territory range.

In Period 2, the ratio of local versus nonlocal obsidian sources is significantly different. The proportion of nonlocal obsidian sources doubles compared to Period 1 and Period 3. The almost even proportion of local versus nonlocal sources in Period 2 suggests increased hunter-gatherer mobility. Figure 6-8 shows a more even distribution of source-to-site distance between 3.4µ to 2.1µ (Period 2). In addition, there is an increase in obsidian sources 44 km to 76 km from the Malheur Headwaters. The following inferences are made (1) in Period 2 the frequency of residential moves increased, (2) the distance traveled between residential locations has decreased, and (3) hunter-gatherers are utilizing more of the maximum foraging territory.

Source Variability

Middle Holocene and Late Holocene obsidian source locations are summarized in Table 6-7. The Middle Holocene was divided into two components the *early Middle Holocene* established by the presence of Northern Side Notched dart points and the *late Middle Holocene* established by the presence of Gatecliff Split Stem, Gatecliff Contracting Stem and Elko dart points. The *Late Holocene* is represented by Rosegate, Small Corner Notched, and Desert Side Notched arrow points.

Over half (64%) of the early Middle Holocene artifacts originate from three local obsidian sources, Whitewater Ridge (4 km), Wolf Creek (9 km), and Bear Creek (9 km). The remaining 36 percent came from 12 discrete sources. Similarly, in the late Middle Holocene over

Table 6-7. Obsidian Sources Represented During the Middle and Late Holocene.

Obsidian Source	Number	Percent	Obsidian Source	Number	Percent
Early-Middle Holocene			**Late-Middle Holocene**		
Whitewater Ridge	19	54	Whitewater Ridge	8	38
Wolf Creek	3	9	Wolf Creek	6	29
Eldorado	2	6	Gregory Creek	2	10
Bear Creek	1	3	Beatys Butte	1	5
Big Stick	1	3	Indian Creek	1	5
Curtis Creek	1	3	Indian Creek Buttes B	1	5
Dog Hill	1	3	Tule Spring	1	5
Glass Buttes 1	1	3	Van Gulch	1	5
Indian Creek	1	3	**Late Holocene**		
Indian Creek Butte	1	3	Whitewater Ridge	17	65
Indian Creek Butte	1	3	Wolf Creek	5	19
Indian Creek Buttes B	1	3	Gregory Creek	3	12
Obsidian Cliffs	1	3	Rimrock Spring	1	4
Tule Spring	1	3			
Venator	1	3			

half (67%) of the projectile points originate from Whitewater Ridge and Wolf Creek sources. The remaining 35 percent comes from six varying sources implying a decrease in source variability. More than half (84%) of the of Late Holocene artifacts originate from Whitewater Ridge and Wolf Creek sources. The remaining 16 percent comes from two sources indicating low source variability.

It should be noted that there is a difference in sample size for each time period. The early Middle Holocene is represented by 35 dart points this is 41 percent of the total number (n = 86) of Northern Side Notched dart points found in the Malheur Headwaters. The late Middle Holocene is represented by 21 projectile points this is 30 percent of the total number (n = 68) of Gatecliff Split Stem, Gatecliff Contracting Stem and Elko dart points found in the archaeological complex. The Late Holocene is represented by 26 arrow points this is 46 percent of the total number (n = 56) of Rosegate, Small Corner Notched, and Desert Side Notched arrow points found in the archaeological complex. The Late Holocene sample selection was unbiased with respect to source as far as is known. This could be evaluated with further sampling.

In all three periods, over 60 percent of the artifacts originated from Whitewater Ridge and Wolf Creek obsidian sources. The proximity of the sources to the Malheur Headwaters suggests that the area was highly utilized through time. Hunter-gatherer populations during the early Middle Holocene and late Middle Holocene were highly mobile based on the diversity of obsidian sources represented in the assemblages. There are two obsidian sources (i.e., Beatys Butte and Van Gulch) represented in the late Middle Holocene that are not observed in other time periods. In addition, artifacts manufactured from Gregory Creek obsidian appear during the late Middle Holocene and persist into the Late Holocene. The appearance of Beatys Butte, Van Gulch, and Gregory Creek obsidian may suggest hunter-gatherers are exploiting new foraging areas. The persistent decrease in source variability into the Late Holocene infers a decrease in residential mobility. In addition, the increase in artifacts manufactured from local obsidian sources (i.e., Whitewater Ridge and Wolf Creek obsidian) may suggest an increase in residence time.

Procurement Range Size

Early Middle Holocene

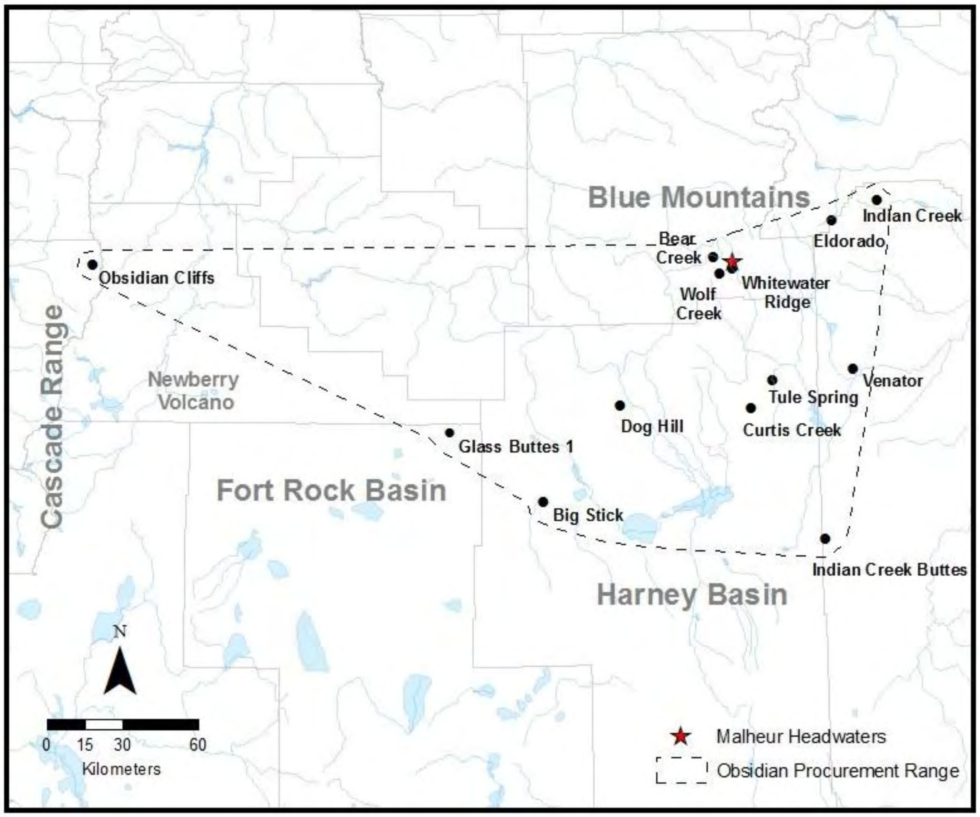


Figure 6-9. Obsidian procurement range: early Middle Holocene.

The obsidian procurement range is determined by plotting artifact provenance. It is assumed that procurement of obsidian sources is embedded in the context of settlement subsistence practices. The obsidian procurement range provides a general view of the foraging area utilized by hunter-gatherers. The early Middle Holocene obsidian procurement range covers an area of 26,428 km^2 (Figure 6-9). The procurement area extended about 63 km northeast of the Malheur Headwaters, west towards the Cascades, and south toward the Harney Basin. People at this time were exploiting a broad foraging area and were moving frequently between resources based on source variability.

Late Middle Holocene

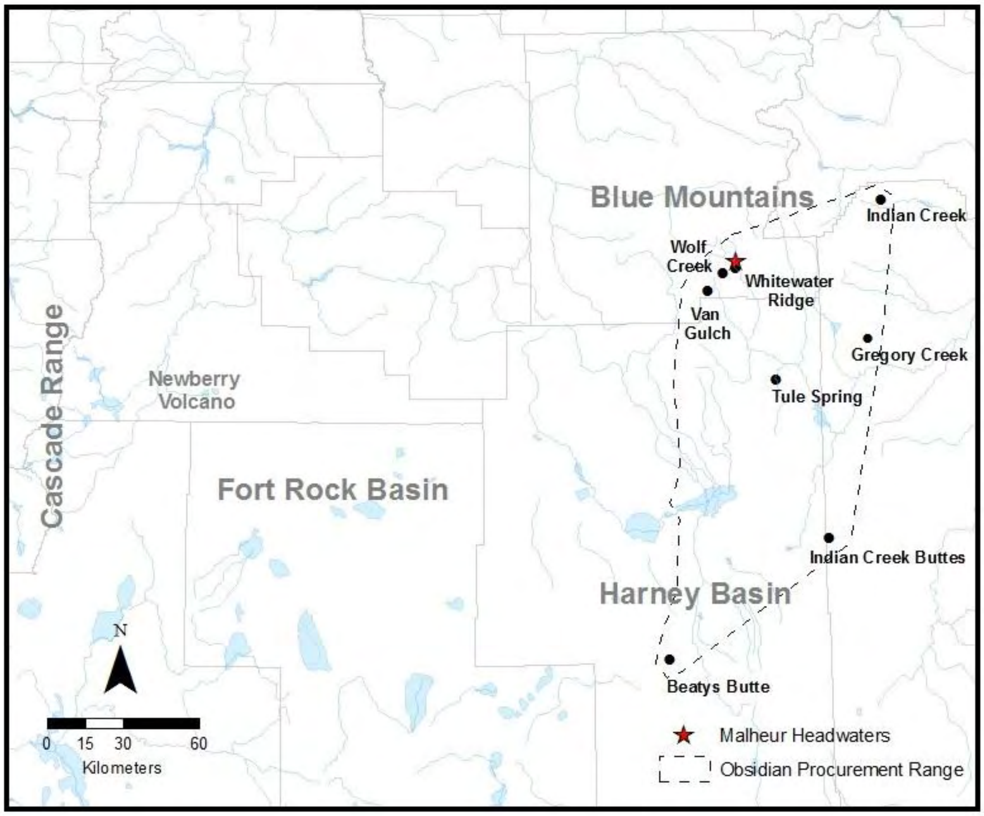


Figure 6-10. Obsidian procurement range: late Middle Holocene.

The late Middle Holocene procurement range covers an area of 11,979 km^2 (Figure 6-10). The western extent of the procurement range was significantly reduced. There was greater movement along the eastern extent of procurement area moving south pass the Harney Basin. The procurement area continued to extend about 63 km northeast of the Malheur Headwaters. Hunter-gatherers at this time decreased their foraging area, focusing on resources located between the Blue Mountains and Harney Basin.

During the late Middle Holocene, the Northern Great Basin experienced an increase in effective moisture which expanded and stabilized marshes (Minckley et al. 2004). Great Basin researchers believe that human populations during the late Middle Holocene were pushed or pulled to more reliable lowland resources (Aikens and Jenkins 1994; Grayson 1993; Jenkins

1994; Jenkins, Connolly and Aikens 2004; Moessner 2004; Oetting 1992). The reduction in foraging area seen in Figure 6-10 may be the product of late Middle Holocene populations exploiting more reliable marsh resources. This greater dependence on marsh resources may also explain why the foraging area expanded further south incorporating more of the Harney Basin.

The frequency of local obsidian sources should decrease if there was a greater dependence on lowland resources during the late Middle Holocene. This did not occur. Sixty-seven percent of late Middle Holocene artifacts originated from local obsidian sources. In the Harney Basin the most expansive system of marshes occurred between 3800 and 2800 BP (Musil 1995:175). It was during this period that a house pit at the Dunn Site (located at the edge of Diamond Swamp, in the Harney Basin) was occupied. The house pit floor was dated to 3255 BP and was associated with a storage pit and large block metate (Musil 1995:175). The high frequency of local obsidian sources may reflect the continued use of upland resources prior to 3800 BP. In addition, it is estimated that the break in hydration sequence seen in Figure 6-8 occurred between 4361 BP and 3673 BP. The break in hydration sequence corresponds to the expansion of marshes in the Harney Basin between 3800 and 2800 BP.

Late Holocene

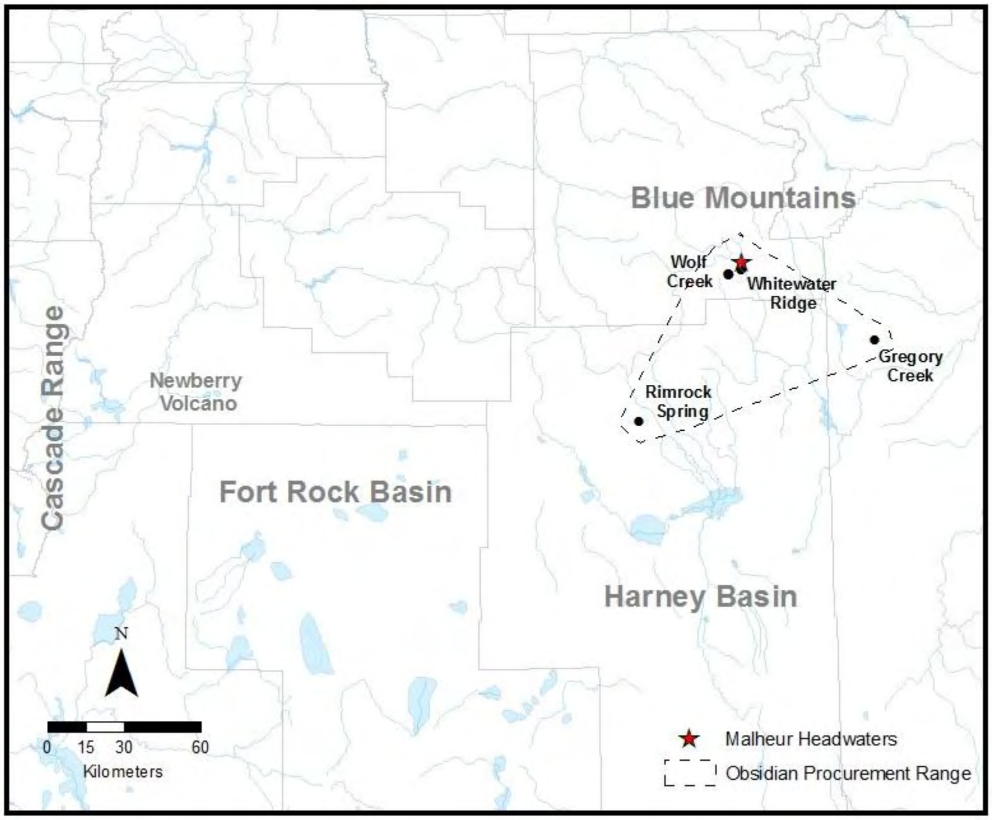


Figure 6-11. Obsidian procurement range: Late Holocene

The Late Holocene procurement range covers an area of 4,450 km^2 (Figure 6-11). The procurement area extends about 76 km southwest and 58 km southeast of the Malheur Headwaters. The foraging area no longer extends northeast of the archaeological complex. Obsidian source variability is substantially reduced during the Late Holocene (Table 6-7). Eighty-four percent (n = 22) of the artifacts originated from local obsidian sources and sixty-five percent (n = 17) were made from the 4 km distant Whitewater Ridge obsidian. The decrease in foraging area and source variability suggests that the Malheur Headwaters was a residential base that allowed hunter-gatherers to procure a number of resources.

The reduction in foraging range and proportion of artifacts originating from Whitewater Ridge obsidian suggest the Malheur Headwaters was part of a semisedentary system. The residential base was a permanent feature in the landscape that was occupied for an extended period of time (probably late spring through late summer). The daily foraging radius was likely within a 10 km radius of the Malheur Headwaters since 84 percent of obsidian was from the 9 km or 4 km distant sources. In fact, the bulk of foraging trips were between on the order of 4 km, but less than 9 km, since 65 percent of obsidian was from the 4 km distant source. This is consistent with the daily foraging radius of ethnographic hunter-gatherers (Kelly 1995:133-134). According to Kelly (1995), the maximum round trip distance hunter-gatherers will walk in a day is 20 to 30 kilometers. In addition, hunter-gatherers usually walk less than the maximum possible walking distance during daily food collecting trips.

Logistical forays requires the task group to stay away from their residential base for at least one night during food collecting trips (Binford 1982). It allows hunter-gatherers to acquire critical resources not available within the daily foraging radius (Binford 1980). Kelly (1983) suggests that logistical mobility distances range from 7 to 48 kilometers based on ethnographic hunter-gatherers. In this study, nonlocal obsidian sources are greater than 49 kilometers from the Malheur Headwaters, except for the 18 km Van Gulch obsidian source.

Nonlocal obsidian was probably acquired through residential or logistical mobility prior to arriving in the Malheur Headwaters and not acquired through foraging and collecting trips while based in the Malheur Headwaters. Therefore the ratio of local and nonlocal obsidian sources reflects a relative index of residential moves into the Malheur Headwaters from locations perhaps 25 or more kilometer distance (half the distance to the next source). The single 18 km sample could have been acquired through either a logistical trip based in the Malheur Headwaters or a residential move into the Malheur Headwaters.

Kelly (1995) suggests the more time and energy spent traveling to a foraging area from the residential base will result in a decrease in the daily foraging-return rate. Kelly (1995) explains that hunter-gatherers will only travel long distances if the resource has a high-return rate. In addition, if the amount of food the forager must procure increases the distance they can travel to forage decreases. In the case of Malheur Headwaters the ratio of local and nonlocal obsidian sources suggests the daily foraging range was likely within 10 km of the archaeological complex with the bulk of the trips within 4 km. In addition, nonlocal obsidian samples were probably acquired prior to arriving at the Malheur Headwaters. The following inferences are made (1) hunter-gatherers were probably not investing in long distant logistical forays from the Malheur Headwaters, and (2) hunter-gatherers may have needed to procure a larger amount of food, requiring them to forage from shorter distances.

Summary

X-ray fluorescence and obsidian hydration data was used to examine changes in hunter-gatherer mobility during the Middle and Late Holocene. Initially, hydration rim measurements were shown to be a reliable measure of time despite source variability. In addition, an empirical rate of hydration (Age BP = 2293.840 (rim) − 4126.061) was established using artifacts manufactured from Whitewater Ridge obsidian.

Hydration rim values allowed source-to-site distances to be viewed in a continuous sequential order. In general, the pattern suggests there is a decrease in mobility over time. There was a possible increase in population during the late Middle Holocene and a shift in mobility strategy. Prior to this shift in mobility there is a break in the distribution of source-to-site distance between 3.7µ and 3.4µ (4361 BP and 3673 BP). This break may correspond to shifts in climate occurring during the late Middle Holocene in both the Northern Great Basin and

Columbia Plateau. In the Late Holocene, a substantial decrease in source-to-site distance infers an increase in residence time at the Malheur Headwaters.

An examination of source variability corresponded with patterns observed in source-to-site distance. Middle Holocene artifacts were manufactured from a variety of obsidian sources, characteristic of high mobility. The late Middle Holocene displayed a different assortment of obsidian sources compared to the early Middle Holocene suggesting a shift in foraging range. There is a significant decrease in source diversity during the Late Holocene inferring a decrease in mobility. In addition, the proportion of Whitewater Ridge and Wolf Creek obsidian suggests that the Malheur Headwaters was a residential base occupied for an extended period of time.

Obsidian procurement ranges are a rough measure of the foraging area utilized by hunter-gatherers. There is a significant decrease in procurement range between the Middle and Late Holocene. Beginning with the early Middle Holocene, the procurement range was 26, 428 km^2. By the late Middle Holocene, the procurement range was 11, 979 km^2 and extended further south. The Late Holocene obsidian procurement range was substantially reduced to 4, 450 km^2 inferring a significant decrease in mobility and increase in time spent at the Malheur Headwaters.

Source-to-site distance, source variability, procurement range size were used to examine changes in hunter-gatherer mobility. If the proportion of raw material is an index of time spent adjacent to each source (Beck and Jones 1990:285), then the proportion of Whitewater Ridge and Wolf Creek obsidian suggest that the Malheur Headwaters was occupied regularly throughout the Middle and Late Holocene. In addition, the proportion of these two sources implies that the Malheur Headwaters was part of productive resource area. The break in distribution between 3.7µ and 3.4µ seen in Figure 6-8 infers a break in occupation during the late Middle Holocene suggesting a decrease in resource productivity. After this break in occupation there may have been an increase in population and shift in foraging area, between the Blue Mountains and Harney Basin. The significant decrease in source-to-site distance, source variability, and obsidian procurement range size during the Late Holocene, points to a reduction in territory exploited, likely reduction in long-distance logistical forays, and less frequent residential mobility.

CHAPTER SEVEN: DISSCUSSION

In the Late Holocene, the Northern Great Basin (Aikens and Jenkins 1994; Wingard 2001) and Southern Columbia Plateau (Prentiss et al. 2005) experienced frequent climatic fluctuations that corresponded to a decrease in residential mobility and increase in resource intensification. In the Northern Great Basin there was a greater dependence on upland root plants and in the Southern Columbia Plateau there is a greater dependence on salmon with an emphasis on root plants. Binford (2001) explains that intensification is a process in which hunter-gatherers extract more food resources from a given area. Archaeological evidence of intensification consist of: (1) a reduction in size of food procurement areas, (2) investments in technology to increase food production, (3) reduced mobility in the number of annual moves and distance traveled in the course of a seasonal round, and (4) an increase in labor to procure and process resources (2001:189). The archaeological assemblages associated with the Late Holocene occupation of the Malheur Headwaters suggest that hunter-gatherers were intensifying on root plant resources, specifically *Lomatium*.

Obsidian projectile points were used to evaluate change in source-to-site distance, source variability, and procurement range size. These artifacts became an index of mobility and a measure of intensification. An evaluation of source-to-site distance and source variability suggest that the Malheur Headwaters was located in a highly productive area. This inference is based on the assumption that the proportion of raw material is an index of time spent adjacent to each source (Beck and Jones 1990:285). The proportion of proximal (less than 9 km) obsidian sources (Whitewater Ridge and Wolf Creek) predominated through time suggesting hunter-gatherers spent a significant amount of time exploiting resources in the area. Following a central place approach, it can be inferred that the Malheur Headwaters allowed hunter-gatherers to position themselves near critical resources. The Malheur Headwaters is located in an area of converging ecological communities that has created a dynamic environment rich in ungulate, plant, and aquatic resources. The Malheur Headwaters would have been an ideal summer residential base.

Initially, early Middle Holocene populations had access to a larger area of resources. The obsidian procurement range during this time covered an area of 26,428 km^2. Source variability would suggest that hunter-gatherers were moving frequently throughout the foraging area while spending a certain amount of time near the archaeological complex. The investment of long distance travel by hunter-gatherers suggests that the Malheur Headwaters was a valuable resource area.

It is during the late Middle Holocene that significant changes in mobility begin to emerge. A break in the hydration sequence shown in Figure 6-8 suggests an absence of obsidian roughly between 3673 BP and 4361 BP. The fact that no artifacts dated to this interval infer two things (1) people were not traveling to the Malheur Headwaters at this time and (2) there may have been a significant decrease in resource productivity. At this time, the Northern Great Basin (Minckley et al. 2004) and Southern Columbia Plateau (Chatters 1995) experienced an increase in effective moisture. Between 3900 BP and 3500 BP there was a decrease in hunter-gatherer population and an increase in mobility in the Southern Columbia Plateau. These changes correspond to a drop in temperature that occurred at 3900 BP that caused a shift in seasonality, resource availability, and seasonal stream flow (Chatters 1995:357).

After the apparent break in occupation, the obsidian procurement range (11,979 km^2) was significantly reduced and there was increase in the proportion of distant obsidian sources represented. However, the proportion of local obsidian sources was still highest. Hunter-gatherers at this time are exploiting a smaller foraging area and there is an increase in the frequency of residential moves possibly as a strategy to combat subsistence pressures. The maximum source-to-site distance represented is significantly less compared to the previous period. Suggesting that the Malheur Headwaters is becoming a more critical resource and travel to more distant locations is more restricted.

The procurement range size during the Late Holocene was 4,450 km^2 considerably less than the Middle Holocene. In addition, 65 percent of the stone tools originated from the 4 km distant Whitewater Ridge obsidian. The significant decrease in source-to-site distance, source variability, and procurement range size point to a decrease in residential mobility.

During the Late Holocene, the Northern Great Basin experienced frequent wet-dry fluctuations which lead to less dependable lowland resources (Aikens and Jenkins 1994; Wingard 2001). In the Southern Columbia Plateau, between 2400 BP and 1700 BP there was an increase in aridity that caused an increase in the distribution of lomatiums (Prentiss et al. 2005). As resource distribution decreased the growing number of hunter-gatherers could not move into new foraging areas. The Malheur Headwaters was already positioned near a number of critical resources based on the frequency of Whitewater Ridge obsidian. As demographic packing increased, residential mobility decreased as hunter-gatherers choose to stay closer to critical resources. Eventually intensification of either root plant or aquatic resources began as hunter-gatherers were pushed into extracting more food resources from a given area.

The question then becomes, is there sufficient evidence of increased plant processing? The Malheur Headwaters contains 200 hopper mortar bases within the valley. Pollen, starch, phytolith, and protein residue analysis of three hopper mortar bases concluded that they were probably used to process biscuit root (*Lomatium sp*) (Varney et al. 2003). The frequency of hopper mortar bases suggests (1) that the density of lomatiums during the Late Holocene was considerable and (2) there was an increase in labor associated with the processing of lomatiums.

The Malheur Headwaters is situated within a mosaic of dry and wet meadows. This unique environmental composition has created a suitable habitat for the growth of lomatiums. This high caloric root resource offers more carbohydrates per 100 edible grams than the common white potato (Couture et al. 1986). At a rate of 4 kg/hr an individual could harvest an annual supply of lomatiums for themselves and their family within 50, eight hour days (Hunn and French 1981). Geophytic roots, like lomatiums can provide 50% of the annual caloric need and combat pressures associated with increase population and periods of rapidly changing environmental conditions (Jenkins 2002, Prouty 1994). The archaeological record illustrates a relationship between proximity to water and the processing of both fish and root crop resources during the Late Holocene (O'Grady 2006; Prentiss et al. 2005; Wingard 2001).

There is no archaeological evidence of the procurement or processing of aquatic resources or the technological innovation of storage at the Malheur Headwaters. However, the Northern Paiute harvested a variety of roots from the Malheur Headwaters and installed fish traps along the Malheur River. At the same time they would prepare roots and fish for storage as well (Couture 1978, 1996; Couture et al. 1986). Interestingly, the Northern Paiute do have a tradition of using hopper mortars. The use of hopper mortars is seen more often in the Southern Columbia Plateau.

Conclusion

Obsidian stone tools from the Malheur Headwaters were used as an index of mobility over time. Differences in source-to-site and source variability suggest that there was a reduction in residential mobility during the Late Holocene. Also, the occurrence of the 4km distant

Whitewater Ridge obsidian source infers that the Malheur Headwaters was part of a productive resource area during most of the Middle and Late Holocene. A break in the hydration sequence infers that the Malheur Headwater encountered a reduction in resource productivity during the late Middle Holocene. The Late Holocene experienced an increase in population, change in climate, and a reduction resource distribution. This lead to increased demographic packing that forced hunter-gatherers to intensify on root plant resources. A reduction in residential mobility and foraging area are signs of intensification. In addition, the density of hopper mortar bases suggests an increase in labor to process root plant resources. The Malheur Headwaters was a central place residence that allowed hunter-gatherers to intensify on lomatiums while exploiting other critical resources.

Appendix A: Description of Obsidian Sources Represented in the Malheur Headwaters.

Geological Source	Description	References
Bear Creek	Found in the Bear Creek drainage of the Malheur National Forest. The prehistoric use of the material appears to have been restricted almost entirely to the local area.	
Beatys Butte	Dense concentrations of surface nodules covering several square kilometers are found on the lower northern, eastern, and western slopes of Beatys Butte and are common in the lacustrine deposits of Pluvial Lake Catlowto the north and east of the butte. Obsidian from this source was widely used in the Steens Mountain area andthe southeastern portion of the state and has been identified as far north as the Malheur National Forest and asfar west as the southern Oregon coast.	Beck (1984) Hughes (1986a) Lyons et al. (2001) Sappington (1981b) Skinner (1983) Skinner (1995a)
Big Stick	Surface nodules of obsidian occur approximately 30 km west of Harney Lake in the vicinity of Big StickRoad. Prehistoric use of this source is poorly known although small quantities have been reported from theFort Rock and Harney-Malheur lake basins.	Hughes (1994) Oetting (1994)
Curtis Creek	This obsidian source was first identified as Unknown 2 during trace element studies of artifacts from theIndian Grade Spring Site in the Stinkingwater Mountains east of Burns. Seventy-two of the 106 characterized specimens from this site were correlated with the Unknown 2 geochemical source. Source outcrops of obsidian nodules correlated with the Unknown 2 source were finally located in the Curtis Creek drainage a few kilometers south of the Indian Grade Spring Site in 1999. Although a few artifacts from the Curtis Creek source have been found to the north of Indian Grade Spring in the Malheur National Forest, most examples are known from only a few sites in the immediate vicinity of the source.	Hughes (1990) Lyons et al. (2001)

Note: Data from Skinner and Thatcher (2003b).
Summaries include results of unpublished field and geochemical source research conducted by NROSL.

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Geological Source	Description	References
Dog Hill	High quality glass occurs as surface float over a wide area about 15-20 km northwest of Burns, Oregon.Small nodules of obsidian from this source have also been identified in secondary gravel deposits in the Harney-Malheur Basin as far south as Wright's Point. The glass occasionally occurs in a very distinctive green color locally known as "Burns Green". The trace element composition is similar to theseveral other nearby sources and they may easily be confused with one another. Glass from this source is often found at archaeological sites in the Harney-Malheur Lake Basin and is occasionally reported from sites in the Malheur National Forest.	Ambroz (1997) Hughes (1986b) Niem (1974) Skinner et al. (1998)
Eldorado	Prehistoric use of this poorly mapped Whitman National Forest obsidian source is documented primarily from characterized artifacts from the Bear Valley region of the Malheur National Forest. The identification and geochemical characterization of this source in 2000 resolved a significant number of Malheur National Forest artifacts that had previously been assigned to unknown sources.	
Glass Buttes	Nine geochemically distinct sources of obsidian (Glass Buttes varieties 1 through 9) are found in association with the Glass Buttes source complex that is located immediately south of Highway 20 in northeastern Lake County (see Figure 6). The Glass Buttes 1 (or Glass Buttes A) source is the most extensive of several different geochemical source groups identified during X-Ray Fluorescence (XRF) and neutron activation analysis (NAA) studies of obsidian from the source complex. This geochemical variety is found throughout the northern half of Glass Buttes and is the same as the Glass Buttes chemical source identified by Skinner (1983) and Hughes (1986). Secondary deposits of obsidian from this and most other Glass Buttes geochemical source groups occur throughout the basin lying north of the source and in the basin located south of the complex (Sinks of Lost Creek). Although obsidian from all of the identified Glass Buttes sources was primarily used in the immediate region surrounding the source complex, glass from the source area has been identified in archaeological sites to the north in Washington and British Columbia, Canada, and as far west as the Western Cascades of Oregon and the Portland Basin.	Ambroz (1997) Ambroz et al. (2001) Atherton (1966) Berri (1982) Carlson (1994) D'Auria et al. (1992) Godfrey-Smith et al. (1993) Hughes (1986a) Johnson (1984) Johnson and Ciancanelli (1984) Roche (1987) Skinner (1983; 1995a, b)

Note: Data from Skinner and Thatcher (2003b).
Summaries include results of unpublished field and geochemical source research conducted by NROSL.

Appendix A: Description of Obsidian Sources Represented in the Malheur Headwaters.

Geological Source	Description	References
Gregory Creek	The Gregory Creek source, first briefly reported by Sappington (1981a), is spread over an area of several square miles in the vicinity of Indian Creek and Gregory Creek. The source has also been called the Jonesboro source and is almost certainly the same as the one identified as the Sugarloaf Butte source by Nelson (1984). Artifacts correlated with the Gregory Creek source are known primarily from sites located in the Malheur National Forest and Upper John Day Basin and from sites located along Oregon Highway 20 in the Jonesboro area. Gregory Creek has also been called the Jonesboro source because of the large proportion of unknown obsidian artifacts from that source that were identified at sites along Oregon Highway 20 in the Jonesboro area.	Brooks and O'Brien (1992) Cole (2001) Evans and Binger (1998) Nelson (1984) Sappington (1981b)
Indian Creek	Also known as the Dooley Mountain or Wallowa source, this geochemical source is one of three varieties associated with the Dooley Mountain rhyolite complex. The Indian Creek source is known primarily from outcrops located on the southern slopes of Dooley Mountain. The Indian Creek glass is by far the best-represented of the Dooley mountain sources among characterized archaeological sites in the source region. Prehistoric use of relatively small quantities of Indian Creek obsidian is well-documented at numerous sites in southeastern Washington and at sites throughout northeast and north-central Oregon.	Gilluly (1937) McDonald (1985, 1986) Reid (1997) Sappington (1981b) Whitson (1988)
Indian Creek Buttes	High quality obsidian associated with Indian Creek Buttes, a 10.32 m.y.-old rhyolite complex, is spread over an area of several square kilometers. Obsidian from this source is also found several km to the east in secondary deposits in Barren Valley where it is known as the Petroglyphs source. Initial trace element analysis of obsidian collected at several locations at Indian Creek Buttes indicates that at least two geochemical varieties (A and B) are distinguishable. Although provenance studies of artifacts from the Indian Creek Buttes region are still relatively uncommon, obsidian from this source has been identified at several archaeological sites to the west in the Harney-Malheur Basin and at a few sites to the north in the Malheur National Forest.	Johnson (1995) Sappington (1981b)

Note: Data from Skinner and Thatcher (2003b).
Summaries include results of unpublished field and geochemical source research conducted by NROSL.

Appendix A: Description of Obsidian Sources Represented in the Malheur Headwaters.

Geological Source	Description	References
Obsidian Cliffs	This large 95,000 yr-old glaciated obsidian-rhyolite flow is located in the central High Cascades near North Sister Volcano. Obsidian nodules from the source can be found in deposits of glacial till to the west of the source and are occasionally found in the gravels of the McKenzie and Willamette rivers in northwestern Oregon. Obsidian artifact manufacturing debris covers a large portion of the Obsidian Cliffs plateau and it is likely that this important source was used throughout much of the post-glacial period. Characterized artifacts from Obsidian Cliffs have been found at many archaeological sites in western Oregon, central and north-central Oregon, and Washington. Artifacts from the source have been reported from as far north as British Columbia, Canada	Anttonen (1972) Carlson (Carlson 1994) Hill (1992) Hughes (1992, 1993) Hughes, S. (1983) Musil and O'Neill (1997) Skinner (1983; 1986 1995a, b) Skinner and Winkler (1991, 1994) South (1999) Taylor (1968) Taylor et al. (1987) White (1974, 1975) Williams (1944)
Rimrock Spring	High quality glass occurs as surface float about 20 km north of Burns, Oregon. Occasionally occurs in a very distinctive green color. The trace element composition is similar to the nearby Dog Hill source and the two sources may be easily confused for one another. Glass from this source is often found at archaeological sites in the Malheur Lake Basin and is occasionally reported from sites in the Malheur National Forest.	Ambroz (1997)
Tule Spring	This source is known from only a few locations in the southeast part of the Malheur National Forest. Prehistoric use of the Van Gulch obsidian has been documented through trace element studies at several locations in the Malheur National Forest although artifacts fromVan Gulch are only rarely encountered outside the immediate source region	Hughes (1990) Lyons et al. (2001) Skinner et al. (1998)

Note: Data from Skinner and Thatcher (2003)
Summaries include results of unpublished field and geochemical source research conducted by NROSL.

Appendix A: Description of Obsidian Sources Represented in the Malheur Headwaters.

Geological Source	Description	References
Van Gulch	This source is known from only a few locations in the southeast part of the Malheur National Forest. Prehistoric use of the Van Gulch obsidian has been documented through trace element studies at several locations in the Malheur National Forest although artifacts fromVan Gulch are only rarely encountered outside the immediate source region.	Skinner and Thatcher (2003a)
Venator	Nodules of high quality obsidian correlated with the Venator geochemical source are distributed over a very large region east of Malheur Lake and the townsite of Venator. Obsidian nodules are common in the river gravels and terrace deposits of the South Fork of the Malheur River in the area from Venator to Riverside and have also been found to the north at Horseshoe Bend in the Juntura area. Venator obsidian is also common in the highlands east of Riverside and has been found at many locations in the vicinity of Skull Springs, Coyote Wells, and Dry Creek Canyon. In at least one location, the obsidian is directly associated with a volcanic ashflow, the probable primary source of this widespread toolstone. A gray microcrystalline variety of excellent toolstone quality also co-occurs with the glassy variety at most source locations. Both the glassy and gray varieties of Venator source artifacts are commonly found at sites located throughout the Harney-Malheur Basin. Characterized artifacts from the source are also occasionally identified at sites in the Malheur National Forest and along Oregon Highway 20 to the north of the source in the Jonesboro area.	Ambroz (1997) Cole (2001) Lyons et al. (2001)
Whitewater Ridge	High quality obsidian correlated with the Whitewater Ridge source group is known from many different widely distributed source localities found along the southern margins and hills immediately south of Bear Valley. Obsidian from this highly variable geochemical source has also been known as the Little Bear Creek, Seneca, Whitewater Spring, Foster Spring, John Day, and Bear Valley sources. Prehistoric use of the Whitewater Ridge source was very extensive, perhaps more so than any other source in northeast Oregon. Artifacts from the source have been found throughout the Malheur National Forest and are common at many north-central Oregon sites in the John Day and Lower Deschutes river basins. Glass from Whitewater Ridge has been identified as far north as North Cascades National Park in Washington, as far west as the Oregon Cascades, as far south as the Malheur Lake Basin, and has possibly been identified in British Columbia, Canada.	Ambroz (1997) Armitage (1995) Carlson (1994) Endzweig (1994) Erlandson et al. (1991) Hughes (1995; 1995) Lyons et al. (2001) Sappington(1981a, b) Skinner (1983; 1995a, b) Skinner and Thatcher (2003a)

Note: Data from Skinner and Thatcher (2003b).
Summaries include results of unpublished field and geochemical source research conducted by NROSL.

Appendix A: Description of Obsidian Sources Represented in the Malheur Headwaters.

Geological Source	Description	References
Wolf Creek	High quality glass occurs in many locations near Glass Mountain (Malheur National Forest) and immediately south and east of the Whitewater Ridge source area. Artifacts from the Wolf Creek source often co-occur with those from Whitewater Ridge, although generally in much lower frequencies. Secondary deposits of Wolf Creek obsidian have also been identified in terrace and gravel bar deposits of the Malheur River in the Drewsey area between Highway 20 and the Drewsey Grange, and a short distance east of Juntura at Horseshoe Bend.	Ambroz (1997) Lyons et al. (2001) Skinner (1995a) Skinner and Thatcher (2003a) Skinner et al. (1998)

Note: Data from Skinner and Thatcher (2003b).
Summaries include results of unpublished field and geochemical source research conducted by NROSL.

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VITA

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