AN ABSTRACT OF THE THESIS OF

Jeffrey R. Ferguson for the degree of Master of Arts in Interdisciplinary Studies in, Anthropology, Anthropology, and Geography presented on May 25, 1999. Title: Bone Cave: A Special-Use Site in the High Lava Plains.

Abstract approved: Signature redacted for privacy.

Barbara J. Roth

Bone Cave is located in the High Lava Plains of Central Oregon, just east of Bend. Excavations were conducted at the site to examine the extent of looter disturbance, and to address research questions focused on prehistoric settlement and subsistence. In the excavation of more than 10 m^3 of sediment from six 1-x-2 meter test units in the front chamber of the lava tube, no undisturbed deposits were encountered.

Due to the disturbed context, analysis of the lithic and faunal assemblages was not able to completely answer questions about culture change or ethnic affiliation, although subsistence, site function and chronology were addressed. Obsidian hydration and obsidian characterization studies indicate that the site was probably occupied exclusively during the Early Holocene, prior to the eruption of Mt. Mazama.

Lithic reduction activities at the site appear to have been limited to late-stage bifacial reduction and tool resharpening. There is no evidence of any early stage core reduction, or large flake or flake tool manufacture. The limited tool assemblage, consisting primarily of well-worked bifacial fragments, supports this conclusion. Lithic debitage was sourced to more local obsidian sources while the tools were mostly produced from distant and unknown sources, suggesting long-term tool curation and retooling at the site using local material.

The large faunal assemblage contains approximately 91 percent rabbit remains. The small amount of medium sized mammal bone fragments, along with a portion of the rabbit remains, exhibit clear cut marks indicative of butchering activity. The site appears to have served as a processing location for large-scale hunts or drives specifically targeting rabbits during the Early Holocene. If the site served such a specialized function, then it implies some degree of logistical organization during the Early Archaic. Communal rabbit drives also suggest a level of political organization not generally associated with the Early Archaic in the Great Basin.

Disturbed sites such as Bone Cave are able to produce valuable information if the proper analytical methods are used. A combination of lithic and faunal analysis can reveal site function, chronology, lithic use and reduction strategy, and subsistence practices, even in the absence of contextual information and formal tool assemblages.

Bone Cave: A Special-Use Site in the High Lava Plains

by

Jeffrey R. Ferguson

A THESIS

submitted to

Oregon State University

in partial fulfillment of

the requirements for the

degree of

Master of Arts in Interdisciplinary Studies

Presented May 25, 1999
Commencement June 2000

ACKNOWLEDGMENT

A research project of this scope could have only been completed with the greatly appreciated help of many friends, instructors, and fellow archaeologists. Dr. Barbara Roth led me through almost every stage of the preparation, fieldwork, analysis and writing of this thesis, and it certainly would not have been possible without her help. Dr. David Brauner assisted with much of the preparation for the fieldwork and the difficult interpretation of a disturbed site. Dr. A. Jon Kimerling taught me how to produce the computer-generated maps and prepared me to handle the technical aspects of figure preparation.

The most important parts of this thesis come from the extensive faunal analysis and obsidian studies that were only made possible by the generosity of two very sympathetic archaeologists. Deborah Olson conducted a detailed faunal analysis on very short notice that completely changed the interpretation of site function. I can only apologize for not doing her analysis justice. Dr. Craig Skinner performed the obsidian characterization and hydration analysis without due compensation. He assisted with interpretation of the obsidian data as well as the site as a whole and prepared Table 5.3, Figures 5.13 and 5.17, and Appendices 1 and 2. Ryan Mitchelltree assisted with the collection of data on the debitage assemblage, and cataloging the collection.

The fieldwork was only possible with the help of numerous volunteers including Susan Dardis, Del Baskerville, Bill Bancroft, John Hatch, Sally Bird, Nancy Nelson and others that I apologize for not listing. I would also like to thank Dr. Bob for challenging me to derive some useful information from such a disturbed context.

Thanks are also due to my family. Thank you Mom, Dad, and Jerald for your support, and for supplying some great fishing to serve as an incentive to finish. My thanks and apologies go to the most important person in my life, Susannah, for putting up with my spending long hours at the computer, and hardly speaking of anything besides Bone Cave.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

Bone Cave: A Special-Use Site in the High Lava Plains

Chapter 1: Introduction

Introduction

Bone Cave is located in the High Lava Plains province in the extreme Northwestern Great Basin, just east of Pilot Butte along Highway 20 in Deschutes County. The excavated portion of the site is inside the front chamber of a lava tube that is part of the expansive Horse Lave Tube covering much of the region directly east of Bend (Greeley 1971). Massive volcanic features and few bodies of water dominate the regional geology. The upper Deschutes River, approximately four miles to the west, is the nearest reliable source of water, although snow accumulation inside Bone Cave and other lava tubes may have served as a water source into the early spring.

Bone Cave was brought to the attention of the Oregon State University Department of Anthropology by one of its former students who had witnessed extensive looting at the site for many years that had continued until just prior to this project. Rockshelters represented important features to the prehistoric populations of the region, and excavations were conducted at the site to address many research questions directed at the chronology and focus of site use, local settlement and subsistence practices, and lithic procurement and use strategies, as well as determining the extent of looter damage to the site.

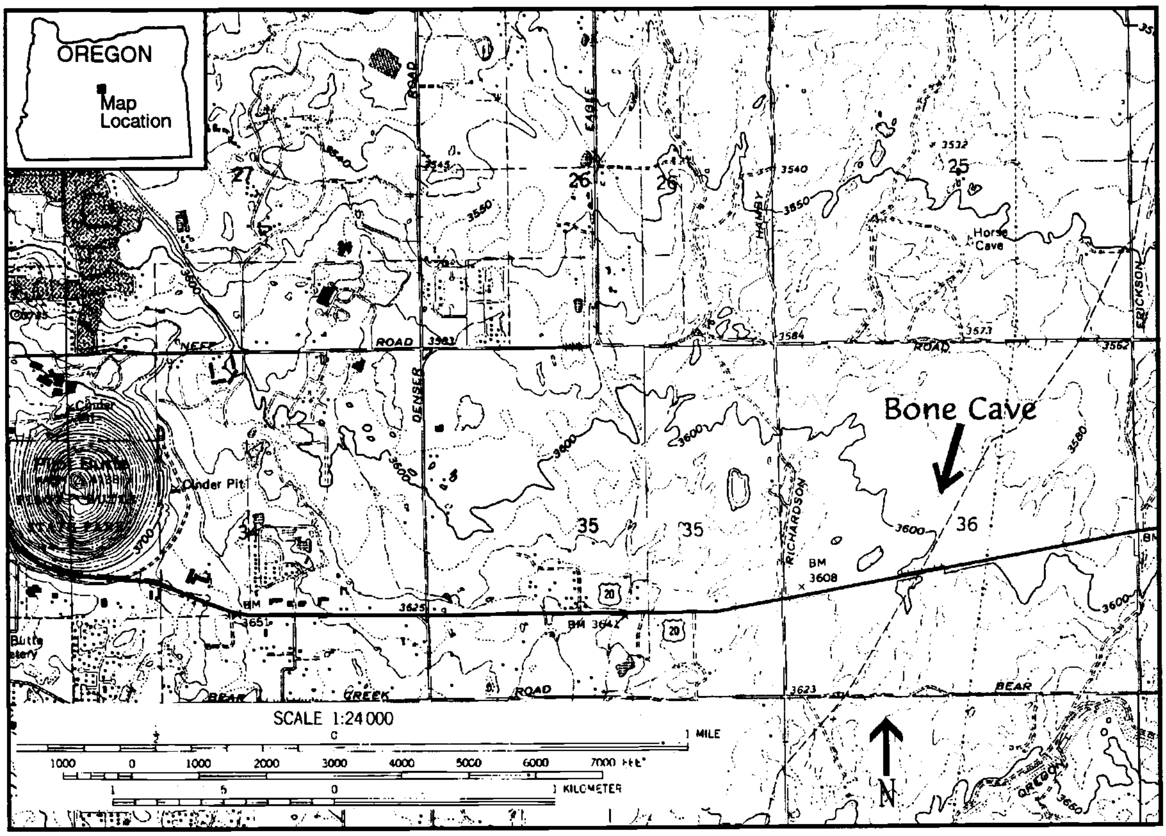

Figure 1.1: Location of Bone Cave. Bend is just west of Pilot Butte (from USGS Bend and Bend Airport 7.5' topographic maps). The site is located in Township 17 South, Range 12 East, Section 36.

Excavations at Bone Cave took place in the summer of 1998 directed by Dr. Barbara Roth of Oregon State University, and assisted by the author and many volunteers from Oregon State University and the Archaeological Society of Central Oregon. Unfortunately, no undisturbed deposits were discovered in the excavation of over 10 m^3 of sediment in six 1-x-2 meter units covering most areas of the front chamber. Sites with this degree of disturbance rarely receive extensive analysis, but as this report will demonstrate, a great deal of information is still available if the proper analytical methods are used.

Very few tool fragments and no complete or diagnostic formal tools were recovered during the excavation, focusing the lithic analysis on the debitage assemblage. Standard techniques of lithic analysis along with obsidian hydration and obsidian characterization studies have provided information about the site chronology, lithic use at the site, and the possible cultural affiliation of cave occupants.

When combined with the preliminary faunal analysis, the site appears to have been used in the Early Archaic Period, prior the eruption of Mount Mazama, by groups from the Northern Great Basin or lower Deschutes Basin as an important rabbit processing site. The site may have been used to process the rabbits collected during communal rabbit drives (Steward 1938; Fowler 1992; Aikens 1993). There is other evidence from the Fort Rock Basin to the south of other similar rabbit processing sites radiocarbon dated to the Early Holocene (Oetting 1994), and this may indicate logistical

Figure 1.2: View to the west showing entrance to Bone Cave.

rabbit hunting and at least some degree of at least temporary political organization above the band level. The butchered remains of larger mammals were recovered, but represent an extremely small portion of the faunal assemblage.

Plant processing and other subsistence activities may have also occurred at Bone Cave but evidence of these practices, such as groundstone artifacts, were not recovered and no features were found. Flotation analysis might have revealed plant remains and other fragments of perishable artifacts, but excavation was stopped at the request of tribal representatives due to the recovery of isolated and disturbed human remains prior to the collection of flotation samples.

The obsidian hydration and characterization analysis showed no sign of any significant human use of the site after the Mazama ashfall. This may be due to the rapid accumulation of volcanic sediments nearly filling in the front chamber that caused post-Mazama groups to relocate to larger lava tubes in the area.

Research Orientations

Evidence of extensive looting activities at the site prompted this project in order to determine the current condition of the archaeological deposits within the front chamber of the lava tube and to examine the site's potential for addressing various archaeological research questions. If the site was intact it could have potentially answered questions about hunter-gatherer use of the High Lava Plains as proposed in the following research questions:

1) What is the chronological extent of site occupation? Specifically, is there any evidence for occupation prior to the eruption of Mount Mazama?

Upon initial examination of the site, it appeared extensively disturbed, but there was the possibility that either the looters did not disturb the deeper stratigraphic levels or they preserved pockets of deposits by chance or through covering them with piles of backdirt. A small profile of a looter pit at the entrance to the front chamber revealed what appeared to be multiple occupation levels. Test excavations would determine the nature of these stratigraphic levels.

The major questions about occupation chronology would be answered by discovery of temporally diagnostic artifacts such as projectile points, or by recovery of suitable samples for dating such as charcoal for radiocarbon analysis. The presence of an intact strata of Mazama ash would serve as a specific temporal time marker. Mount Mazama erupted twice between 6800 and 7000 B.P., forming modern Crater Lake, and resulting in significant ash deposits across Eastern Oregon and much of the Pacific Northwest (Matz 1991). Occupations within the region of the Mazama tephra-falls are often distinguished according to pre- and post-Mazama periods (Synder 1981) and little pre-Mazama data exist for the Deschutes area of the High Lava Plains.

Unfortunately the disturbed nature of the deposits precluded the recovery of any diagnostic projectile points or any stratigraphic or radiocarbon dating, but a combination of obsidian hydration and X-ray fluorescence (XRF) analysis may allow for an estimate of the time and duration of site use.

2) What was the nature of cave occupation? Was the lava tube used for extended habitation or specialized resource procurement/processing activities? Was the site seasonally used and was it reoccupied? How did the nature of site use change over time?

The relationship between Bone Cave and other sites in the region is based on the determination of the types of activities carried out at the site. Sites are often viewed according to two opposing ends of the forager/collector continuum (Binford 1980). Foraging groups tend to utilize temporary residential camps that contain a fairly large sample of the total material culture of the group. Collectors maintain longer-term residential sites that exhibit extensive tool repair and manufacture along with logistical procurement sites that generally contain evidence of specific portions of the culture's total material culture. Archaeological assemblages can be used to address the degree and type of mobility exhibited by the site inhabitants (Binford 1979). Stone assemblages in particular provide information about the organization of the lithic technology with regard to mobility (Bamforth 1986; Kelly 1988; Bamforth 1991; Carr 1994). Had stratified deposits been present it would have been possible to observe any changes in the mobility pattern that may be tied to environmental changes such as general climate change, population growth, resource distribution, or the accumulation of the Mazama tephra (which certainly caused a substantial impact on the regional populations (Matz 1991)).

Many types of data are helpful for developing a complete picture of site use. These may include pollen analysis, faunal studies, lithic analysis, and flotation analysis. The highly disturbed nature of the deposits precluded sample collection for flotation or pollen analysis. Perishables are often recovered in sheltered sites in the Northern Great Basin, but no perishables were encountered during the excavation. The form and manufacturing technique of perishable items can provide further support for site function determination (Adovasio, Andrews et al. 1977; Adovasio and Andrews 1986; Webster and Hays-Gilpin 1994).

The excavation of archaeological features such as hearths or storage pits is also important for understanding site use. Logistically organized groups would likely produce larger numbers of more formal hearths and possible caching features. The looting of the site greatly reduced the possibility of uncovering any features other than those created by the looters themselves such as the concentrations of rocks and bone resulting from screen dumps.

With the disturbed status of the Bone Cave deposits, the primary data set useful to establishing the nature of prehistoric site use is the lithic assemblage. As will be described later, the obsidian hydration and XRF data point to little if any site occupation after about 7,000 B.P. This may in part be due to the extensive filling of the site from Mazama ash and other natural accumulation. The floor in the front chamber of the cave currently averages only about one meter from the cave roof potentially making this site less desirable compared to other larger lava tubes in the area. If the lithic assemblage derived from a fairly short time span as the hydration values indicate, then the assemblage may represent a single settlement pattern adaptation instead of a long term, complex mix of adaptations. The XRF sourcing information is capable of estimating the range of mobility if embedded procurement dominates (Morrow and Jeffries 1989). It is possible for trade to account for the presence of widely distributed sources, but no evidence exists for substantial trade in the Early or Middle Archaic Period in the Northern Great Basin (Minor and Toepel 1989).

Different mobility strategies play out in the organization of lithic technology, although mobility may be only one of many factors that may include, among others, subsistence, raw material distribution and quality, and political boundaries (Andrefsky 1994). In areas with dispersed lithic sources, highly mobile groups tend to utilize a more "embedded" raw material procurement strategy and must take greater consideration of tool efficiency due to the limits of materials that can be carried (Binford 1979; Kelly 1983; Gould and Saggers 1985; Bamforth 1986). Groups exhibiting less residential mobility tend to procure lithic raw materials through logistical collecting trips, and the residential base camps contain evidence of the manufacture of tools specific to processing resources (Binford 1979; Nelson 1991). Biface production and repair debris often occurs at residential sites while logistical resource procurement sites contain predominantly broken bifaces and evidence of maintenance and repair (Kelly 1988).

The high degree of mobility exhibited by prehistoric groups in the Northern Great Basin suggests that few sites were occupied for long periods of time prior to the Late Archaic. The season of site occupation could provide important information as to the specific resources exploited during site occupation. The presence of seasonally available plant remains may pinpoint a period of site use. Similarly, the age structure of faunal remains provides estimates of the season of the hunting activities (Monks 1981).

3) What were the subsistence practices utilized at Bone Cave?

Understanding of the subsistence practices aids in determining the reason for site occupation. Data from the site can be used to determine the relative importance of plant and animal exploitation. Dry caves provide an opportunity to examine a more complete assemblage of subsistence remains than is typically preserved in open archaeological sites. In order to understand the role of this location in seasonal movements, it is important to determine if the groups were targeting specific resources such as large game, waterfowl or seeds.

The absence of cultural features or undisturbed deposits prevented the collection of flotation and pollen samples that would have aided in subsistence analysis but, as the site name implies, an abundance of faunal remains was recovered. Faunal analysis may indicate not only the various species exploited, but also their relative contribution. Careful analysis of the faunal assemblage is necessary prior to drawing any conclusions, because, unlike the lithic assemblage, faunal remains can be left by non-human species (Schmitt and Juell 1994) and natural deaths. Sheltered sites such as Bone Cave provide ideal locations for many species such as coyotes, rabbits and various rodents. At the time of the excavation a rabbit and at least two rodent species were noted within the front chamber, and a coyote den could be heard in close proximity to the site.

Artifact assemblages can also aid in determining subsistence practices. Particular forms of ground stone such as hand stones and basin metates that exhibit specific wear patterns are generally associated with plant processing (Schneider 1993). Thus, if plant exploitation was an important activity at the site, then associated ground stone should comprise a portion of the stone tool assemblage. The presence of chipped stone tools such as large choppers and core tools also correlate with plant processing, while scrapers used for hide processing and projectile points are typically associated with hunting and butchering activities. Use-wear analysis may be necessary for distinguishing the function of some tool forms (Adams 1993).

4) What was the nature of the interaction between the groups who lived at Bone Cave and other groups in the region?

A common method of examining group interaction through archaeological assemblages is through artifacts with culturally diagnostic stylistic variation (Jones 1997). Lithic and perishable technologies generally exhibit culturally specific attributes (Adovasio, Andrews et al. 1977; Flenniken 1985; Lohse 1995) that can be used to document exchange of goods and/or ideas, or denote the presence of site use by different cultures. Bone Cave is located in a culturally dynamic region. There is evidence of alternate occupation of the Deschutes drainage by groups with ties to the Northern Great Basin to the south and other groups linked with the Columbia River to the north (Jenkins and Connolly 1994). Projectile point types would establish the cultural orientation of the inhabitants of the site. Unfortunately the artifacts most helpful in determining cultural affiliation are also those specifically targeted by modern looters, and only one fragmented possibly diagnostic artifact was recovered during the excavation.

Without artifact style to aid in group identification it was necessary to turn to the lithic debris to address the range of mobility and the general adaptation of lithic technology. Debitage is rarely collected by looters and represents the most complete data set available on the technology. Distinct cultures often differ enough in the general pattern of stone tool use that it is evident in the debitage. Obsidian sourcing information can reveal the direction of either group movement or trade relations that are important in establishing cultural ties.

5) What can the extent and nature of looter damage tell us about looter behavior? Is it possible to make predictions about looter behavior that would help other researchers maximize data recovery from looted sites?

Preliminary examination showed the site was subjected to extensive looting, and the excavation strategy was aimed at locating both disturbed and intact deposits. A pattern may emerge from the distribution of the disturbed portions of the site that could help other researchers efficiently locate intact portions of disturbed sites. Comparison between the looted and intact artifact assemblages would show the specific targets of the looting, and determine what portions or classes of the artifact assemblage survive looting. For example, it would be useful to know if looters remove primarily complete formal tools or if they collect all artifacts large enough to remain in large-mesh screens. Obviously individual looters differ in their reason and completeness of their excavation, but this could supply a base of data to compare with other sites.

The deposits within the front chamber have undergone decades of looting extending all the way up to just prior to this project. It is quite possible that the same matrix has been illegally excavated multiple times by different individuals. With more than 10 cubic meters of excavation in six units no undisturbed deposits were located. The presence of some tool fragments, lithic debitage, and faunal remains still allows for some conclusions about looter behavior, but a comparative sample of undisturbed deposits was not encountered.

Chapter 2: Theoretical Perspective

The theory of behavioral ecology, a subset of evolutionary ecology (Broughton and O'Connell 1999), dominates most archaeological research on hunter-gatherers in Western North America and especially the Great Basin. By the early 1980s most Great Basin researchers had realized the limitations of the cultural-historical approach and found that evolutionary and behavioral ecology provided a better theoretical framework (Aikens 1982; O'Connell 1982). This approach uses the general biological concept of natural selection to explain the choices made by individuals and cultures (Smith 1983; Boone and Smith 1998). This theory allows cultures to be viewed as both stable responses to specific technoenvironmental conditions as with Steward's (1938) cultural ecology, and as dynamic systems that change due to both internal and external pressures (Bettinger 1991). Unlike evolutionary archaeological studies, in behavioral ecology cultural phenotypes vary according to cultural selection and transmission without requiring every behavioral choice to undergo genetic natural selection (Boone and Smith 1998, Smith 1983). Evolutionary archaeologists argue that individuals exhibit phenotypic cultural traits that are subject to the same selective pressures as other phenotypic traits such as hair or eye color (O'Brien 1996). Behavioral ecology takes a less rigid stance and claims that the decision-making ability of individuals is assumed to be the product of natural selection and individuals should behave in order to maximize their own fitness. Although the different theoretical approaches assume that natural selection operates at different levels, both use the same biological definition of natural selection. Natural selection is the mechanism that directs adaptive evolution by favoring individuals with the best-adapted traits to leave more reproductively viable offspring (Krebs 1994).

Often these fitness-bearing choices are explained in terms of optimization of costs and benefits (Smith 1983). This type of analysis is widely used in attempting to explain almost every cultural interaction with the environment from food foraging behavior to raw material selection for the manufacture of stone tools. Among these explanatory models, optimal foraging theory has been extensively applied to foraging behavior in the Great Basin. Optimal foraging theory, specifically the diet-breadth model, analyzes the distribution of, the costs of searching for, and the effort in processing a particular resource compared to the caloric and nutritional benefits that the resource provides (Kelly 1995). Comparing all of the variables allows for a prediction of the breadth of resources exploited by a culture given an accurate assessment of the technological and environmental conditions. By comparing the prediction with the archaeological data from different time periods or environmental circumstances it is possible to document cultural responses to environmental or technological changes such as climate change or the development of the bow and arrow (Broughton and Grayson 1993).

Not all behavioral ecology is as precise or quantitative as optimal foraging theory. Archaeologists often look for rational responses of cultures to existing conditions, particularly when concerned with settlement pattern and technology. For example, groups will tend to be more mobile when the food resources they exploit are located at different elevations during different seasons, and these groups are likely to use lithic raw material sources that are located along these seasonal rounds (Binford 1979). This less quantitative form of behavioral ecology is useful in examining human settlement and subsistence adaptations to particular environmental conditions.

Settlement and subsistence research comprises a large portion of Great Basin archaeology since the 1970s (Bettinger 1993). Research is focused on these areas in large part because they are key to understanding cultures as well as being typically visible in the archaeological record. The framework generally employed attempts to categorize cultures along a forager-collector continuum (Binford 1980). Data from an excavation could be used to determine if the archaeological deposits at the site represent the remains of residentially mobile foragers who moved throughout the region following the seasonally available plant and animal resources or if they were logistically organized, living at a series of base camps and making forays to collect additional resources (Binford 1979; Binford 1980). When multiple occupations are recovered within a site, it becomes possible to link the settlement and subsistence with changing environmental conditions (Kelly 1983). The association between documented environmental fluctuations in the Northern Great Basin (Aikens and Jenkins 1994) and change in settlement or subsistence strategy can provide important data to understanding regional archaeology (Oetting 1992) and human behavior in general.

Analysis of flaked stone assemblages can supply information about group mobility and procurement range. Highly residentially mobile groups tend to produce more expedient tool forms when there is ready access to raw material, while in cases of resource scarcity, greater sedentism, or logistical mobility, groups tend to use a more formal, and often bifacial, lithic technology (Kelly 1983; Bamforth 1986; Kelly 1988; Bamforth 1991; Andrefsky 1994; Shott 1996). The residential bases of logistically organized groups tend to exhibit the manufacture and curation of tools used to procure resources (Binford 1979), although the definition of "curation" is not unanimous among archaeologists (Shott 1996).

Key to understanding the implications of the lithic assemblage is a complete knowledge of available sources of raw material. The region around Bone Cave is fairly unique in the extensive information about the temporal availability of specific obsidian flows (Ozbun 1991). Using the theory of behavioral ecology, groups should try to maximize the use of lithic material balanced against the cost of material collection and manufacture.

Obsidian source analysis is possibly the best available measure of prehistoric group mobility in the Northern Great Basin due to its ability to precisely determine the source material locations. Mobile hunter-gatherers often embed necessary lithic material procurement with the general subsistence-based settlement pattern (Gould and Saggers 1985). The geographic distribution of obsidian from an archaeological assemblage may show the geographic extent of the settlement pattern or seasonal round. Trade could account for some of the sources found within a site, but almost no archaeological data exists for the Northern Great Basin to suggest that most toolstone was procured through trade (Minor and Toepel 1989).

Obsidian source data cannot only provide information about group mobility, but along with the analysis of the style of diagnostic artifacts they may also shed light on questions of ethnicity. Recent studies suggest that the High Lava Plains represents a fluid contact zone between Northern Great Basin and Columbia Plateau groups, particularly along the major tributaries of the Columbia River such as the Deschutes River (Connolly, Jenkins et al. 1993; Jenkins and Connolly 1994). Environmental fluctuations may have created conditions ideal for either Plateau or Basin groups to expand into this area on a seasonal basis. The distribution of obsidian sources represented within Bone Cave may show the ethnic orientation of site occupants (Bouey and Basgall 1984; Connolly and Jenkins 1997).

With the high density of obsidian sources around Bone Cave, either logistically or residentially mobile groups that may have used the rockshelter would have likely encountered multiple chemically distinct obsidian outcrops. Thus the composition of sources found at the site should reflect the direction and distance of prior movements as well as the type of technology and the tool requirements at the time when they encountered the source.

In addition to lithic sources, projectile point styles can provide further evidence of group identification and the chronology of site use. Although the validity of point typologies, particularly those in the Great Basin, have come under criticism (Flenniken and Raymond 1986), most archaeologists (Thomas 1986; Bettinger, O'Connell et al. 1991) accept some anomalous aspects of projectile point typologies but claim that with a sufficient sample size, types differentiate in time and space. Differences between the distinct culture areas of the Plateau and Basin should be apparent using western projectile point typologies (Lohse 1995). Small-scale regional variation in point typologies are prevalent (Thomas 1986) in the Great Basin, but these point forms differ substantially from those of the Columbia Plateau, with the exception of some Paleoindian types. Problems can arise when assigning cultural affiliation based on projectile points alone due to the high trade value of these items, but when combined with lithic sourcing and other assemblage features, cultural affiliation should be apparent. Another possibility is that the High Lava Plains represents a distinct cultural adaptation that may or may not incorporate aspects of either the Plateau or the Basin. However, regional studies tend not to support this idea, assigning sites to predominantly one of the two cultures based on projectile point assemblages, lithic technology, obsidian sourcing, site structure, and other archaeological features (Jenkins and Connolly 1994).

The analysis of the lithic and faunal assemblage should provide at least some information about the ethnicity, technology, settlement, and subsistence adaptations of Bone Cave inhabitants. An understanding of these adaptations at Bone Cave in light of the principles of behavioral ecology can add to the synchronic and diachronic understanding of human responses to cultural and environmental influences. It is also important to document the limited, yet significant, data that can still be recovered from heavily disturbed sites. Often disturbed sites are ignored and even destroyed without any examination, and this study shows that this may not be a justified course of action.

Chapter 3: Environmental and Cultural Setting

Environmental Setting

Geologic setting

Bone Cave is located within the High Lava Plains province, a transitional region between the Great Basin and the Columbia Plateau (Baldwin 1976). This physiographic province consists predominantly of recent north-sloping lava flows that have formed lava buttes, cinder cones, and extensive systems of lava tubes (Aikens 1993). The entire region was formed by repeated lava flows that originated from both the Newberry vicinity and from Pilot Butte (Peterson 1976). Since the last Pleistocene basalt flow many volcanic events as far away as Mount Mazama have deposited pumice and ash throughout the region (Peterson 1976; Matz 1991).

Soils consisting of loamy sand in the vicinity of Bone Cave are interspersed with frequent basalt outcrops. Soil accumulation is predominantly in depressions and the deposits contain large amounts of pumice, probably derived from the eruption of Mount Mazama which deposited 15-30 cm in this area (Matz 1991). Other eruptions such as those at Newberry Volcano could have produced some of the pumice and may have been mixed with the Mazama ashfall, but intact deposits within the site would have been necessary to determine the exact nature of the volcanic deposits.

Bone Cave is a part of the Horse Cave Lava Tube System that consists of numerous predominantly north-south branching and isolated tubes that all likely resulted from a single volcanic event. These tubes form as rivers of lava cool and solidify

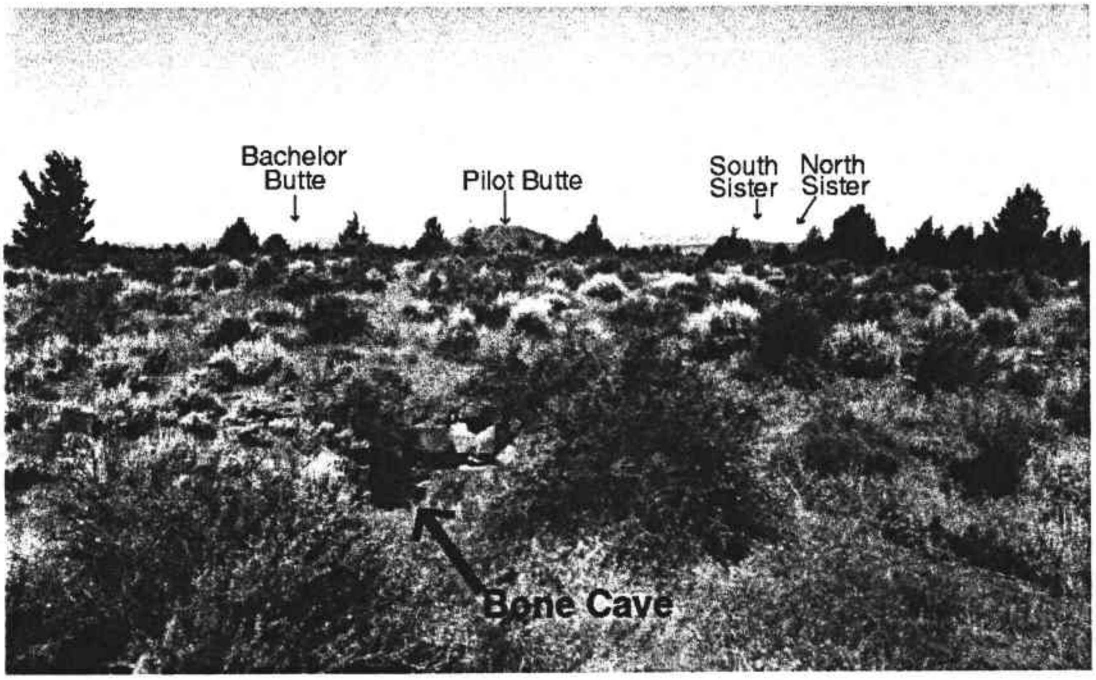

Figure 3.1: View to the west of Bone Cave. Note site entrance in the foreground and various peaks on the horizon.

forming a shell with moving lava inside. As the interior of the tubes continues to move out of the crust, the last of the flow exits the tube leaving behind the lava tubes. The complete extent of the Horse Cave system is unknown because both ends are covered by more recent basalt flows (Greeley 1971). Although no ice was observed during excavation of Bone Cave in the summer, many of the tubes in the Horse Cave system contain seasonal ice accumulation.

The nearest permanent water source is the Deschutes River approximately 4 to 5 miles to the west. Small drainages and basins in the area may contain water on a seasonal basis, and they may have been more reliable water sources during periods of much wetter climate. Slightly wetter climate may have existed in the Northern Great Basin than present during the Early Holocene (10,000 to 7,000 B.P.) and again after 4,500 B.P.

(Grayson 1977; Aikens and Jenkins 1994). The large Pleistocene lakes were limited to the closed Basins such as Fort Rock Valley and Warner Valley, and did not significantly impact the Western High Lava Plains (Freidel 1994).

Climate

The current average temperature for Bend is 8° Celsius (46° F) with an average range from –6.5° C (20° F) to 28.7° C (83° F) with Januaury the coldest month and July the warmest (BECON 1982). As with the seasonal fluctuations, daily temperature variations are also extreme, changing as much as 50° F within a single day (Aikens 1993). Summers are typically hot and dry and winters are cool and wet. Average annual precipitation is around 318 mm (12 inches), and only 50 mm (2 inches) falls in the summer. Winter snowfalls average almost 1 meter (3 feet).

While these conditions are fairly consistent across the Great Basin today, drastic climate changes have occurred in the last 11,000 to 13,000 years of estimated human occupation of the region. Long term climate trends reveal cool, wet conditions that were most extreme around 18,000 B.P. and became much warmer and drier by approximately 10,000-9,000 B.P. (Freidel 1994). Extensive lakes and wetlands collected in closed basins throughout the Great Basin and certainly affected the distribution and availability of resources. From about 7,000 to 4,000 B.P. extreme aridity caused many of the wetlands in the region to completely dry and well-dated archaeological sites from the Middle Holocene are, not surprisingly, rare (Grayson 1993). After 4,500 B.P. the Great Basin returned to the cooler and slightly wetter conditions that have persisted to the present (Aikens 1993). Within these broader climate shifts short-term changes and local variations have created an extremely complex climate history.

Little information is available on the paleoclimate of the area. A study of the rabbit species recovered during the excavation of Youngs Cave, a lava tube site approximately five miles from Bone Cave, suggests that conditions similar to today existed during the Early Holocene, and that these conditions were slightly warmer and drier than the climate in the Fort Rock Basin (BECON 1982).

Flora

Native flora is dominated by an open juniper woodland consisting primarily of dispersed sagebrush (*Artemisa tridentata*) and western juniper (*Juniperus occidentalis*) (BECON 1982). In addition to sagebrush other understory vegetation includes grasses such as: western needlegrass (*Stipa occidentalis*), thurber needlegrass (*Stipa thurberiana*), sandberg's bluegrass (*Poa sandbergii*), Indian ricegrass (*Oryzopsis hymenoides*); and shrubs such as antelope bitterbrush (*Purshia tridentata*), shrubby buckwheat (*Eriogonum spp.*), and purple sage (*Artemisia spp.*). General pine nuts may have provided some subsistence value to the prehistoric population, but pinyon has yet to reach Oregon in its spread from southeastern California. Pinyon has only expanded as far as the Reno, Nevada area within the last 500 years (Kelly 1997). The general aridity and poor soil quality discourage many species found in the Columbia Plateau to the north, the Cascades to the west, and the Basin and Range to the south and east.

The invasion of non-native cheat grass (*Bromus tectorum*) has largely resulted from the extensive livestock grazing throughout the region. The prehistoric availability of plant resources certainly influenced human use of the area. Compared to surrounding areas, this region contains few edible roots, and the juniper berries were not highly ranked among the ethnographic Paiute (Masten 1985).

Fauna

The larger mammalian species in the region include mule deer (*Odocoileus hemionus*), pronghorn antelope (*Antilocapra americana*), badger (*Taxidea taxus*), and porcupine (*Erethizon dorsatum*). Smaller mammalian species include jackrabbits (*Lepus californicus*), cottontail rabbits (*Sylvilagus nuttallii*), pika (*Ochotona princeps*), and numerous bat species (Yocum and Brown 1971). The large variety of mammalian predators typical of the area are cougar (*Felis concolor*), coyote (*Canis latrans*), and gray fox (*Urocyon cinereoargentus*).

Included among the larger bird species in the area are many hawk species, turkey vulture (*Cathartes aura*), prairie falcon (*Falco mexicanus*), several owl species, ravens (*Corvus corax*), quail and numerous other small birds (Yocum and Brown 1971). Reptile species are fairly limited in the area and include the sagebrush lizard (*Sceloporous graciosus*), northern alligator lizard (*Gerrhonotus coeruleus*), and the western rattlesnake (*Crotalus viridis*) (Yocum and Brown 1971).

Current Property Use

The privately owned property on which Bone cave is located is not currently used for any private or commercial purposes other than the large power lines and gas transmission lines that travel north-south approximately 200 meters to the east of the site.

There is a small dirt road that extends from the power substation on Highway 20 to within two meters of the entrance to the lava tube. Immediately surrounding the property are many commercial establishments, residential areas, and agricultural properties.

Ethnographic Background

Although ethnographic accounts influenced archaeological interpretation long before the development of the "new archaeology," the work of Binford and others since the 1960's has demonstrated the archaeological value of ethnographic accounts. Ethnographic data can serve to propose potential interpretations for archaeological phenomena that then require further testing with the archaeological record (Binford 1967). The ethnographic accounts from the Great Basin have proven extremely informative, but it is necessary to remember that most of the data were collected more than a century after first contact with European cultures and after waves of devastating diseases drastically altered the population size and consequently the culture itself (Clemmer and Stewart 1986).

The similarities between the ethnographic and archaeological records are remarkable in the Basin. Regional variation certainly existed during both prehistoric and ethnographic periods (Fowler 1982; Bettinger 1993), but many archaeologists have based interpretations and predictions on the general ethnographic data. Jennings saw a clear cultural stasis from the Early Holocene through the ethnographic period throughout the desert west that he termed the Desert Culture (Jennings and Norbeck 1955; Fowler 1986). Although the archaeological record has since shown that both regional variation and culture change were understated in the Desert Culture model (Bettinger 1978), Steward's

(1938) Basin-Plateau ethnography has been tested with the archaeological record (Thomas 1973) to show links between prehistoric and ethnographic settlement patterns. Even on a smaller scale, ethnographic records are excellent sources of potential explanations for archaeological artifacts and features.

While the ethnographic record may provide potential interpretations (Binford 1967) of archaeological data, caution and care is certainly required when examining ethnographic data. For example there are many problems with Thomas' (1973) ethnographic-based settlement model. Thomas used only one ethnographic source that was compiled after Shoshone groups had been prevented from accessing the most productive resource patches, certainly affecting the settlement pattern. He also biased his sample to include predominantly the poor resource areas discussed by Steward (1938), and used only surface scatters. The use of ethnographic data required consideration of the context of the ethnography as well as an appropriate sampling strategy to compare the archaeological and ethnographic records.

Much of the ethnographic work prior to the 1870s treated the Native American groups in the Great Basin as natural history subjects more than the object of anthropological study (Fowler 1980). Systematic ethnographic fieldwork began with the work of John Wesley Powell from 1868-1880 (Fowler and Fowler 1971) and culminated the Steward's (1938) ethnography of the Shoshone. Other more recent work in the Stillwater Marsh area has contributed greatly to the understanding of subsistence and settlement strategies as well as the technology on a regional level (Wheat 1967; Fowler 1992).

The Juniper-Deer Eater Band of the Northern Paiute apparently occupied the region surrounding Bone Cave at the time of European contact (BECON 1982), but there is a great deal of debate about when the Numic-speaking Northern Paiutes entered the area. There is archaeological evidence throughout the Great Basin for a large-scale population replacement within the last 1 to 2,000 years (Smith, Bettinger et al. 1994; Hopkins 1965; Bettinger 1982; Sutton 1986). It has been suggested that the Paiute populations entered the Deschutes Basin as late as the 1800s (Houser 1996). If the ethnographic population recently occupied the area, then the ethnographic data must be interpreted with even greater caution, but these groups were coping with the same environmental conditions and resource distributions, and thus their survival strategies should be fairly similar.

Little ethnographic data exist for this band, but detailed ethnographic reports were produced about other Northern Paiute groups that are probably quite similar to the occupants of the Bend Area. The Northern Paiute were a Numic language speaking group that ethnographically occupied portions of Eastern California, Western Nevada, Southeastern Oregon, and Southwestern Idaho (Steward 1938). As with many groups in Western North America, the Northern Paiute language and mythology was extensively recorded and studied (Fowler and Fowler 1971), but unlike other Great Basin groups much of the material culture and settlement and subsistence strategies were not well documented (with the main exception of the fairly recent works on the residents of the Stillwater Marsh area of Western Nevada (Wheat 1967; Fowler 1992)).

Population Density

Information about Great Basin settlement patterns, population density, and political organization comes primarily from the work of Julian Steward (1938), but it must be considered in light of the extensive devastation from disease that had occurred by the early part of the twentieth century. Steward examined many sources to estimate Great Basin population densities. Specific regions varied widely in population density with anywhere from about one person per square mile in the Reese River Valley to less than one person per 50 square miles in areas of Central Idaho (Steward 1938). Given the sparse density of resources, the High Lava Plains area likely supported a population density toward the low end of this spectrum, and the density probably fluctuated greatly on a seasonal basis. Regardless of the specific population density (which certainly would have varied along with environmental conditions), population size of the High Lava Plains would have been small in comparison to the margins of the wetlands in the Great Basin and to the margins of the Columbia River and it major tributaries due to the high density of predictable resources in these areas (Aikens 1993).

Subsistence/Settlement

The schedule of available food resources largely determined the subsistence and settlement strategy for Great Basin groups. Aikens (1993, see Figure 1.4) describes the ethnographic seasonal round for the Harney Valley Paiutes. The subsistence and settlement patterns of the prehistoric groups that utilized the Western High Lava Plains may have been quite similar to that of the ethnographic Harney Valley Paiute with the possible addition of Cascade Mountain resources. In early spring, groups subsisting on

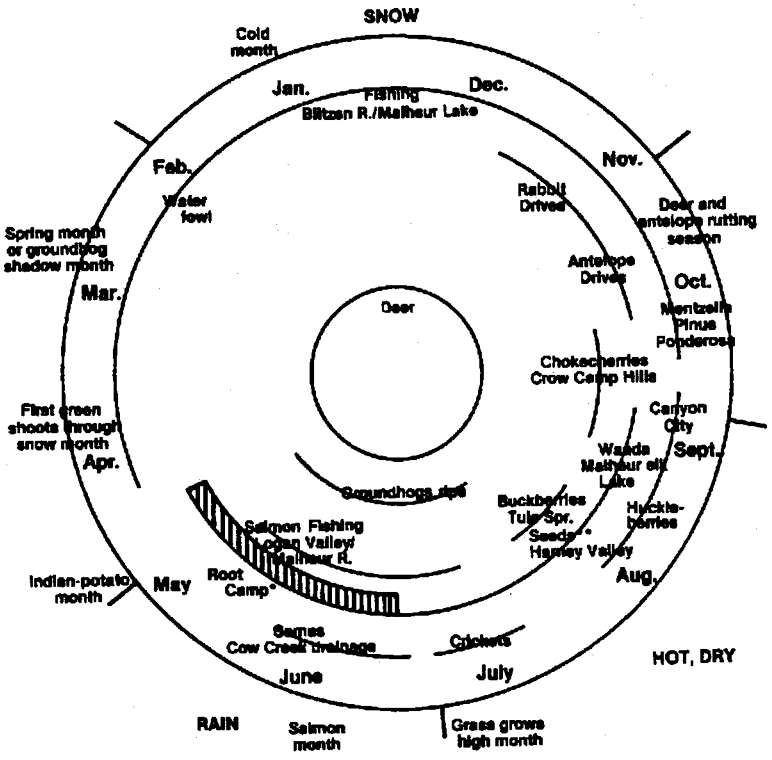

Figure 3.2: Ethnographic seasonal round of the Harney Valley Paiutes (Aikens 1993:16).

the remaining stores of food would leave the large winter camps and congregate at the expansive root grounds around Stinkingwater Pass. Both Great Basin and Columbia Plateau groups convened to collect this productive resource, with some groups traveling over 100 miles. Among the predominant plants gathered include bitterroot, biscutroot, yampa, and wild onion (Aikens 1993). During the root harvest small groups of men would move to the head of the Malheur River to exploit the salmon runs and return in early June with stores of dried salmon. Vast camas fields bloomed during May and the local residents collected and baked the camas roots in large earth ovens for winter storage. Through July and August small groups dispersed in search of game and scattered plant resources such as currants and huckleberries. It is quite possible that at this time groups wintering in more productive areas such as the Harney Valley moved into the Western High Lava Plains to hunt game and visit nearby obsidian sources to restock lithic raw material.

In August and September many of the Harney Valley Paiutes congregated along the shores of the desert lakes such as Malheur Lake to collect large quantities of small seeds including wada, goosefoot, Indian ricegrass, and Great Basin wild rye (Aikens 1993). Areas with productive berry yields were also visited at this time. Communal hunts for rabbits and larger game took place during October and November and then groups began to establish their winter camps near their caches of stored foods. According to Steward (1938) other factors influencing the location of winter camps included: access to water, adequate fuel supply, and at least some protection for extreme cold. Northern Paiute winter camps were reportedly located near fresh water sources at the foot of hills or in other protected locations (Whiting 1950).

Material Culture

Documentation of the prehistoric and ethnographic material culture may show distinct correlations that can reveal similarities in settlement and subsistence. Some of the best documentation of Great Basin material culture comes from ethnographic work conducted in the Stillwater Marsh area (Wheat 1967; Fowler 1992). Steward (1938) mentions certain items in use throughout much of the Great Basin such as rabbit nets, bows and arrows, and clothing items, but includes little information about their attributes, manufacture, or specific uses. The informants from the Cattail Eaters of the Stillwater Marsh Paiute had minimal first-hand experience with much of the technology, but they had seen much of it produced by their elders when they were children. The ethnographic Cattail Eaters recalled a seasonal subsistence cycle much like the Harney Valley Paiute described above with the notable inclusion of trout and squirrel to supplement winter stores (Wheat 1967). Aikens (1993) also makes no mention of the waterfowl that, along with other spring marsh tethered resources such as cattails, were extensively utilized.

Much of the Stillwater Marsh material culture involved in their subsistence practices was manufactured from perishable materials. For example, duck hunting required tule and duck skin decoys, tule boats, nets, clothing, and belts or baskets to haul the gear and catch (Wheat 1967). Of all of this technology, only the net weights and possibly stone or bone tools involved in the manufacture of these items would be expected to survive long in the archaeological record except in rare instances of exceptional preservation.

The technology of the Stillwater Marsh Paiute is easily described according to the resource it was used to procure or process. Pine nut harvesting required hooked sticks for knocking down the cones, conical burden baskets for collecting the cones, winnowing trays for roasting the nuts and separating the nuts from the shells, a groundstone huller for cracking the shells, and larger manos and metates that were left at the harvesting camps (Fowler 1992). The manufacture of many perishable items such as tule boats, tule duck decoys, basketry, cordage and living structures required some stone tools including modified and unmodified flakes and stone knives as well as bone tools such as awls and punches. The perishable items were used in almost all aspects of daily life.

Fishing technology involved any combination of fishing nets, bone or wood harpoons and fishhooks, fish baskets, and knives for processing the fish. Deadfalls and snares that rarely leave any archaeological trace took many small mammals. Much of the clothing was made from animal hides and/or plant fibers and possibly bone, stone, or shell ornamentation (Wheat 1967). This list by no means encompasses all of the material culture for all Great Basin groups, but it does demonstrate the variety and potential archaeological signature of the technology and its use.

Whiting (1950) lists even more material culture items used by the Northern Paiute than the Stillwater Marsh ethnographies, but does not provide detailed information about the items. Resource acquisition tools included the mano and metate, mortar and pestle, stone knives, digging sticks, bows, arrows, projectile points, deer antler pressure-flaker, shaft straightener, fire drill, basketry, scraper, drill, and cobble tool. Attire included sagebrush sandals and clothing worn by both sexes, skin aprons and dresses for women, and skin shirts and breech clouts worn by men. Ornamentation included quills, shells, and various beads (Whiting 1950).

Political Organization

According to Steward, an informal political organization dominated in the Great Basin. Certain individuals would assume temporary leadership roles during communal hunts, but this control was not absolute and dissolved after the hunt. The primary political unit was the family band consisting of the nuclear family and often a few additional relatives (Steward 1938), and collection of most resources did not become more efficient with larger groups. Multiple related family bands typically converged at winter camps, but the composition of the winter camps varied according to the availability and distribution of natural resources. The winter camps and the communal hunts provided an opportunity to conduct ceremonial dances such as the Bear Dance and the recent Sun Dance. The large gatherings also allowed for other important social functions such as exchange of information about resource locations and negotiations of marriages (Steward 1938). In areas of the Basin-Plateau region that either contained dense and predictable resources or easy travel routes to procure resources, larger bands with more permanent leadership developed. These situations were limited to small regions generally focused around wetlands such as in the Owens Valley (Steward 1938).

Other ethnographers have documented a political structure involving designated leaders. Steward attributed this documentation of distinct rulers as a result of European contact in which Great Basin groups attempted to coalesce under the direction of individuals in order to defend themselves against the invading population (Fowler 1992). Paiute informants in the middle part of this century from the Stillwater Marsh area recalled two classes of leaders; one that organized the communal activities and another that served as group spokesmen (Wheat 1967). Taking all of this information into account it is apparent that given the high mobility necessary to acquire widely dispersed and unpredictable resources characteristic of most of the Great Basin, organized sociopolitical organization, and even land ownership, would have been extremely difficult to maintain.

The ethnographic record of the Northern Great Basin supplies a baseline for comparison with the archaeological data, although extending the ethnographic data back more than 7,000 years is certainly problematic. Correlates between the settlement and subsistence patterns, political organization, and material culture between the ethnographic and archaeological records have been found, especially in the most recent archaeological sites. The ethnographic record shows an adaptation to a specific set of environmental conditions (and contact with Euroamericans and their diseases) that can be compared with similar prehistoric adaptations evident in the archaeological record.

Archaeological Background

This archaeological summary will focus primarily on the Oregon portion of the Northern Great Basin, although the cultural similarities throughout most of the Great Basin have produced similar archaeological studies. The majority of Great Basin hunter-gatherer archaeology tends to follow the same theoretical and methodological shifts, thus some studies outside of the Northern Great Basin have influenced research in Oregon. Following the general Great Basin discussion, the local archaeology will be presented for six subregions.

The degree of cultural variation between regions within the Great Basin has only fairly recently been acknowledged. Much of the Great Basin followed the same prehistoric cultural-historical sequence as outlined below, but individual regions experienced different environmental and social conditions that influenced and differentiated the local cultures.

According to the dominant view, the Paleoindians entered the New World either through an ice-free corridor between the Cordilleran and Laurentian ice sheets or by a coastal migration along the Pacific Coast (Kelly 1988). The Paleoindian fluted point tradition represents the earliest well-documented human occupation of the Great Basin

(Aikens 1993). The Clovis tradition, almost always found as isolates and in the Great Basin except in extremely rare stratified sites such as the Dietz site in southeastern Oregon, is well-dated throughout North America to between at least 11,500 and 10,600 B.P. A controversial date from the lower levels of Fort Rock Cave could push human occupation back to almost 14,000 B.P., but this is not generally accepted as reliable (Grayson 1993).

The Western Stemmed Point Tradition may have been contemporaneous with the fluted point tradition (Bryan 1988). Functional analysis suggests that the Stemmed points may have served a more general use as both knives and projectile points, while the fluted

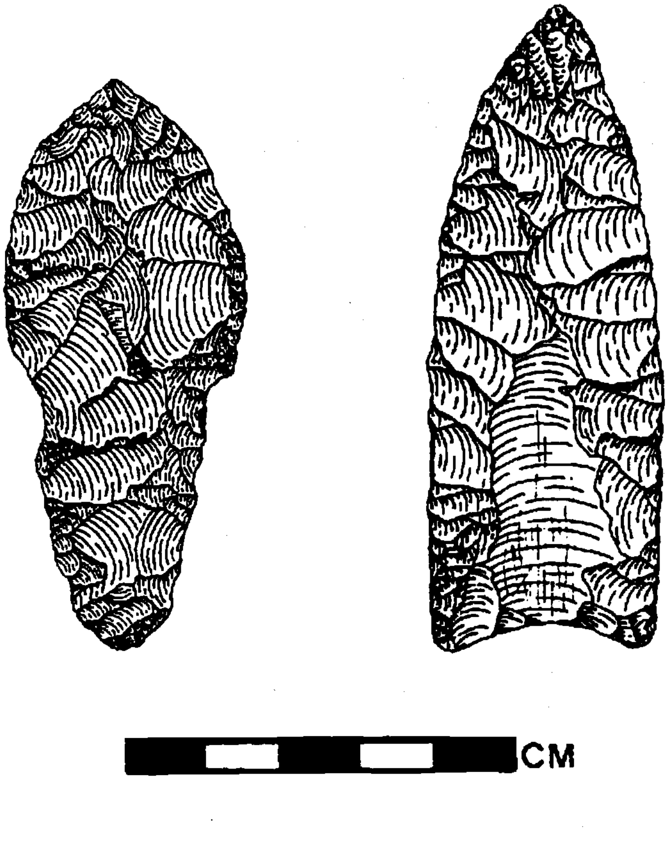

Figure 3.3: Examples of Western Stemmed (left) and Fluted (right) Traditions in the Great Basin (from Willig, Aikins and Fagan 1989:cover).

points may have served primarily as projectile points (Beck and Jones 1993). Although much of the available data show Western Clovis precedes the Western Stemmed traditions in the Great Basin, this technological interface may not be the transitional relationship originally postulated. With the use of radiocarbon dating, researchers have demonstrated little overlap between the fluted and stemmed traditions, but technological studies as well as further dating may continue to alter the standard view of an in-situ cultural transition at around 10,500 B.P. The Western Stemmed tradition may have been in place as early as 11,000 B.P. (Willig and Aikens 1988), and it appears to have persisted in the Great Basin much longer than the fluted traditions resulting in greater cultural variation among Western Stemmed sites (Grayson 1993). While the two technologies may have had similar functions, Clovis points are generally found only along the shores of Pleistocene lakes, while Western Stemmed points also appear in riverine and upland contexts (Beck and Jones 1997).

Archaeological evidence of the Paleoindian occupation in the Great Basin is scarce, and what little there is consists primarily of lithic scatters that contain almost no subsistence data (Beck and Jones 1997). Some subsistence data are available from human coprolites recovered in Danger and Hogup caves that shows a heavy reliance on plant resources, particularly seeds and berries. Small mammals dominate the rare faunal assemblage dating to the end of the Pleistocene although some sites contain larger animals such as elk, mountain sheep and bison (Beck and Jones 1997). The Terminal Pleistocene occupation of the Great Basin tends to be focused around the expansive Pleistocene lakes and encompassed large amounts of seeds, small mammals, and fish, which differs from the hunting-based patterns typical of the Paleoindian occupations elsewhere on the continent (Fagan 1987; Kelly 1988).

The Western Pluvial Lakes tradition was originally thought to be synonymous with the Western Stemmed Tradition, but as the distribution of Western Stemmed sites revealed, stemmed points were found in upland as well as lacustrine settings. Despite this inconsistency, the terminology is still used to describe a Late Pleistocene/ Early Holocene cultural adaptation focused on the numerous pluvial lakes (Amick 1993). Although the Western Stemmed points are not always associated with the large lake and wetland resources, the end of the Western Stemmed Tradition roughly correlates with the drying of the pluvial lakes at around 7,500 B.P. (Grayson 1993) which hints at the importance of wetlands to this cultural adaptation.

Compared to the Early Holocene in the Great Basin, the Middle Holocene inhabitants of the region experienced a vastly diminished resource base due to the shrinking or complete drying of the expansive pluvial lake systems (Grayson 1993; Young 1995). Although the Great Basin did not undergo the long-term extreme drought between 7,000 and 4,500 B.P. proposed by Anteves (1948), there certainly was a drying trend that resulted in decreased wetlands (Kelly 1997). Northern Great Basin sites from this period tend to cluster around dependable springs and other water sources, and Kelly (1997) suggests that residential mobility decreased due to the limited availability of water throughout the region. The extremely low site density from Middle Holocene may reflect a regional population decrease and/or less visible temporary camps left by highly mobile groups searching for dispersed resources.

The Northern Great Basin demonstrates a dichotomy in site distribution between the upland and the lacustrine environments from the Middle to Late Holocene. Prior to 6,000 B.P. sites are generally clustered around the large lake basins and thus upland sites from this period are rare. Between 6,000 and 4,000 B.P. the productivity of the lake basins diminishes and populations disperse to exploit scattered resources, including those in the uplands. Upland occupation appears to peak around 4,000 to 3,000 B.P. and then sites begin to decline in both number and size, possibly resulting from logistical use of the uplands by lowland populations (Kelly 1997) that are present into the ethnographic period (Aikens 1993).

Great Basin Post-Mazama (since ~6,700 B.P.) projectile chronologies vary by location as well as any other archaeological component. While some argue about the temporal specificity of projectile point typologies in the Great Basin (Flenniken and Raymond 1986), work in the Monitor Valley, especially the excavation of Gatecliff Shelter in Central Nevada, has produced a local chronology with general implications for almost all of the Great Basin (Thomas 1981; Thomas 1986; Bettinger, O'Connell et al. 1991). Concave-based points dominate the Gatecliff assemblage between 5,500 and 3,500 B.P. followed by the short-term appearance of Gatecliff split and contracting stem points. Elko series were extremely abundant in strata dating from 3,350 to 1,400 B.P. and were replaced by smaller Rosegate and Desert side-notched after 1,400 B.P. (Thomas 1981). The shift from Elko to the smaller types within the last 2,000 years may reflect a shift in the hunting technology from atlatl and throwing stick to bow and arrow that is fairly consistent across the continent (Thomas 1978; Rondeau 1996).

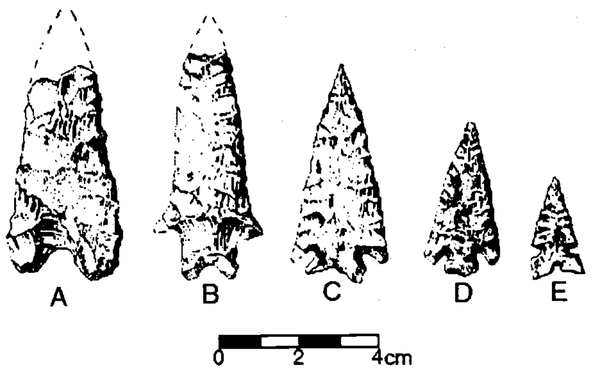

Figure 3.4: Examples of Gatecliff projectile points, A: Humboldt Concave Base, B: Gatecliff Split Stem, C: Elko Earred, D: Rosegate, E: Desert Side-notched (adapted from Thomas 1981).

This general cultural chronology holds for most of the Great Basin, but local environmental differences significantly contribute to local cultural variation. The Northern Great Basin reveals substantial differences as will be shown between the following six regions within Oregon. The regional subdivisions (see Figure 3.5) are not necessarily culturally based, but instead represent the major basins and or other geographical regions within the Northern Great Basin.

Warner Valley

The Warner Valley is located in the extreme south-central region of Oregon and consists of an environmentally complex basin flanked by steep mountain ranges (Young 1998). Compared to other regions of the Northern Great Basin, such as the Fort Rock Basin, the Warner Valley has received little archaeological attention. As with most arid regions, the Warner Valley contains few well-dated sites due to generally poor preservation in open sites, but the limited chronological data show a significant deviation

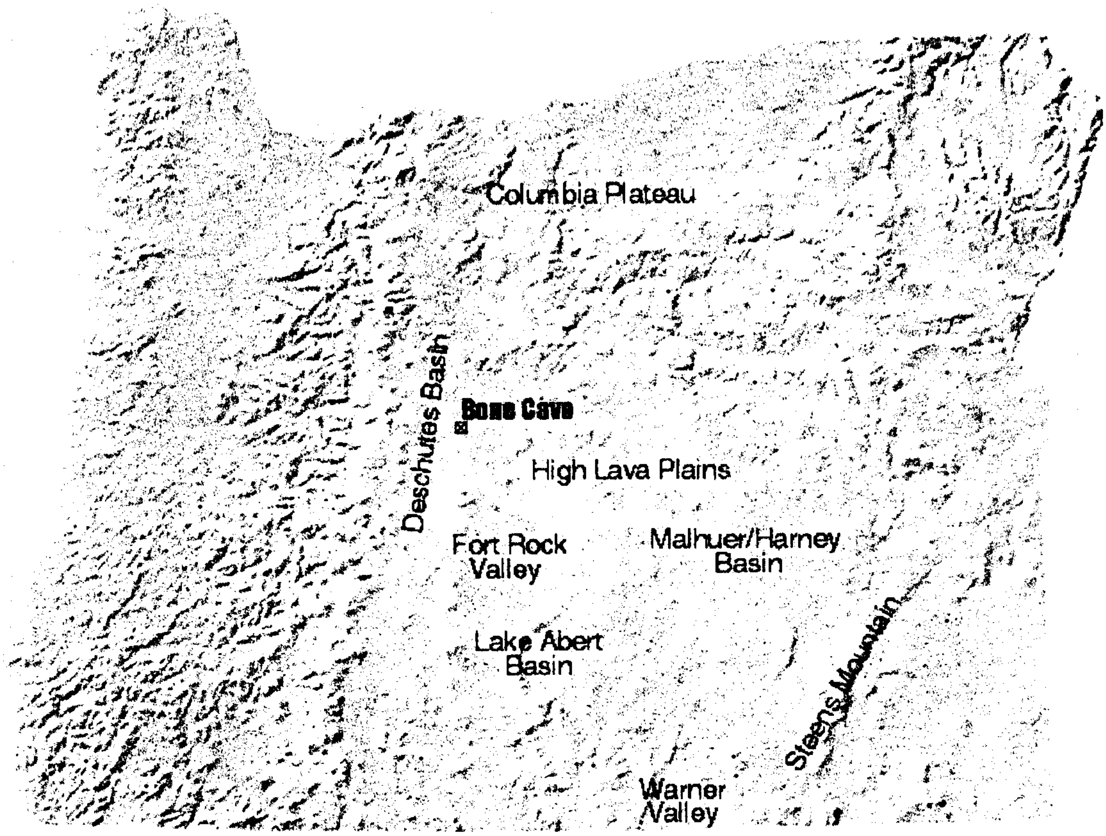

Figure 3.5: Major regions within Oregon discusses in text.

from the Central Great Basin in the temporal use of Elko series projectile points. The Elko points probably represent the remains of dart and atlatl hunting technologies, and they date between 7,000 and 2,000 B.P., more than 3,000 years earlier and extending 500 years later than at Gatecliff shelter (Thomas 1981; Young 1998). After 2,000 B.P. the projectile point assemblage in Warner Valley consists of Rosegate and Desert series points.

Young (1998) notes that within the Valley all sites with residential features which may represent the remains of large winter camps consistently post-date 2,000 B.P., based on diagnostic projectile point assemblages and limited radiocarbon dates. These sites tend to possess a wide variety of groundstone not present in other sites. This appearance of large residential sites correlates with the increased productivity of the marshes after 2,000 B.P. Food processing sites become less common after the appearance of the residential sites possibly because groups began to process food resources at the base camps, which would explain the diversity of groundstone at these sites. Along with the use of large residential bases, small lithic scatters interpreted as logistical sites increased in frequency after 2,000 B.P. The large repeated-use lithic processing sites on the valley bottom became much less prevalent as the marsh productivity increased (Young 1998). While use of the marsh environment certainly changed along with marsh productivity, the use of the uplands did not vary significantly. Although groups shifted some resource focus to the marshes after 2,000 B.P., the general pattern of small hunting sites varied little. Contrary to the conclusions of Young (1998), earlier work in the region has shown the presence of small sites with groundstone artifacts and the remains of pithouse depressions that indicate repeated or fairly long term occupation of these Middle Archaic (7,000 to 3,000 B.P.) sites for plant gathering (Cannon, Creger et al. 1990).

Aikens (1993) suggests a fairly constant cultural adaptation for the last 7,000 years in the Warner Valley. Wetland resources tethered the population to the valley for most of the year except from late spring to late summer, during which groups would exploit upland resources such as bitterroot, camas, and berries. As the more recent work by Young (1993) demonstrates, the adaptive strategy in use in the Warner Valley was tied to the productivity of the marsh environment, and further environmental and archaeological research is necessary to better understand the cultural chronology of this region.

Steens Mountain/Alvord Basin/Owyhee Uplands

Steens Mountain comprises the largest upland feature for all of Southeastern Oregon. For the purposes of this summary, this region also includes some of the area from Steens Mountain east and south to the Oregon border, which encompasses the Alvord Basin and Owyhee uplands. Much of the research in the area has been guided by extensive fieldwork in the region during the early 1980s (Aikens 1993). Initially thought to represent special use locations, small sites with little artifact diversity only appeared to have been special purpose due to their small sample size. Some differences in the lithic assemblage between sites were observed relating to the use or manufacture of flake tools. Certain sites contained little flaking debris but many utilized flakes. Sites showing evidence of both tool manufacture and use are common in the Catlow Uplands (Aikens 1993), yet the specific resources procured and/or processed at these sites is unclear.

Aikens (1993) has summarized the general early settlement pattern for the region over the last 10,000 years. Corresponding to the wet, cool conditions the populations from 10,000 to 6,000 B.P. were focused on the wetland resources of the lowlands, with rare use of upland environments. Possibly improved moisture conditions between 6,000 and 3,000 B.P. may have resulted in population dispersion and increased use of a wider variety of sites, including the uplands (Aikens 1993). Contrary to the Warner Valley, from 2,000 to 400 B.P. the region experienced significant drying that resulted in abundant but small and dispersed sites (Wilde 1989). The excavation at the Tule Springs Hearth

Site in the Alvord Basin provides an example of a conglomerate of short-term use sites dating to after 2,000 B.P. that fits in with the general settlement pattern for the Steens Mountain area. Wilde (1989) suggests that the separate relatively short-term uses of the site demonstrate the dispersed nature of the population, with few sites occupied for extended periods.

The Owyhee uplands provide an important site that adds support for the settlement pattern witnessed in the Steens Mountain area to the northwest. Dirty Shame Rockshelter is located in a deep narrow canyon cut into a generally high arid plateau (Kittleman 1977). Based on numerous radiocarbon dates, occupation of the site had spanned most of the last 10,000 years with the exception of 5,900-2,800 B.P. (Aikens, Cole et al. 1977). This 3,200 year abandonment of the site corresponds well with the environmental and settlement data from the region showing much drier conditions that caused the population to occupy more sites for a shorter period of time. If the creek outside the shelter stopped flowing reliably during this period it may have made travel to the site unproductive enough to not attract even small groups.

The excavation of Dirty Shame Rockshelter provided information supporting regional settlement models. The lithic (Hanes 1977) and faunal assemblages(Grayson 1977; Hall 1977) from the site show little change other than from the introduction of the bow and arrow. The site also produced perishable articles well preserved in the dry environment of the shelter. Sandal and basketry fragments were common throughout the cultural deposits, and the surface of the site still held the remains of multiple living structures (Willig 1981). Some of the perishable articles lend evidence for the Numic expansion, a recent population replacement that is seen across the Great Basin (Adovasio and Andrews 1986).

Malheur/Harney Basin

North and west of Steens Mountain lies an interconnected system of lakes and marshes, including Malheur and Harney Lakes, that are bordered by the Wagontire and Blue Mountains (Aikens 1993), The high elevations of these mountain ranges funnel precipitation along large rivers into the lush wetlands. The earliest occupation of the region probably dates to between 10,800 and 7,500 B.P. as evidenced by the recovery of large stemmed points belonging to the Western Stemmed Tradition (Willig and Aikens 1988; Musil 1995). Although human settlement patterns around the Malheur/Harney Basin have certainly changed in response to both short and long term climactic variation, the archaeological evidence from the last 4,000 years reveals a pattern of winter sedentism and summer mobility practiced among the ethnographic population in the area (Aikens 1993).

Based on the limited archaeological data consisting almost entirely of lithic material, the Early Holocene occupation of the Harney and Malheur Basins appears to mimic occupations of the same age from throughout the Northern Great Basin and the Columbia Plateau (Musil 1995). Drier conditions during most of the Middle Holocene correlates with the abandonment of many of the major archaeological sites occupied before the drying trend and sometime after wetter conditions returned. It appears as though much of the marsh-oriented population shifted to exploiting high elevation springs during the Middle Holocene dry period (Jenkins and Connolly 1990). As the marsh productivity rose due to the increased moisture between 4,000 and 2,000 B.P. the earliest housepit occupation appeared in the Diamond Swamp area (Musil 1995). The most intense occupation in the area appears to coincide with the increased effective moisture after 4,000 B.P. There is archaeological support for large village sites dating after 2,500 B.P. The primary occupation of the Head Quarters site along Malheur Lake shows extensive exploitation of wetland resources including muskrat and fish (Aikens and Greenspan 1988). Surveys in the area following the severe drought of the early 1980s produced several large, possibly reoccupied pithouse villages and a large burial population (Oetting 1992). A shift after 1,000 B.P. to smaller and more dispersed sites may actually be the result of the Numic speaking groups entering the area instead of a response to climatic conditions, although there is no stylistic basis from stratified sites that provides evidence for such a population replacement (Musil 1995).

Just north of Malheur and Harney Lakes, the Indian Grade Spring Site provides interesting settlement data for the last 3,000 years. The earliest component dating to between 2,000 and 1,400 B.P. contains evidence of a very general hunting and gathering use of the site, while during the middle component the site was used as a specialized wood-processing camp, and the upper component exhibited a return to a more generalized site use (Jenkins and Connolly 1990). While interpreting settlement patterns from a single site is inherently problematic, the middle component may provide evidence of a millenium-long collector subsistence strategy (Binford 1980).

The Malheur/Harney Basin appears to sit right on the border between Great Basin groups to the south and the Columbia Plateau groups to the north. The Strawberry Mountain obsidian source in the Malheur National Forest that is north of the Malheur

Basin is extremely common in assemblages throughout the Columbia Plateau, particularly along the John Day River (Rotell, Skinner et al. 1998). The multiethnic use of the area may correspond with the ethnographic pattern of the Harney Basin (Aikens 1993) in which groups from the Columbia Plateau would join the Harney Valley Paiutes at the spring root grounds.

Lake Abert Basin

The Lake Abert Basin, consisting of Lake Abert, the Chewaucan River and the Chewaucan Marshes, are approximately fifty miles south of the Fort Rock Basin (Aikens 1993). Multiple large-scale contract projects along Lake Abert have revealed the remains of extensive housepit villages dating to the last 4,000 years (Pettrigrew, 1985 ; Oetting, 1989) that accompany increased regional moisture (Musil 1995). Oetting (1989, 1994) developed a cultural chronology for the Lake Abert Basin based on projectile points and radiocarbon dates that is often used for the Fort Rock Valley as well.

> The **Initial Archaic** (11000 BP to 7000 BP) is characterized by Great Basin Stemmed Points. The **Early Archaic** (7000 BP to 5000 BP) is dominated by Northern side-notched points, but Elko series points may be present in low proportions. The **Middle Archaic** (5000 BP to 2000 BP) has two phases. The early part, Middle Archaic I, contains Gatecliff Split Stem and Elko series specimens, while the Middle Archaic II is characterized by high proportions of Elko series points. The **Late Archaic** (2000 BP to Euroamerican contact) is also divided into two phases. The Late Archaic I has equivalent numbers of Elko series and Rosegate series points. Desert Side-notched and Cottonwood Triangular points were associated with Late Archaic II sites...(Oetting 1994:58).

This type of cultural chronology is necessary for a region consisting largely of surface sites.

The majority of the Initial Archaic and Early Archaic sites are lithic scatters, many with groundstone (Oetting 1989). Village sites become more common during the

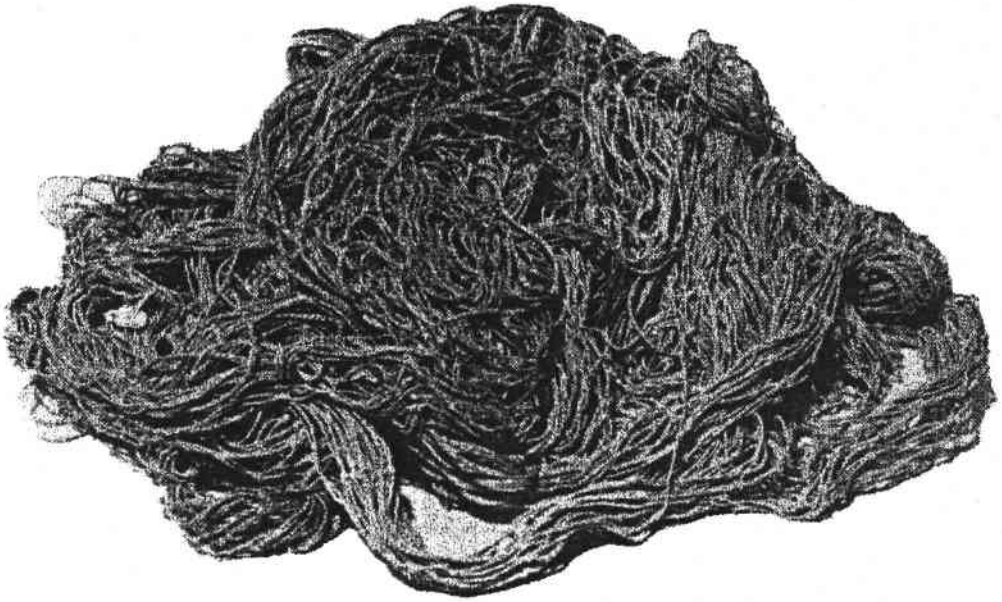

Figure 3.6: Large rabbit net from Chewaucan Cave (from Aikens 1993:52).

Middle and Late Archaic, particularly the Late Archaic II after 1,150 B.P. (Aikens 1993). These late period village sites appear to be focused on exploiting the marsh and riparian zone resources (Musil 1995). Exceptional preservation in Chewaucan Cave protected many perishable artifacts, but private collectors excavated the site without any chronological control, although the artifacts appear to date to the Late Archaic (see Figure 3.6).

Aikens (1993) describes many scenarios to explain the recent abandonment of the Lake Abert area. The recent shrinking of the lake has concentrated minerals in the lake, killing all but the algae and some small shrimp species. The local population that relied on the lake and marsh resources may have been forced to abandon the region for more productive areas. Oetting argues that an influx of Paiute groups within the last 1,000 years corresponding to the Numic spread may have forced the local Klamath population to retreat to the West (Oetting 1990). It is also possible that high resource productivity may have occurred during periods of low lake levels because of the exposure of freshwater springs that are generally submerged by the lake during periods of high lake levels (Aikens 1993).

Fort Rock Valley

The research at Fort Rock Cave within the Fort Rock Valley has been very important in the development of Northern Great Basin archaeology for two primary reasons. First, this was where the original studies of the Mazama ash took place, proving the ancient human occupation in the area. The organic cultural remains from beneath the ash were later some of the first artifacts subject to radiocarbon dating, showing occupation of the region dating back more than 11,000 years (Bedwell and Cressman 1972; Aikens 1993). The importance of radiocarbon dating cannot be understated. Prior to its development the most common dating method for early sites in Oregon was to compare the cultural strata with the Mazama ash (Cressman 1948).

Although the work from the middle part of this century showed the archaeological value of the Fort Rock Valley, ongoing work by the University of Oregon continues to refine the understanding of prehistoric culture in the region, as well as human response to the environment (Jenkins 1998). As with many other regions in the Northern Great Basin, the population of Fort Rock Valley appears to have become more sedentary following the return of a moister environment after 4,900 B.P., although Jenkins (1998) believes this to be a culturally, and not environmentally, driven response. Had the environment been the only influence prohibiting sedentism, the groups would have responded much more rapidly to the environmental changes.

Particularly after 4,900 B.P. fish, namely tui chub (*Gila bicolor*), and other wetland resources contributed much more to the subsistence base (Toepel and Greenspan 1985; Jenkins 1998). Along with the increased sedentism groups also began to collect, process, and store larger quantities of seeds. Possibly resulting from greater sedentism, groups in the Fort Rock Valley established expansive trade networks extending all the way into Southern California during the Middle Holocene (Jenkins and Erlandson 1996). This pattern continued up until about 1,500 B.P. when drier conditions returned and groups began to occupy large village sites in the uplands, such as Boulder Village, in addition to utilizing the wetland resources (Musil 1995).

Some of the most interesting data from this region come from the large sample (almost 900 pieces) of projectile points and other obsidian artifacts that have undergone obsidian hydration and X-ray fluorescence characterization analysis. The highly mobile groups using the region between 10,000 and 6,000 B.P. brought lithic material from all directions. By 6,000 B.P. the Fort Rock inhabitants focused lithic production on more local sources, and sources to the northwest that were common before this period are no longer present. The predominance of local material may reflect increased sedentism. With the appearance of arrow points about 2,000 B.P. non-local sources increase in frequency, but not from all areas. Materials from the east toward Harney Basin dominate the assemblage, and use of Abert Basin sources drops off dramatically (Jenkins, Skinner et al. 1999).

High Lava Plains/Upper Deschutes Basin

This area is considerably more geographically complex than many of the closed drainage basins described earlier and consists primarily of the area drained by the Crooked and Upper Deschutes River systems. Included in this area are the easternmost extent of the Cascade foothills on the west and the Southern Ochoco Mountains to the northeast. The area is bounded on the east and south by the Harney and Fort Rock Basins, respectively.

Most of the Upper Deschutes and Crooked River drainage basins lacks dated evidence of a Paleoindian occupation. Aside from occasional isolated fluted points, the Paleoindian occupation of the region is presumed based on its documentation in adjacent regions. Although some Paleoindian and Early Archaic (pre-7,000 B.P.) sites may have been preserved by the large volume of Mazama ash that fell in the area, the ash deposits also obscure surfaces of this age from revealing archaeological sites (Pettigrew 1996).

The INFOTEC Pipeline Expansion Project that extended from Northern California into Idaho, further documented Early Archaic occupation of the region. Analysis of the project data has suggested a sparse population that utilized a wide diversity of food resources compared to the Paleoindian occupation (Pettigrew 1996). The generally small sites from this period cluster around surface water features. There is little evidence of diversity between sites, and no trace of significant food storage. The excavations of two sites for the pipeline expansion, including one stratified rockshelter, have suggested a fairly mobile adaptation with an emphasis on bifacial technology. Excavations by Connolly (1995) have revealed the remains of a residential base camp within the Newberry caldera. Component II (10,500 to 8,500 B.P.) contained evidence of at least one residential structure (Connolly 1995). The data from the Newberry site support the proposed mobile, water-tethered settlement pattern for the Early Archaic (Pettigrew 1996). This pattern is similar to other regions in the Northern Great Basin in which later Pre-Mazama sites appear to have been occupied by small mobile groups focused on wetland environments.

The Middle Archaic (7,000-2,000 B.P.) corresponds with a shift from residentially to logistically mobile groups that began to exploit storable food resources (Pettigrew 1996). Stored resources allowed groups to congregate during the winter, which was not possible given the scarce winter food resources. The Mazama tephra had a significant effect on the local population level for possibly thousands of years following its eruption (Matz 1991; Pettigrew 1996). In most of the area, population levels had rebounded by 4,000 B.P., and reached a peak between 3,000 and 1,500 B.P. There appears to have been a significant gap in regional occupation between 5,000 and 4,400 B.P. that is also seen in the Columbia Plateau and Fort Rock Valley, but it is still unclear why. Pithouse village sites dating to 3,000 to 2,000 B.P. representing logistical winter camps become more common although still surprisingly scarce (Pettigrew 1996).

The Lava Butte Site, located south of Bend near the Deschutes River, represents a large Middle Holocene residential base camp (Ice 1962; Davis and Scott 1991). Ice (1962) had originally associated the site with Plateau-oriented groups, but re-analysis by Davis and Scott (1991) has associated the site with Great Basin groups to the south. The lack of organic preservation precludes the identification of the specific resources used, but the abundance of projectile points and lack of preforms reflects a strong hunting focus (Davis and Scott 1991). The site is also located along a major migration route for deer between their summer range in the Deschutes Basin and their winter range in the Fort Rock Basin, suggesting a spring and fall use of the site. The groundstone present is possible evidence of fall plant collecting and processing. It appears as though it was also used as a major reduction site for obsidian quarried from the Newberry flows. Davis and Scott (1991) note that although the residentially mobile foragers occupied numerous temporary residential base camps such as Lava Butte. The site was reoccupied during the Late Archaic (after 2,000 B.P.) by groups utilizing Rosegate and Desert series points, but this occupation was less intense and probably related to task-specific use.

Middle Archaic use of Newberry Crater differed from its Early Archaic use (Connolly 1995). Mazama ash likely created unfavorable foraging conditions for the early part of the Middle Archaic, but obsidian flows dating to around 4,000 B.P. attracted groups to the area. Middle Archaic sites after 4,000 B.P. are almost exclusively oriented toward mining and processing the Newberry obsidians. There is evidence from sites within the Newberry caldera for the production of large cores up to 20 cm and bifaces approximately 12 cm in length (Ozbun 1991), although the reconstruction of the maximum sizes is based primarily based on questionable reconstruction techniques. Regardless of the size of the artifacts, it is clear the post-Mazama occupation of the Newberry area was focused on obsidian procurement and processing (Connolly 1995). Sites throughout the upper Deschutes Basin dating to after 4,000 B.P. often contain high frequencies from the later Newberry obsidian flows, some of which are chemically distinct (Skinner 1999: personal communication).

The Middle Archaic occupation throughout the region underwent considerable cultural change associated with a positive feedback relationship between intensified logistical land use and an increasing population size (Pettigrew 1996). Plant processing sites around root grounds and other productive patches are common in the Middle Archaic compared to the Early Archaic.

Further resource intensification continued into the Late Archaic (2,000 B.P. to the present). Population pressure appears to have forced large portions of the regional population to shift their settlements to the main tributaries of the Columbia River, such as the middle and upper Deschutes, to exploit the salmon and root grounds capable of supporting the larger population (Connolly, Jenkins et al. 1993; Jenkins and Connolly 1994; Pettigrew 1996). During this period use of the Newberry obsidian flows appears to have reduced dramatically, possibly reflecting a shift in the focus of the population (Connolly 1995) or the reduced obsidian requirements brought on by the introduction of the bow and arrow (Pettigrew 1996). There is evidence for more of a logistical organization in the early part of the Late Archaic along the upper Deschutes south of Bend. Base camp sites located near the Deschutes are associated with numerous logistical hunting camp sites in the surrounding foothills (Pettigrew and Spear 1984).

The different land-use patterns between the Early and Late Archaic are clearly evident from the excavations of the Lava Island Rockshelter (Minor and Toepel 1984). The Early Archaic/possibly Paleoindian assemblage consists primarily of projectile points and late stage flaking debris, suggesting a temporary hunting camp used for repairing and retooling hunting equipment. The Late Archaic occupation similarly included the remains of hunting activities but it also produced the remains of a bark lined storage pit ethnographically associated with food storage. Late Archaic site occupants may have used the site as a logistical camp focused on hunting but also included some plant gathering, processing, and storage. Just north of the Lava Island Rockshelter a series of small lithic scatters dating to the Middle and Late Archaic were excavated (Minor, Toepel et al. 1988). The lithic scatters were interpreted as the remains of temporary hunting camps, based on the low tool frequencies compared to the large amount of lithic debris. This interpretation fits well with the evidence of increased logistical organization in the region during the Middle and Late Archaic.

Resource and habitation intensification during the Late Archaic is clearly evident in the occupation of Big Summit Prairie in the Ochoco Mountains (Barber and Holtzapple 1998). The Dudley Site contains over 40 surface depressions, most of which are presumed to be house pit features that were confirmed by the excavation of some of these features. A radiocarbon date from a hearth within one of the housepits, along with a Rosegate projectile point assemblage, confidently place the site in the Late Archaic. The site is interpreted to have been used as a base camp for seasonal hunting and root gathering activities.

Two contract archaeological projects comprise the limited archaeological research conducted in the vicinity of Bone Cave. An archaeological survey from the Bonneville Power Administration's Pilot Butte substation, approximately 500 meters from Bone Cave discovered only one isolated cryptocrystaline flake within fifteen miles of the linear survey that ran to the north from the substation (Masten 1985). The survey also located numerous historic scatters and three historic wagon trails. If Bone Cave represents a typical prehistoric site in the area that is focused on the use of lava tubes, then surface surveys may not be extremely productive in locating prehistoric cultural resources.

The second project has greater relevance to the interpretation of Bone Cave. During the early 1980s the city of Bend proposed to dispose of excess sewage waste into multiple nearby lava tubes. Testing was conducted in five of these tubes and one, Youngs Cave (35DS115), was found to contain evidence of prehistoric use prior to 7,000 B.P. and extending as late as 200 B.P. (BECON 1982). A 50 cm thick sterile sandy layer separates the earlier occupation that contained a lanceolate point form generally predating 7,000 B.P. from the later occupation that produced a point resembling a Rosegate series that probably post-dates 2,000 B.P. Both occupations contained flaking debris and a faunal assemblage dominated by multiple rabbit species.

The lower levels of Youngs Cave contained prehistoric cultural material, but historic objects were recovered up to two meters below the surface. The lack of colluvium and presence of eolian stratigraphic deposits suggests arid conditions similar to the present were in place for at least the last 9,000 years (BECON 1982). The deposits contained a large amount of redeposited pumice that could have derived from either Mt. Mazama or the Tumalo and Laidlaw Butte pumice deposits. Examination of the rabbit species recovered from Youngs Cave provided evidence of a warmer and drier climate in the area compared to the Fort Rock Basin, prior to the Mazama ashfall (BECON 1982).

Chapter 4: Excavation Procedure and Description

Field Methods

The field methods used in this project were chosen to best address the research questions. The primary goal was to determine the condition and extent of archaeological deposits within the front chamber. Six 1-x-2 meter test units were placed to allow for maximum horizontal spatial coverage and to encounter different surface features such as obvious looter backfill piles and pathways in order to test for intact deposits (see Figure 4.1).

Excavation proceeded using 10-cm arbitrary levels in an attempt to discern any stratigraphic change. Had any natural strata been encountered they would have been excavated as natural levels, but all of the deposits excavated in this project appeared mixed due to looter activity, with the exception of Unit 4, which still produced a large amount of modern debris. Almost all of the excavation was done with trowels except for the lower levels of Unit 3 in which shovels were also used. The excavated fill was removed from the cave in buckets and then screened through 1/8th inch mesh. All lithic debris was collected from the screen and bagged by unit and level as were most of the historic artifacts. Lithic tools were bagged individually. All bags containing lithic and historic artifacts were given a field number (FN).

With the exception of the upper 40 cm of Unit 1, only fragments greater than 8-mm or diagnostic bone fragments were collected. The site produced an abundance of small bone fragments that required an incredible amount of time to collect from the screens. All bone fragments would have been collected in undisturbed portions of the site in addition to the collection of pollen and flotation samples. The bone was collected

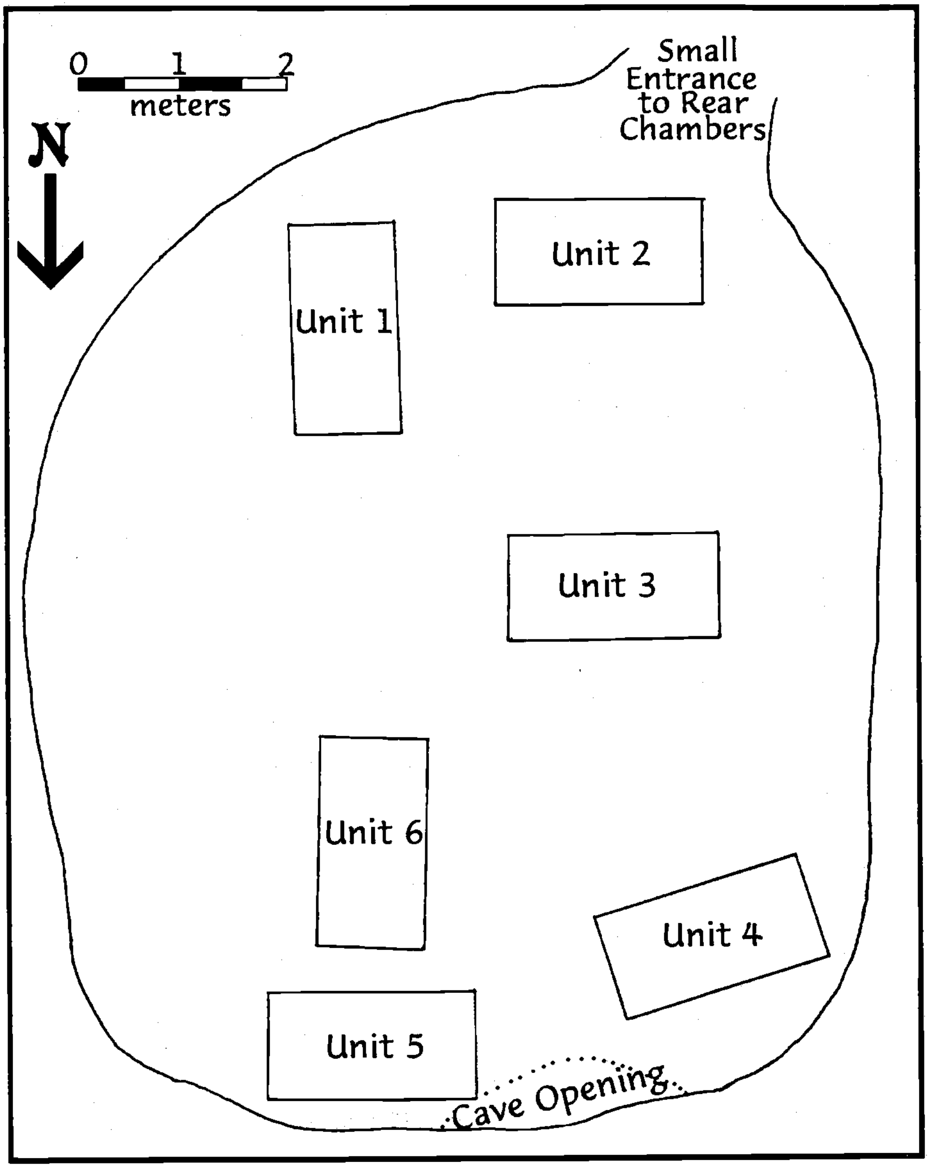

Figure 4.1: Map of the Front Chamber of Bone Cave showing Unit locations.

and bagged by unit and level with each bag receiving a SN (sample number). The samples of the tephra layer near the cave entrance were also assigned a SN.

The disturbed context prevented the collection of any pollen or radiocarbon samples. Unlike obsidian hydration dating which provides at least a relative date for a specific cultural event, radiocarbon dating requires organic material that may not be linked to a specific behavioral event and in a disturbed context may provide confusing or no useful information unless the specific object dated was of cultural origin, such as modified bone or wood. Pollen samples are extremely useful for recreating the environmental conditions at a particular time. With the degree of sediment mixture in Bone Cave the pollen would not represent an actual plant community, but instead a mixture of possibly tens of thousands of years worth of plant communities. Had the project not been terminated by the consulting tribes due to the recovery of isolated human remains, some flotation samples may have been collected from the sidewalls of some of the units. Although the value of flotation analysis in examining subsistence changes was greatly reduced by the mixed deposits, flotation may have still provided useful information about microdebitage and possibly distinguishing differential lithic reduction activities in different regions of the front chamber.

The dark conditions of the site and the obvious presence of rodents suggested the possibility of Hantavirus exposure to the field crew. Most excavators during work inside the cave used masks, and most of the fill was sprayed with either Lysol or a 10% bleach solution (Fink 1994) and allowed to dry on the screens. This treatment may have some effect on the potential for residue analysis and on the condition of the faunal assemblage.

Approximately 10 cubic meters of fill was excavated from six 1-x-2 meter units. The units were distributed to sample a wide area of the front chamber. The locations for the units were also selected in an attempt to avoid obvious looter backfill piles and to reach the deeper portions of the site that were likely to exhibit the greatest integrity, but portions of some backfill piles were tested in case they were protecting intact deposits.

Two units were placed approximately two meters apart in the rear of the chamber, two in the center of the site, and one just on each side of the entrance.

Unit Descriptions

Unit 1: Unit 1 is a 1-x-2 m unit set up in the rear of the front chamber to the east of the main pathway that leads to the rear chambers. The unit is oriented with the long axis toward the entrance of the cave. Excavation was conducted in 10-cm arbitrary levels to a depth of 130 cm. Base rock and large roof-fall severely limited the amount of material excavated in the lowest three levels. The unit was closed when almost no soil was accessible between the large rocks.

Particularly within the upper seven levels were pockets of bone and small roof fall that are likely the result of looter screen dumps. The unit fill was extremely uniform with a slight moisture gradient increasing with depth. The loose nature of the fill made sidewall collapse a persistent problem, especially at the greater depths. The sediment consisted primarily of small brown volcanic grains well mixed with light colored pumice and variably sized roof-fall. No wall profile was made of this unit because of the homogenous deposits and lack of an intact wall.

Prehistoric cultural material was uniformly distributed throughout the levels and included lithic debris (predominantly obsidian), a proximal projectile point fragment, a distal biface fragment, a possible flake tool, and abundant faunal remains. Historic artifacts were also recovered as deep as 1 meter below the surface. Modern brown and clear bottle glass dominated the historic assemblage that also included two large boards that may have been part of a screening station.

Unit 2: Unit 2 is located in the rear of the front chamber across the compressed pathway to the rear chamber. The 1-x-2 m unit was placed in the hope that looter damage would have been less along the main pathway and because along the path were large backfill piles that were certain to not contain undisturbed deposits. Due to the absence of any natural strata, excavation was conducted in arbitrary 10 cm levels screened through 1/8th inch screens to a depth of 80 cm. Work in this unit stopped at the request of the consulting tribes upon the discovery of a human skeletal fragment.

Evidence of looter disturbance occurred throughout the unit. A large concentration of aluminum cans at (less than ten years old) and other recent debris was encountered at 65-75 cm, immediately above the skeletal fragment. The sediment

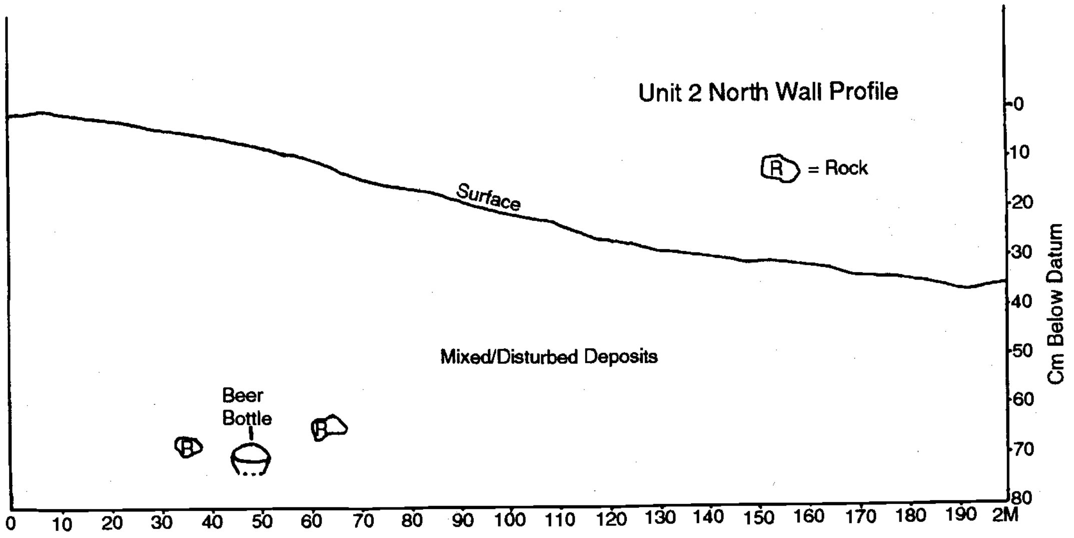

Figure 4.2: North wall profile of Unit 2.

composition and moisture gradient in this unit was generally similar to that in Unit 1. The upper levels consisted of extremely loosely compacted sediment and produced higher than usual concentration of faunal remains and lithic debris, but the assemblage variation and lack of diagnostics persisted. One obsidian core was recovered in the same level (70-80 cm) as the human skeletal fragment.

Unit 3: This 1-x-2 m unit was placed in the center of the western portion of the chamber in an attempt to avoid some of the backfill piles. The unit was excavated in 10-cm arbitrary to a depth of 120 cm below the original surface. Excavation was stopped due to the recovery of two human teeth and a fragment of shell that were discovered while screening the last buckets from the 110-120 cm level.

Although historic trash was recovered throughout the unit, in the lower two levels there were patches of dark black soil that were originally thought to represent undisturbed deposits, but historic debris was found within these dark patches. The sediment differences were not consistent enough to justify excavating them as natural levels. Most of the sediment remained well-mixed brown sand and white pumice, with an increasing moisture content with depth. Large roof fall became common in the lower levels, substantially reducing the amount of excavated fill. All of the units experienced problems with sidewall integrity, but Unit 3 was particularly problematic due the depth of the excavation. Only one wall remained intact to allow an accurate profile . This unit contained fairly dense lithic debitage, faunal remains (predominantly small mammals), and historic debris, along with one biface fragment.

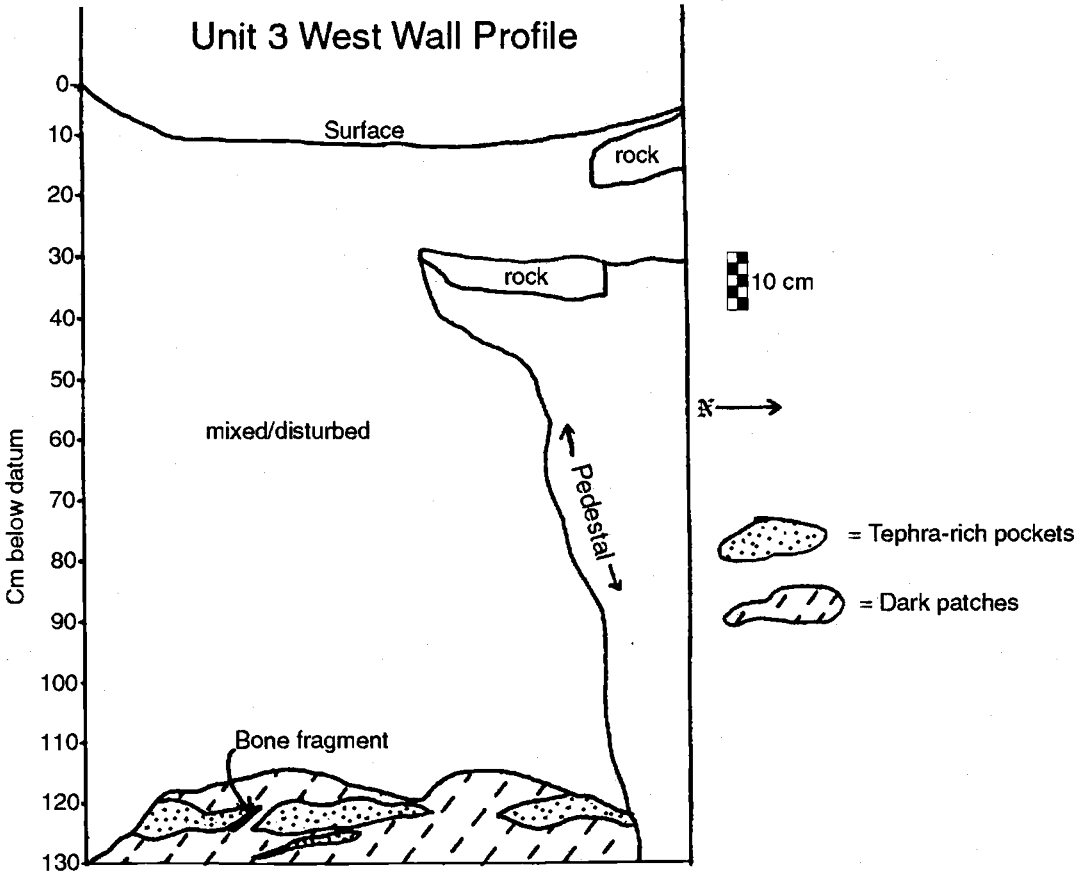

Figure 4.3: Unit 3 West sidewall profile

Unit 4: This 1-x-2 meter unit was located just to the west side of the entrance to the cave. According to a local resident that often visited the site, there had not been any looting at this location for many years, and large boulders and an extremely low roof suggested that the deposits might be intact. Extensive dark patches and thin layers of pumice were found throughout the unit, but unfortunately so were historic artifacts. The dark patches could be the result of local residents dumping their used motor oil into the cave (Craig Skinner, personal communication, 1998). This would explain the extremely dark and oily nature of those deposits. None of the sediments were extensive enough to require excavation as natural levels. All levels were excavated in 10-cm arbitrary levels and

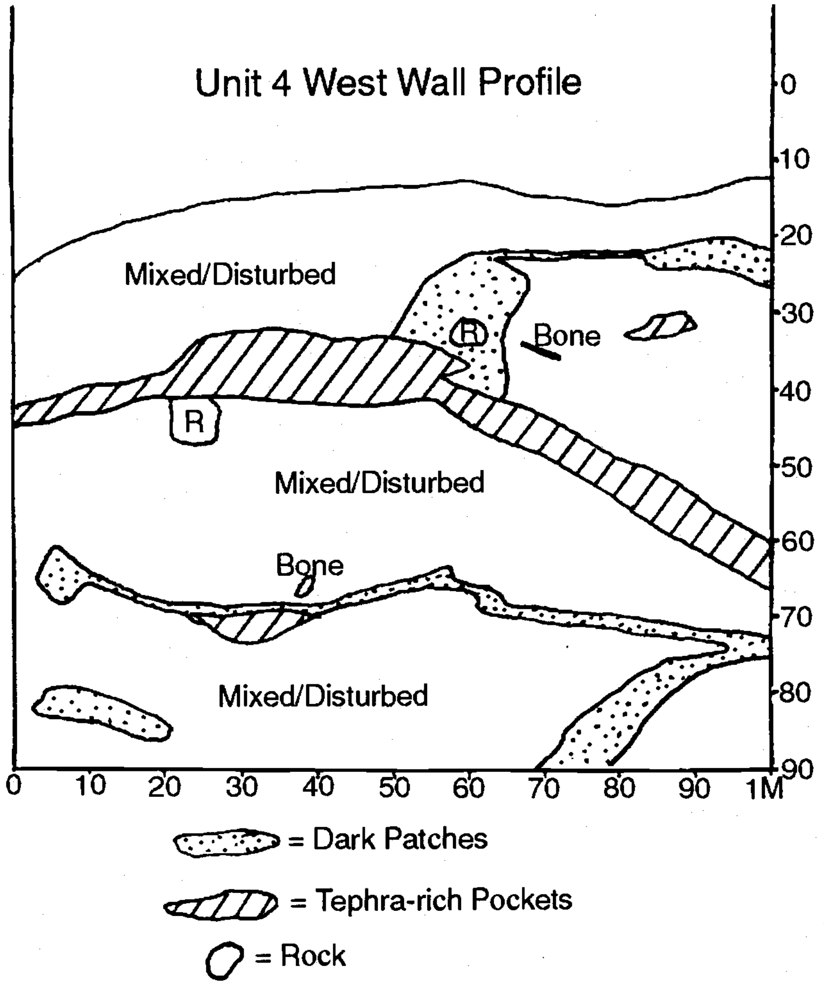

Figure 4.4: Unit 4 West sidewall profile.

screened through 1/8" mesh. Probably as a result of the proximity to the cave entrance, the first three levels were relatively dry, making it difficult to maintain sidewall integrity. Moderate sized (>25 cm) roof fall was common throughout the levels. This unit contained the highest density of bone and lithics recovered during the excavation, particularly in the upper levels. As with the other units, lithics consisted almost exclusively of small tertiary obsidian flakes. Other prehistoric artifacts include a distal biface fragment and an edge-modified flake. Excavation in this unit was halted in Level 8 (70-80 cm) due the discovery of isolated human remains in Units 1 and 3.

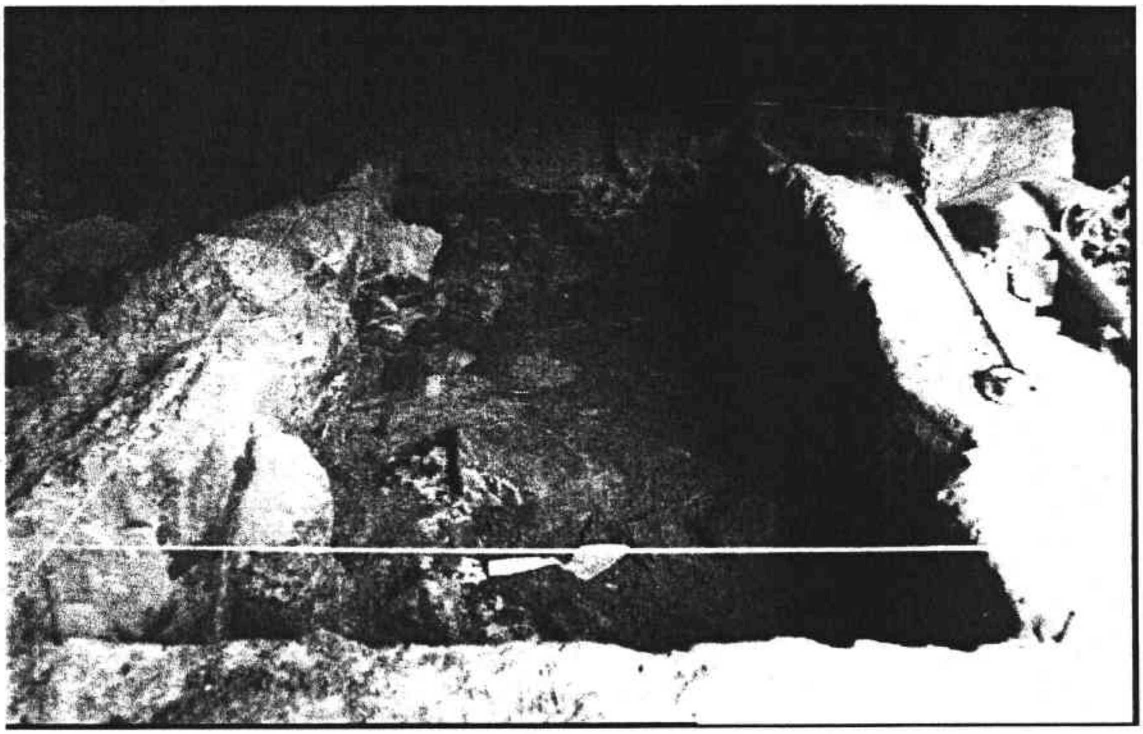

Figure 4.5: View of Unit 4 at 50cm. Note light patches in the dark sediment.

Unit 5: Unit 5 was located on the east side of the entrance to the front chamber opposite Unit 4. The 1-x-2 meter unit was placed in an area that had been recently excavated in an attempt to reach undisturbed deposits below the looter disturbance. Under the collapsed sidewall of the chamber was a tephra layer approximately 5 to 7 cm thick. The unit began below this tephra layer and the sediments consisted primarily of brown sand, some of which may have recently washed in through a small second opening into the front chamber. Excavation was stopped in Level 5 (40-50 cm) at the request of the tribes. The unit produced considerably less bone and lithics than the other units. Lithics consisted of primarily small tertiary flakes, and small mammal bone comprised most if not all of the faunal assemblage. No profile map was made because of the incomplete excavation and lack of any stratigraphy.

Unit 6: Unit 6 was a 1-x-2 m unit located near the entrance of the front chamber along the center of the worn pathway. As with Unit 2, it was hoped that the looters would have avoided disturbing the main pathway. The fill was excavated in 10-cm arbitrary levels and screened through 1/8th inch mesh. Excavation stopped in Level 3 (30-40 cm) at the request of the tribes. The excavated portion contained the usual heavily mixed deposits consisting of brown silty sand and volcanic pumice. A lack of stratigraphic differences precluded the inclusion of a wall profile. Small amounts of bone and lithics were recovered. The upper levels were certainly heavily disturbed by both looting activities and foot and equipment travel over the pathway.

Summary

The unexpected extent of the looter disturbance influenced almost every aspect of the excavation. The units were placed in attempt to avoid obvious disturbance and to encounter intact deposits. All of the units contained similar mixed sediments and lithic and bone assemblages. The concentrations of artifacts differed among the units, but no other significant differences were noted. The lithic assemblage consists primarily of small, late stage finish flaking debris and occasional large flakes and tool fragments. Small mammals comprise the vast majority of the faunal assemblage, with only a small portion showing any sign of heat alteration.

Chapter 5: Analysis

Lithic Analysis

Excavations of Bone Cave resulted in the recovery of nearly 3,000 lithic artifacts, all of which were chipped stone tools or debitage. The extremely disturbed condition of the Bone Cave sediments greatly influenced the type of lithic analysis performed. The looting activities at the site likely focused on the lithic tool assemblage, and consequently reduced the emphasis on analysis of the limited formal tool assemblage that will be presented later in the chapter. Lithic debitage analysis is capable of revealing tool-use and production behavior that is often not evident in the complementary assemblage of curated tools. Debitage is also least subject to both prehistoric and modern collection (Shott 1994).

This analysis will incorporate both individual and mass analysis in addition to considering both form and size attributes (Baumler and Downum 1989; Shott 1994). Although the direct correlation between specific formal attributes and diagnostic cultural behavior is often questionable, a recent proliferation of experimental studies (Dibble and Pelcin 1995; Pelcin 1997) have begun to shed light on the subject. The variables in producing flake attributes are only partially understood, but when large assemblages are analyzed trends can reveal patterned lithic reduction behavior. Shott (1994) also notes that the number, type, and definition of attributes vary considerably among lithic studies. Rather than attempt to mimic any specific lithic analysis, the formal and metric attributes and the method of data collection will be described.

There are four primary research questions that will be addressed in this analysis:

1) *Are there any differences in the debitage assemblages from the area (front, middle, and rear) within the site in flake size and weight distribution relating to general activity areas that may have produced different lithic assemblages?*
2) *If no differences are found within the site, what can be said about the lithic reduction that took place at the site as a whole, such as early or late stage reduction, raw material preference, primary indentor type, and the type of core technology?*
3) *What can the features of the Bone Cave debitage assemblage reveal about the degree of mobility, curation, and general settlement pattern of the prehistoric populations(s) that occupied the site?*
4) *The tool assemblage has obviously been seriously altered by the looting activities, but what can the remaining tool assemblage that was recovered add to the interpretation of site activities?*

Methodology:

No formal study of the debitage for any type of macroscopic or microscopic edge damage has been conducted. The value of such studies are quite high (Lawrence 1979; Young and Bamforth 1990; Malstrom 1996), but unfortunately they are also extremely time consuming. Trampling, digging and screening can also produce flakes that appear to have been utilized (Shea and Klenck 1993; Wilson 1996), and the Bone Cave samples have undergone these processes more than once.

All of the following individual attributes, where appropriate, were collected for each flake, and then counts and weights were taken for each size class by unit and level.

Metric data were measured by a set of standard dial calipers with 0.01mm accuracy and an AND EK-120A electronic scale with 120g x .01g capacity. A basic definition of the various attributes follows, and a thorough discussion of each is included in the analysis. Each non-metric attribute was coded to aid in data recording and computer entry.

Material: Five distinct raw materials were observed within the assemblage including obsidian, basalt, cryptocrystaline silicates (no attempt was made to separate this class further), chalcedony, and quartzite. The determination of the raw material was made by visual observation of the color and macro-crystalline structure.

Size Class: The size class refers to the maximum dimension of the flake. Five different classes were established according to Table 5.1. The size classes present within the assemblage can aid in the determination of the stage of manufacture and the extent of core reduction.

Size Class	Flake Size
1	< 0.5 cm
2	0.5 – 1.0 cm
3	1.01 – 2.0 cm
4	2.01 – 3.0 cm
5	> 3.0 cm

Table 5.1: Values for size classes.

Flake Type: The flake type is another attribute recorded for all of the assemblage. The categories include complete, proximal (broken flake with platform still present), fragment (medial or distal flake fragment), and debris (lithic debitage that does not exhibit any recognizable flake characteristics).

Length: Maximum flake length measured from the platform was recorded only for the complete flakes.

Width: Width was measured on the complete flakes at approximately the mid-point of flake length.

Thickness: Thickness for complete flakes was measured at the same location as the flake width.

Heat Treatment: The presence or absence of heat treatment was recorded for all pieces, but with the small sample of CCS material, no heat treated flakes were observed, and therefore this attribute is not discussed further in this analysis.

Cortex: The percentage of cortex on the dorsal surface of a piece of debitage can provide information as to the general stage of lithic reduction. This attribute was visually separated into unequal classes according to Table 5.2 that attempt to define important reduction stages.

Cortex Class	% Dorsal Cortex Cover
1	0 %
2	1-10 %
3	11-50 %
4	51-90 %
5	91-99%
6	100%

Table 5.2: Dorsal cortex cover categories.

Platform Type: For complete and proximal flakes, the types of platforms include plain, cortical, faceted, crushed, and absent. The type of platform can help in determining the stage and type of reduction that took place as well as suggest core morphology.

Platform Preparation: For the flakes with platforms, the presence and type of platform preparation was recorded. The different preparation techniques include grinding, scarring, trimming, and no apparent preparation.

Lipping: The presence of a lip just to the distal side of the platform on the ventral surface is often indicative of soft hammer percussion, which is typical of later stage reduction, although this has not been supported through controlled experimentation (Pelcin 1997). The lipping may actually correlate with different techniques and angles of impact used for soft-hammer percussion, not the percussor itself. The presence or absence of a lip was recorded for all complete and proximal flakes.

Platform Width: The maximum width of the platform for all complete and proximal flakes was recorded to the nearest .01 cm.

Platform Thickness: The maximum platform thickness was taken for all complete and proximal flakes.

The data on the above attributes were hand recorded onto preprinted data collection sheets. The data were then entered into an identical Excel spreadsheet, and all of the frequency calculations were made by hand, on a calculator, or in Excel.

Analysis

Given the obviously disturbed context of the site (see section on obsidian hydration analysis), a diachronic analysis based on differences between the levels would unlikely yield reliable results, as all indications are that excavated areas had been previously excavated as well as screened. The distribution of looter holes and backfill piles suggests that as the site was looted the material was screened close to the location from where it was excavated. Archaeological and ethnological data on rockshelter occupation demonstrate that individuals and groups inhabiting the closed sites differentiate activity areas based on the availability of outside light and other physical features of the shelter (Walthall 1998). For example, sleeping areas and small hearths are often located in the rear of the chamber, while maintenance and cooking activities generally take place near the shelter entrance. For this reason, the first part of this analysis will attempt to determine if different lithic assemblages are present in the front, middle and rear of the shelter.

Units 1 and 2 were located near the rear of the front chamber and are combined to form the rear analytical unit. The total volume excavated from these two units is 4.2 m^3. Unit 3, with a total excavated volume of 2.6 m^3, will comprise the complete sample from the middle of the chamber. Units 4, 5, and 6 were all located near the cave entrance and obviously receive the most intense sunlight (see Figure 4.1 for unit locations). Total excavated volume of these three units is 3.4 m^3. Although these three analytical units encompass different volumes of excavated material, the analysis will use percentages to

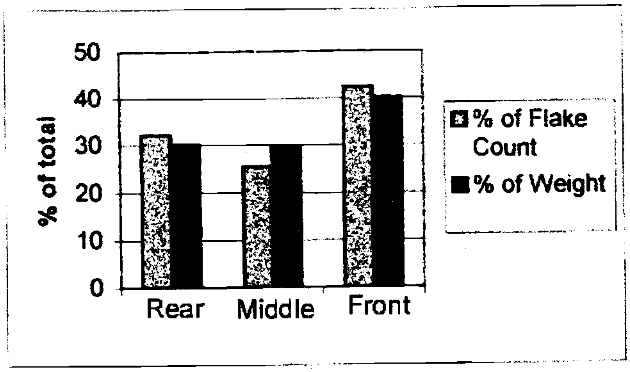

Figure 5.1: Frequency of count and weight by area.

minimize these differences. Figure 5.1 shows the percent distribution of the lithic debitage among these three areas by both weight and count, revealing slightly denser lithic material recovered by both weight and count in the front units.

Of all metric attributes, the distribution of size classes is likely to be one of the easiest ways to detect major differences in the general stage of reduction (Shott 1994). Both size class and weight often co-vary with other metric attributes such as length and thickness (Andrefsky 1998). Rather than use a traditional stage typology involving multiple specifically defined stages (Muto 1971; Callahan 1979) that is difficult to support archaeologically (Patterson 1990; Scott 1991), this analysis will view lithic reduction as more of a continuum (Sullivan and Rozen 1985; Rozen and Sullivan 1989; Shott 1996). Early and late stage reduction represent opposite ends of this continuum. An assemblage exhibiting early stage reduction will contain larger flakes with a greater frequency of cortex, while a late stage assemblage, indicative of tool finishing and resharpening, will encompass smaller flakes and a very low frequency of cortex.

If late stage tool maintenance and finishing activities took place in a different area of the site than early stage reduction or flake production, then this may be expressed as

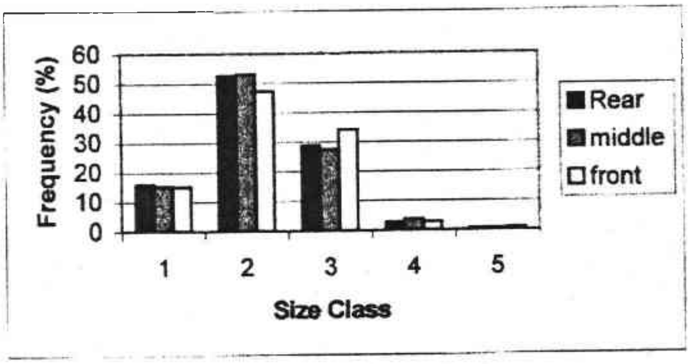

Figure 5.2: Distribution of size class by area within the site.

differences in the size and weight distribution between the three analytical units described above. As shown in Figure 5.2, the percentages of the five size classes for the three different site areas reveal no major differences between any of the areas, especially for size class 1. If different activities were taking place then they either produced remarkably similar sized flakes or the differences were mixed as a result of the looting activity. The distribution of the weight percent by size class (Figure 5.3) shows only slightly more variation than the percent of each size class by count.

There do not appear to be any significant technological differences in the disturbed deposits from the three areas of the site. While this limits the interpretations as to the intra-site spatial organization of the lithic reduction behavior, it does allow the entire assemblage to be grouped into a single analytical unit in an effort to determine the pattern of lithic tool use in general.

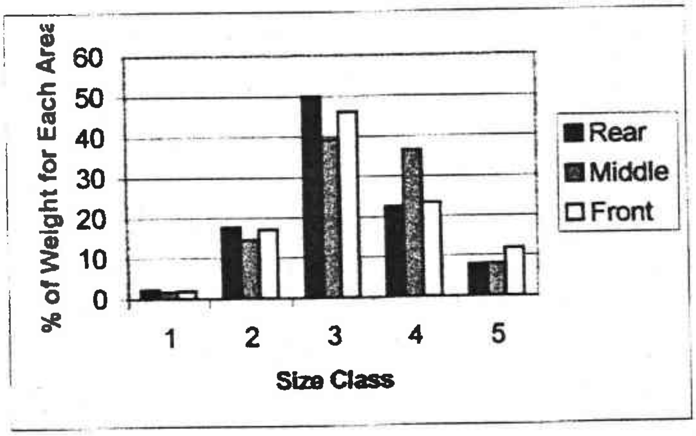

Figure 5.3: Distribution of the size classes by weight for the three areas.

Raw Material

The differential use of raw materials may produce variance exhibited in the size class distribution that would require further analysis to be tailored to specific raw material. This analysis excludes different sources of the same general geologic material, and focuses only on the five raw material classes present in the assemblage (for a detailed analysis of various obsidian sources utilized at the site see the chapter on obsidian characterization). Obsidian comprises more than 92 percent of the debitage. The remaining four material types total less than 8 percent of the total number of flakes (see Figure 5.4). The availability of the non-obsidian lithic raw material is unknown.

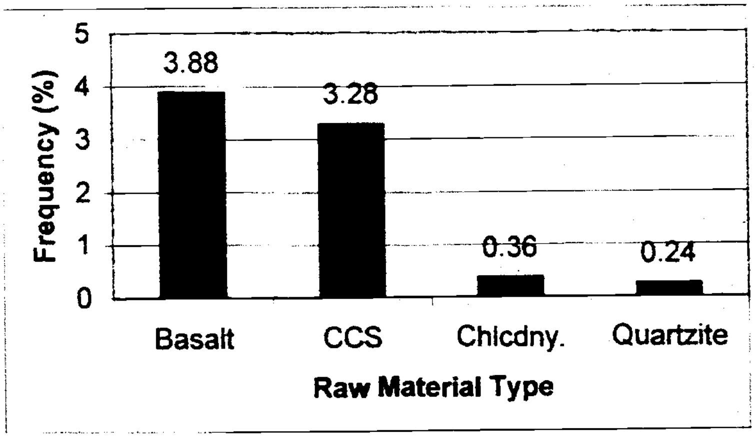

Figure 5.4: Raw material frequency of non-obsidian debitage.

The differential use of the materials could be evident in the different size class distribution of the materials. If certain raw materials were used primarily for expedient flake production then this would manifest as a greater percentage of large flakes. Material reserved for specialized curated tools would be present predominantly as smaller debitage as a result of tool rejuvenation. Figure 5.5 shows the size class distribution

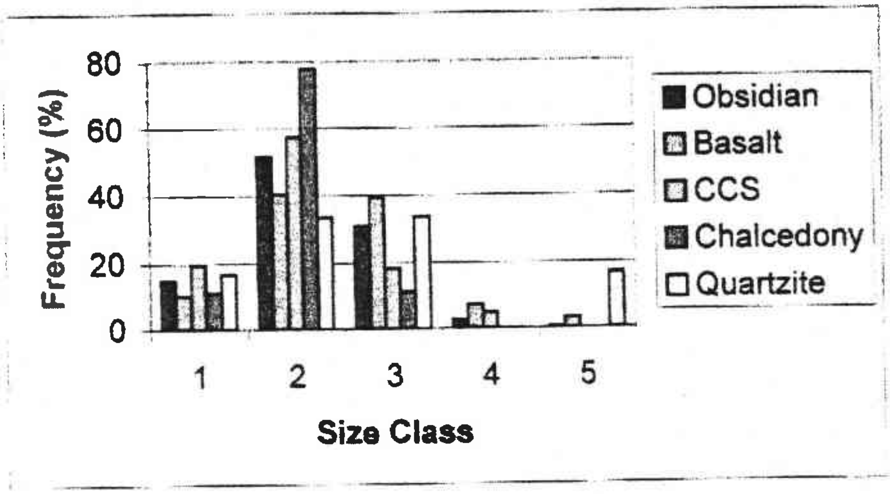

Figure 5.5: Size class distribution according to material type.

according to raw material type. Taking into consideration the extremely small sample size for chalcedony and quartzite, none of the materials show a substantially different size distribution. It is surprising that the fine-grained obsidian and chalcedony do not show a significant difference in use than the coarse-grained basalt and quartzite.

Size Class

The size class data previously discussed, when pooled, can provide some information about the general stage of lithic reduction that took place at the site (Mauldin and Amick 1989). Figure 5.6 displays the relative proportions of the five size classes by count and weight for the entire debitage assemblage. The weight frequency reveals a fairly normal distribution compared with the count distribution, which favors the smaller classes. This would be expected given the vastly smaller weight for the smaller size classes. Various studies have shown that the count distribution is often skewed towards the smaller flakes if the primary activity consisted of late stage lithic reduction, tool repair, rejuvenation, and recycling (Shott 1994). Given the lack of any obsidian sources

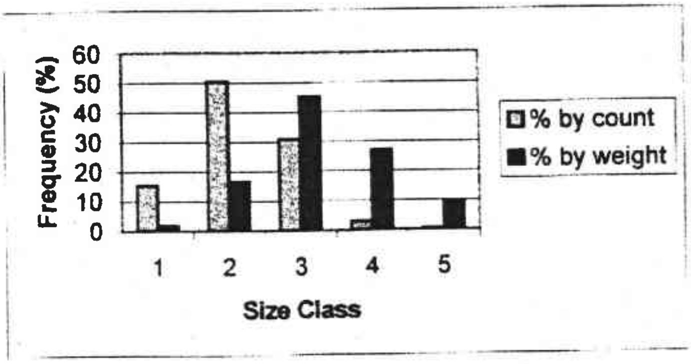

Figure 5.6: Frequency distribution by count and weight for each size class.

within 15-20 km of the site, it would be unlikely to have a high frequency of large flakes (see section on obsidian characterization in this chapter for a model of lithic strategies at Bone Cave). Based on the frequency and weight distributions by size class it appears that the dominant flintknapping activity at Bone Cave involved primarily the latest stages of lithic reduction/repair, although the validity of assessing manufacture stage by size distribution alone is debated (Baumler and Downum 1989). No attempt will be made to distinguish between percussion and pressure flakes due to the lack of satisfactory diagnostic attributes (Tuohy 1987; Andrefsky 1998). There are three other possibilities that may explain the distribution seen in Figure 5.6.

1) The larger flakes were removed from the site by the prehistoric groups to serve as tools or blanks for tool production.
2) The looters collected the larger flakes. This does not appear very likely, in fact, analysts often rely only on lithic debitage assemblages to reconstruct stone tool use at looted sites (Shott 1994).
3) The larger flakes were broken by either historic or prehistoric activities, increasing the frequency of smaller flakes.

Although for different reasons, both prehistoric and modern collection of flakes would probably produce a similar assemblage bias. Distinguishing between the first two possibilities is very difficult without a sample from an unlooted portion of the site to serve as a control. The third scenario is addressed by comparing the condition of flakes from Bone Cave with a study by Sullivan and Rozen (1985).

Flake Condition

The categories used by Sullivan and Rozen are very similar to those in this study and have been converted to the same terminology as the Bone Cave data set including complete and proximal flakes, flake fragments, and debris. Sullivan and Rozen interpreted the middle data set in Figure 5.7 as the result of tool production, while the data set on the right (black) represents an assemblage suggestive of core reduction (Sullivan and Rozen 1985). The Sullivan and Rozen data have been recalculated to exclude tools to allow comparison with the Bone Cave assemblage. As Figure 5.7 shows,

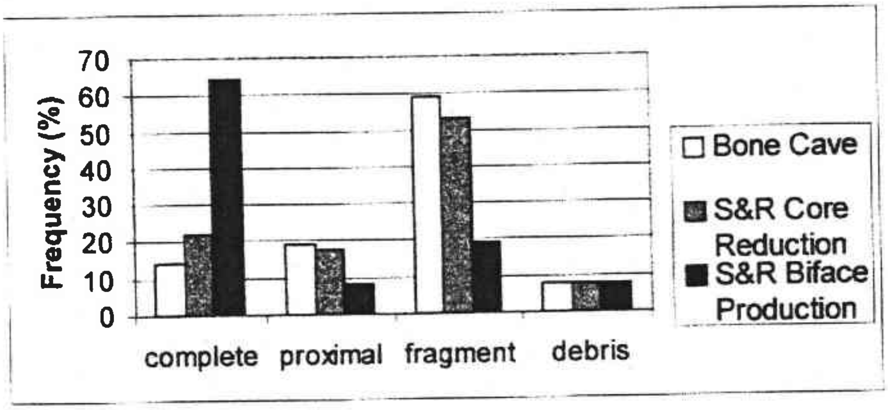

Figure 5.7: Frequency distribution of flake types from Bone Cave and two Sullivan and Rozen (1985:763) lithic assemblages.

the high frequency of flake fragments could easily be explained as the result of tool production, not post-depositional flake fracturing. It is interesting just how similar the Bone Cave and Sullivan and Rozen tool production data are. This complements the interpretations made from the size class distribution that suggest late stage tool finishing/reworking.

Using essentially the same flake condition categories as Sullivan and Rozen, Baumler and Downum (1989) compared the debitage assemblages produced by core reduction compared to scraper retouch. They found debris to be the most diagnostic flake type, comprising 27.5 to 37 percent of the core reduction assemblage and 1.3 to 10.8 percent for scraper retouch (Baumler and Downum 1989). If tool resharpening constituted the primary activity at Bone Cave this would probably produce a similar debris percentage. Approximately 8 percent of the Bone Cave debitage is debris, well within the expected frequency for retouch, but less than one third of the proposed frequency for core reduction.

Not all lithic analysts agree with the methodology proposed by Sullivan and Rozen. While some controlled experiments have supported the methodology, Sullivan and Rozen did not base their analysis on experimentation, resulting in significant error (Prentiss and Romanski 1989). For example, Sullivan and Rozen ignore the possible effects of trampling by claiming that the sediments were extremely soft and unlikely to induce flake fracture. Experimental analysis has demonstrated edge modification resulting from human and animal trampling (Wilson 1996; McBrearty, Bishop et al. 1998), and flake breakage could certainly result from the same process (Prentiss and Romanski 1989). Further experimentation is necessary to better understand factors determining flake condition, but there is a correlation between the late-stage reduction/retouch in multiple archaeological assemblages and the Bone Cave assemblage.

Cortex

The amount of cortex - the weathered exterior of lithic raw materials – on chipped-stone debitage has often been used as an indicator of the stage of tool reduction (Shott 1994; Andrefsky 1998), although some argue that a high frequency of cortical flakes is only indicative of the earliest stage of reduction, and cannot distinguish between middle and late stages (Magne 1989; Mauldin and Amick 1989). The removal of at least some of the cortex is required before non-cortical flakes may be removed, and the amount of cortex on the dorsal surfaces of flakes generally decreases as the reduction process continues, but this is not always the case (Sullivan and Rozen 1985). Sullivan and Rozen (1985) describe at least five separate variables influencing the presence of cortex on lithic artifacts. The primary form of reduction that produces large numbers of late-stage cortical flakes is non-bifacial core reduction such as unifacial and bipolar techniques (Kobayashi 1982). The limited tool assemblage from the site consists entirely of bifacial tools. Cortical flakes are extremely rare in the later stages of bifacial reduction. In contrast, quarry sites that were used for early stage bifacial reduction often contain extremely high frequencies of flakes with cortex (Bloomer 1991).

Figure 5.8 shows how skewed the Bone Cave assemblage is toward interior flakes. Less than 4% of the flakes exhibited any cortex at all, and less than 2% had more than 10% cortex on the dorsal surface. This is very similar to the distribution found at

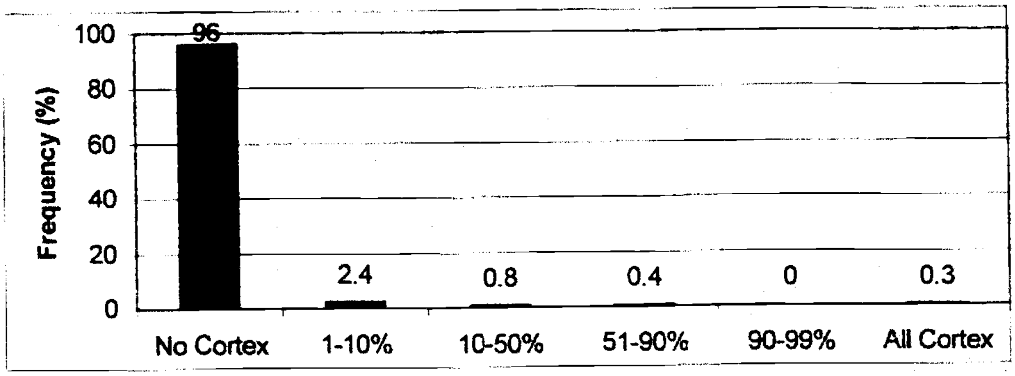

Figure 5.8: Frequency of flakes for each dorsal cortex category.

Mitchell Cave (Connolly, Jenkins et al. 1993) that was determined to contain almost entirely the resultant debitage from finished tool modification. The assemblage from Bone Cave certainly appears to result from the latest stage of lithic reduction, possibly including tool modification as shown by the distribution of size classes, flake condition, and presence of cortex. Magne (1989) links abundant small debitage and low frequency of cortex with logistical or emergency camps. The logistical use of Bone Cave is thus evident in the lithic assemblage.

Platform Attributes

Platform attributes can further indicate the type of lithic technology employed at a site. Numerous studies have considered platform angle and thickness as important independent variables in determining other flake attributes (Dibble and Pelcin 1995; Pelcin 1997). Unfortunately, platform angle was not measured during data collection, therefore further platform analysis will focus on platform type. Shott (1994) recommends two platform type categories: plain and multifaceted. He warns that further subdivision can easily lead to measurement or coding error. While plain and faceted platforms are important attributes, cortical and crushed platforms are also very informative. Cortical platforms are indicative of the earliest reduction stage, and crushed platforms are common in bipolar reduction assemblages (Kobayashi 1982; Shott 1989). Platform type coding error was a significant problem during data collection because the majority of the flakes were quite small and exhibited grinding that was often mistaken for plain platforms. This is quite possibly the reason for the high percentage of plain platforms shown in Figure 5.9. Andrefsky (1998) correlates flat (or plain) and cortical striking platforms with non-bifacial core reduction, namely unifacial core reduction, but plain platforms can also indicate bifacial reduction (Mauldin and Amick 1989). The high frequency of flat platforms from the Bone Cave analysis suggests either a non-bifacial technology or predominantly early stage bifacial reduction, but all other attributes such as flake size and cortex as well as the limited tool assemblage imply late stage bifacial finishing and resharpening activities. Plain platforms are also often indicative of expedient core reduction or planned blade production that is typically oriented toward the production of flakes to serve as tools or tool blanks. If the frequency of plain platforms were to actually correlate with the production of flake tools, then the size class

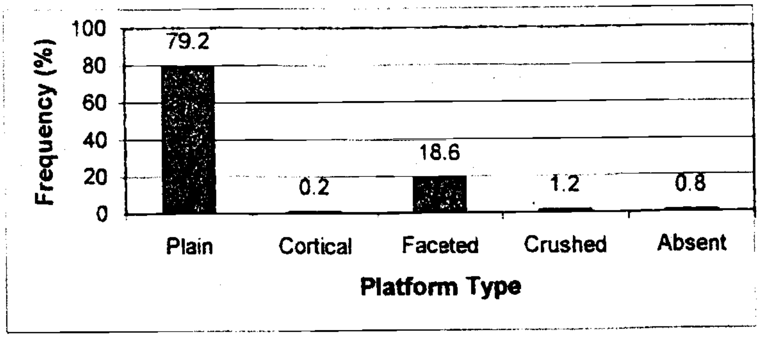

Figure 5.9: Frequency of platform types.

distribution would have shown a much higher tendency toward larger flakes, and broken or discarded flakes or blades would have been more prevalent in the assemblage. On the contrary, more than 65 percent of the flakes recovered (a figure that certainly would be higher had smaller mesh screens been used in the field) measure less than 1 cm in maximum dimension, and are unlikely to have served as flake tools or tool blanks. The greater percentage of faceted as opposed to cortical platforms indicates the absence of primary reduction compared to later stage bifacial reduction. In this case, the flake size hindered the interpretation of platform type, and thus it may not provide useful information as analyzed here.

The use of a soft-hammer indentor is often associated with the later stages of bifacial reduction and also the presence of lipped platforms (Hayden and Hutchings 1989), although the latter association has been questioned in numerous recent experimental studies (Pelcin 1997). Hard and soft-hammer reduction have been shown to produce overlapping flake attributes that may be more of a function of the technique incorporated by the individual knapper (Pelcin 1997). The role of pressure flaking in the production of lipped platforms is also poorly understood (Tuohy 1987), and represents a

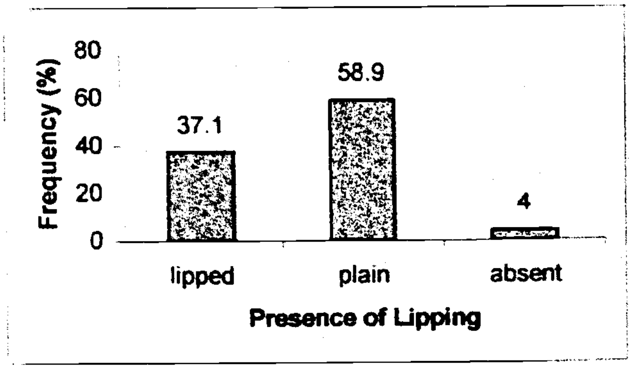

Figure 5.10: Frequency of lipped platforms.

problem in an assemblage such as Bone Cave's because of the prevalence of extremely small flakes. Figure 5.10 shows the frequency of lipped, unlipped, and undetermined platforms from Bone Cave. If lipped platforms are indicative of soft-hammer percussion, then this represents a substantial portion of the assemblage, and suggests late stage bifacial reduction.

With the possible exception of platform type, all of the flake attributes imply final tool production and repair at Bone Cave. There is no indication of primary reduction taking place within the front chamber of the site. The tools also suggest finishing/reworking activities but this data set is almost certainly incomplete.

Tool Assemblage

Tool assemblages recovered during excavation only represent a biased sample of the variety and ratios of tools in use by the site inhabitants. Except in rare cases of tool caches (Scott, Davis et al. 1986), or rapid site abandonment (Sheets 1994), most archaeological stone tool assemblages are biased toward broken and discarded tools. Bone Cave almost certainly contained diagnostic formal tools, but unfortunately these are the quarry of most looters (Gaston 1983). The small tool sample recovered from Bone Cave represents artifacts either passed over or missed by the looters. Unlike the debitage assemblage, looted tool assemblages are extremely dangerous to interpret (Shott 1994) and therefore the following tool analysis will primarily consist of descriptions with little interpretation.

Seven non-diagnostic obsidian tool or tool fragments were recovered from Bone Cave (Figure 5.11) including five small biface fragments, one retouched flake, and one

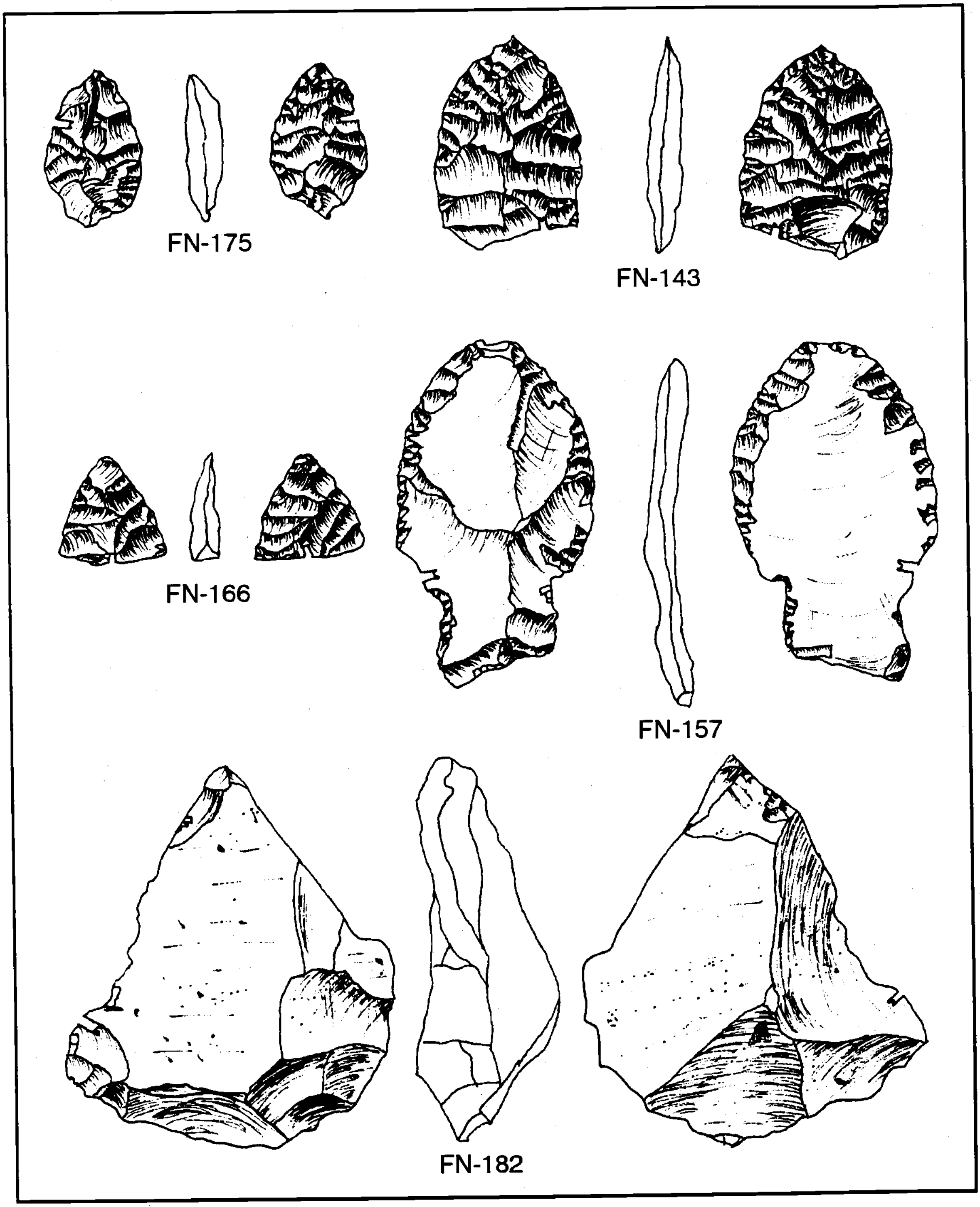

Figure 5.11: Obsidian tool assemblage (actual size).

possible bifacial core. Only a few of the flakes recovered from the site even approach the size of most of the tools, suggesting that the tools were not manufactured from flake or bifacial blanks produced at the site. FN-157, a bifacially retouched flake, could represent a resharpened flake cutting tool or possibly a blank that was intended to be worked into a biface or small projectile point. The largest lithic artifact recovered, FN-182, is a slightly worked core. Two small undiagnostic biface fragments are not included in Figure 5.11.

All three CCS tools recovered appear to be fragments of small projectile points or bifaces (Figure 5.12). FN-196 is a rounded terminal undiagnostic biface fragment, and FN-136 is the distal end of a biface. FN-102 exhibits a slightly concave base, but unfortunately is too fragmentary to be diagnostic. FN-102 does still possess some of its original detachment scar on one side, suggesting that it was produced from a flake blank.

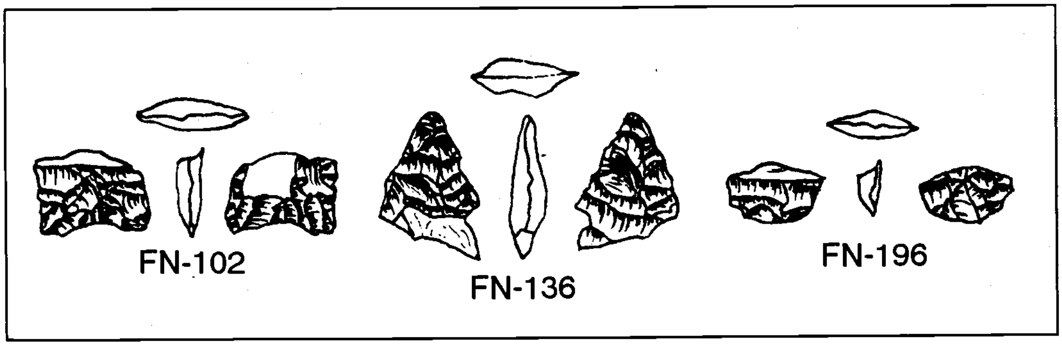

Figure 5.12: CCS tool assemblage (actual size).

Obsidian comprises more than 92 percent of the debitage compared to only 70 percent of the tools. This may be related to looter selection of obsidian tools, a small sample size (N=10), or greater curation of obsidian than other tools. Obsidian flakes and tools also require more frequent resharpening than the other, more durable, lithic materials (Amick and Mauldin 1997) resulting in more debitage.

Obsidian Studies

With the abundance of obsidian sources and intense use by prehistoric populations in the Northern Great Basin, obsidian studies have been applied extensively to archaeological collections from the region. Concurrent use of the two primary methods, obsidian characterization and obsidian hydration, can provide relative chronological information as well as the geographic distribution of sources found in an assemblage. The following obsidian characterization analysis looks at source distribution in an effort to model obsidian use and procurement by groups using Bone Cave. The next section on hydration analysis establishes a site-use chronology based on comparison with other regional pre-Mazama hydration measurements. Both of these techniques represent an avenue worth exploring at all sites, even those as disturbed as Bone Cave.

Obsidian Characterization

Obsidian studies in the Great Basin and elsewhere have undergone significant changes with the development of trace element analysis, or x-ray fluorescence (XRF) (Hughes 1984). Trace element analysis represents a significant improvement over more traditional visual sourcing techniques (Bettinger, Delacorte et al. 1984). Determining the location from which lithic raw material originated has been provided information about "seasonal procurement ranges, territorial and ethnic boundaries, the trails and travel routes, the curational value of particular sources or formal artifact types, cultural preferences regarding glass quality and colors, trade and exchange systems, group interaction, and the exchange of prestige items between elites of different groups" (Skinner 1995a:4-10).

Most geologically distinct obsidian sources exhibit a homogenous signature trace element profile, allowing for reliable identification, and the sources are generally limited in geographic distribution. Unlike some other characterization studies, the trace element profile of an artifact is unaffected by its manufacture or use (Nelson 1984). Prior to examining the chemical composition of an artifact, it is necessary to determine the geographic location and distribution of raw material sources, and then determine a standard profile for a specific geochemical source (Earle and Ericson 1977; Hughes 1984; Glascock, Braswell et al. 1998). The Western United States, and Central Oregon in particular, has an extensive inventory of obsidian sources allowing for productive analysis (Skinner 1995), but the technique has been applied in many regions such as the Southwest (Shackley 1996), Central America (Sidrys and Kimberlin 1979; Glascock, Braswell et al. 1998), the Mediterranean (Tykot 1998), Oceania (Weisler and Clague 1998), and other areas throughout the world. The sourcing ability of trace element analysis is not limited to obsidian (Skinner 1999). Other volcanic rocks such as fine-grained rhyloites and basalts are increasingly sourced as the chemical variability and geographic distributions of these sources are discovered.

The use of trace element analysis to determine the parent geological source has gained wide use with the introduction of non-destructive analysis that does not require a sample to be pulverized and formed into a pellet (Hampel 1984). XRF analysts had originally focused on the use of destructive methods until experimentation revealed that lenticular or biconvex artifact surfaces produced comparable results to the analysis of the prepared pellets (Skinner 1995). There are two primary non-destructive methods of XRF: energy dispersive and wavelength dispersive. The former utilizes a low-power x-ray tube compared to the high-power tube and greater cost for the later. All samples for this study were measured using energy dispersive XRF. This technique is described below.

The samples were analyzed by Craig Skinner of Northwest Obsidian Labs, Corvallis, Oregon. A Spectrace 5000 energy dispersive X-ray fluorescence spectrometer measured the amount of each of the following trace elements: Ti, Mn, $Fe_2O_3^T$, Zn, Ga, Rb, Sr, Y, Zr, Nb, and Ba (Skinner 1999). In general, samples should exceed 1 cm in diameter and 1.5 mm in thickness. Smaller samples will exhibit some distortion but can often still be characterized. The potential bias that the minimum sample size creates will be discussed later in this chapter.

Paints, labels, and residues can all affect XRF results, but none of the Bone Cave samples were labeled prior to analysis. During his analysis of the INFOTEC pipeline project, Skinner (1995a) noted the presence of a light gray patina obscuring accurate XRF characterization that likely resulted from silica that precipitated from the pumice-rich soils in the region. The Bone Cave samples generally had the patina on only one side, allowing for at least one clean surface. Where necessary, the patina was removed by scraping with an X-ACTO knife. If not removed, the patina is especially problematic in blurring the distinctions between the McKay Butte and Quartz Mountain obsidian sources.

Correlating artifacts with their parent geologic sources generally requires analysis of four diagnostic elements (Rb, Sr, Y, and Zr), but if these do not differentiate between multiple sources within two standard deviations of the mean value for the source standards, then the other elements listed above are measured (Skinner 1995). When a distinction between two closely related sources is not possible, then it is reported as possibly from either source, such as the case of the Silver Lake/Sycan Marsh sample from Bone Cave.

Not all samples submitted for XRF analysis were assigned to a source. Skinner (1995a) lists three possible reasons for obtaining an unknown result: 1) the geologic source has yet to be located and/or analyzed, 2) the sample is from a known source with an underestimated range of chemical variability, or 3) error in analysis resulting from small artifact size, contamination, etc. The locations of some unknown sources, such as Unknown X, have been estimated by comparison of unknown geochemistry with known sources and by mapping the distribution of artifacts from archaeological sites. North-Central Oregon has numerous unknown sources that are either from chemically diverse known sources or are possibly located in the Ohcoco-Malheur National Forest area (Skinner 1995).

In total, 59 artifacts from Bone Cave were submitted for obsidian characterization (See Appendix 2 for complete XRF and hydration data set). Eleven of these were either not obsidian or too small for analysis, 10 were from unknown sources and 38 were assigned to known Oregon obsidian sources. All 48 obsidian samples were also submitted for obsidian hydration analysis (See section on hydration analysis for a discussion of the hydration results). All obsidian tools large enough for analysis were

Obsidian Source	**N**	**Percent**
Big Obsidian Flow (Buried Obsidian Flow)	7	14.3
Brooks Canyon	1	2.0
Chickahominy	1	2.0
Cougar Mountain	2	4.1
McKay Butte	14	28.6
Obsidian Cliffs	5	10.2
Quartz Mountain	6	12.2
Silver Lake/Sycan Marsh	2	4.1
Unknown X	5	10.2
Unknown 1	1	2.0
Unknown 2	3	6.1
Unknown 3	1	2.0
Whitewater Ridge	1	2.0
	49	99.8

Table 5.3: Count and percentage of each source from the Bone Cave sample.

included in the sample (N=8) and two debitage samples were selected from each level of Units 1 and 4, 40 of which produced positive source identification. Debitage sample selection entailed the random assignment of a number to each obsidian flake larger than 1 cm in diameter from a level, and then random numbers corresponding to two of the flakes were selected by drawing slips of paper from a cup. Table 4.1 lists the number of samples assigned to each source. All but one obsidian sample submitted for XRF produced acceptable results. Figure 5.13 shows the distribution of the samples according

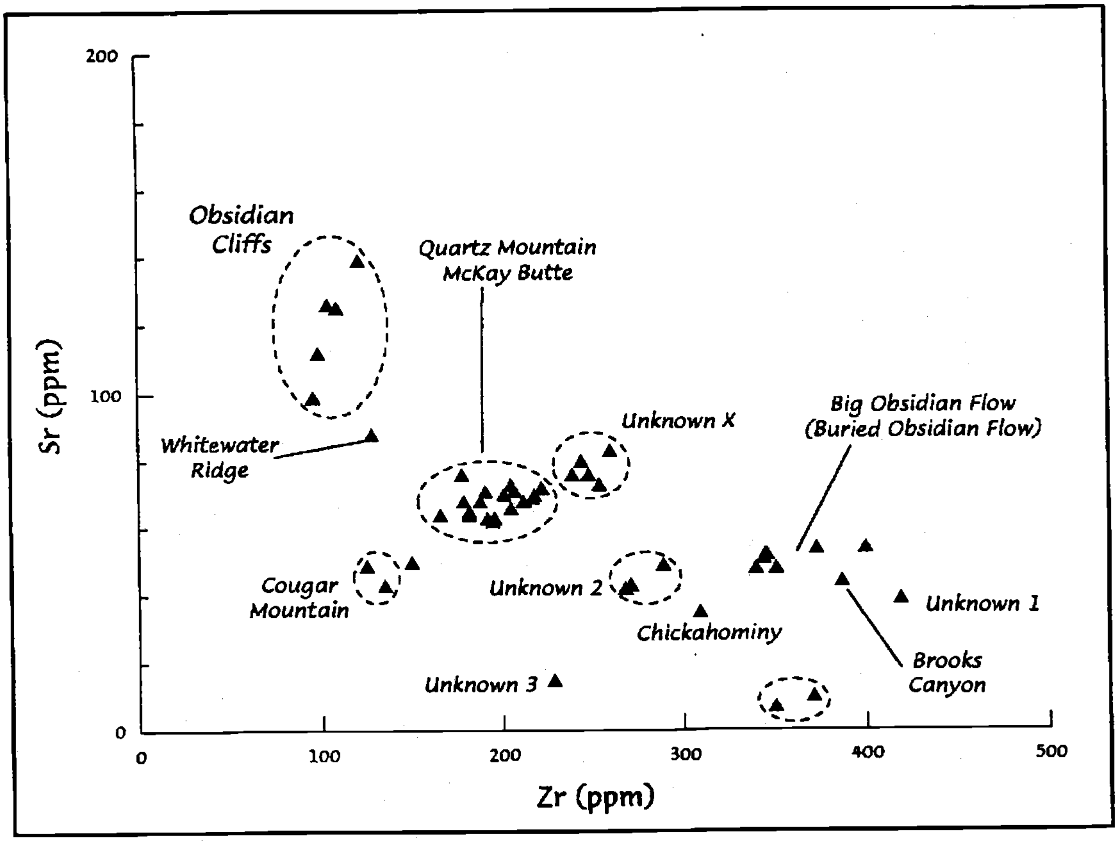

Figure 5.13: Scatterplot of Sr versus Zr for the Bone Cave XRF assemblage.

to two diagnostic elements, Strontium (Sr) and Zirconium (Zr). While some of the sources appear scattered or very close to other sources, these are only two of the elements used in the characterization analysis, and closely related sources were also distinguished on the basis of other trace elements.

Bone Cave produced an unusually high percentage of unknown sources. Compared to the sample from the INFOTEC pipeline project from Oregon (Skinner 1995) which contained only 8 percent unknown sources (N=6,595), the Bone Cave sample contained 22.3 percent unknowns. The pipeline project consisted of both surface survey and numerous excavations extending from Central California, through Central

Oregon, Washington, and ending in Idaho. There are two probable explanations for the difference: 1) the Bone Cave data is based on a considerably smaller data set, and 2) much of the Central Oregon sample analyzed for the pipeline project came from more recent sites heavily focused on the well known Newberry complex.

The presence of Unknown X (a well-known unknown) not only provides information about the general area of source location, but also some estimate of site use chronology. The source is estimated to be somewhere in the vicinity of the Newberry and McKay Butte sources, but almost certainly in the upper Deschutes Basin, and is thus treated as a more local source for Bone Cave. Use of Unknown X, as well as McKay Butte, falls off dramatically after the Mazama ashfall, and its abundant presence in the Bone Cave assemblage suggests a pre-Mazama component (Skinner 1995). The site use chronology based on both the obsidian characterization and obsidian hydration is discussed in the section on obsidian hydration analysis.

Most studies of North American hunter-gatherer lithic technology assume a direct procurement model of raw material access unless otherwise indicated (Bouey and Basgall 1984; Ingbar 1994). Direct procurement implies that groups have access to the raw material source and do not need to trade with other groups controlling the distribution of the raw material. There is no evidence from the Northern Great Basin of any extensive exchange systems controlling the flow of obsidian, in fact, there is a general assumption about predominantly direct procurement (Minor and Toepel 1989). There is a small possibility that a small sample of obsidian from distant sources may have been obtained through incidental trade, but this does not alter significantly the general procurement strategy, and it is very difficult to detect archaeologically.

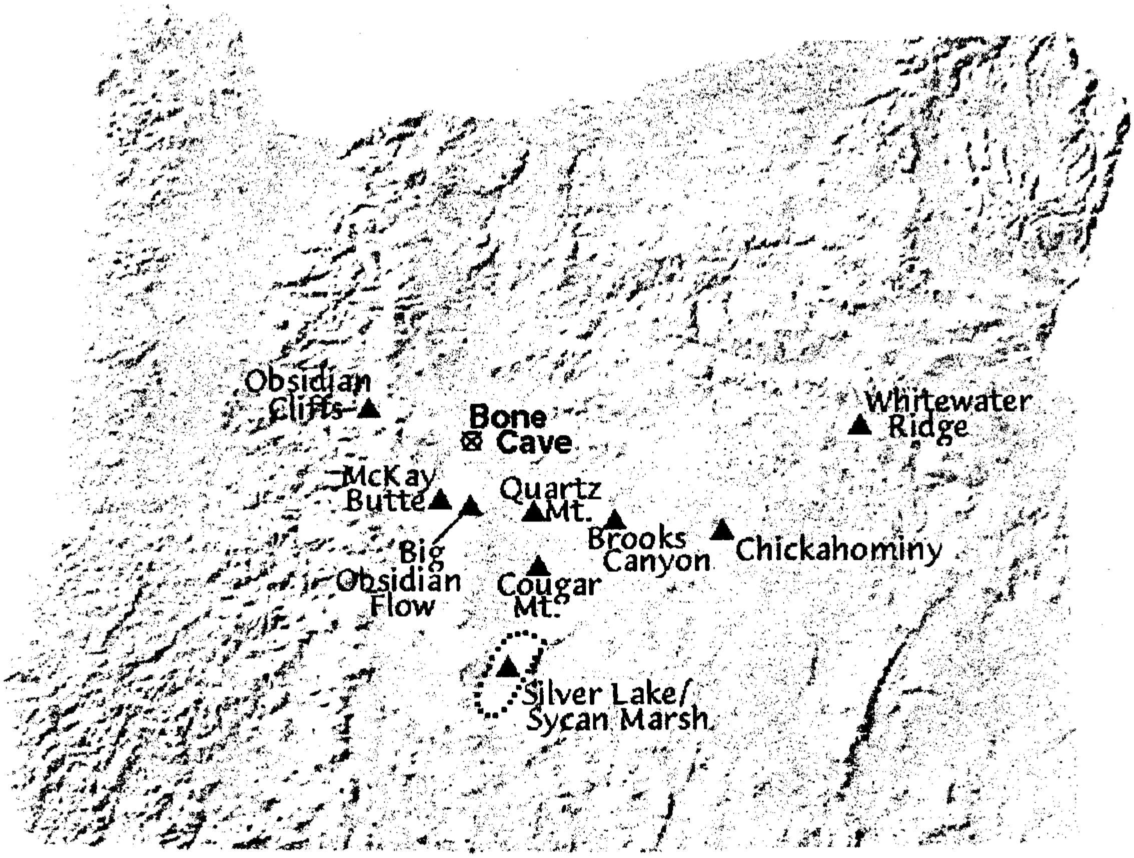

Figure 5.14: Approximate locations of obsidian sources recovered from Bone Cave.

The known sources present in the Bone Cave sample show an interesting geographical distribution. Figure 5.14 displays the approximate geographical distribution of all of the known sources present at Bone Cave. Obviously this material selection heavily favors Great Basin sources primarily to the south and east, and this may be in part due the natural distribution of the obsidian sources that are abundant in the Northern Great Basin and Central Oregon. Of the two sources located outside of the Great Basin, Obsidian Cliffs could have been incorporated into seasonal or logistic movements of any group occupying the extreme Northwestern Great Basin, and although Whitewater Ridge was utilized by both Great Basin and Plateau groups (Rotell, Skinner et al. 1998) the prevalence of Great Basin sources at Bone Cave supports a Great Basin exploitation of this source. Due to the lack of any diagnostic tools, the distribution of obsidian sources provides possibly the best evidence of a Great Basin affiliation for the inhabitants of Bone Cave. Although some of the unsourced CCS, chalcedony, and basalt material may have originated from another culture area such as the lower Deschutes or Columbia Plateau, the obsidian dominated the lithic assemblage (92%). If the site was occupied predominantly by cultures to the north or west, then the non-obsidian material or obsidian sources outside the Great Basin should be much more prevalent.

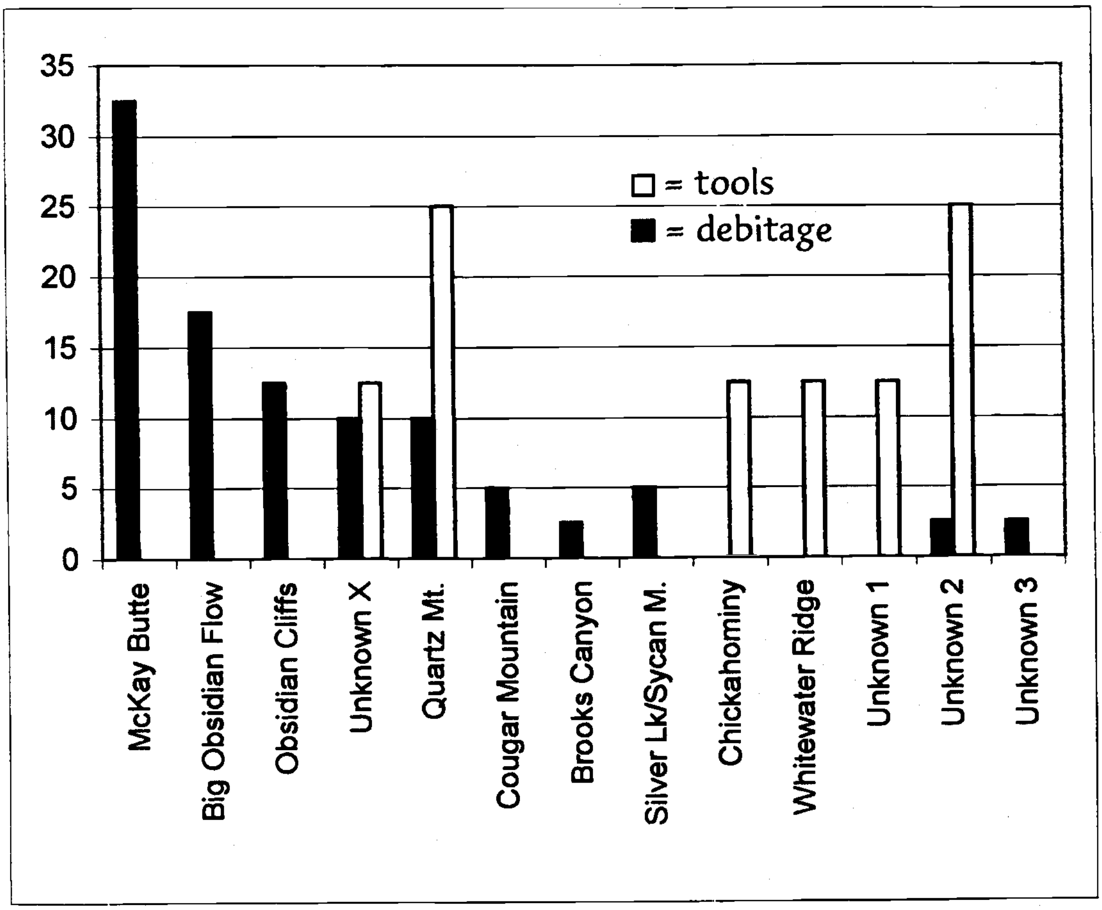

Figure 5.15: Frequency of tools compared to debitage for each source. Sources are ordered according to approximate distance from Bone Cave (except for Unknowns 1-3).

In addition to the distribution of sources, the comparison of the formal tool and debitage assemblages provides information about the lithic technology of groups that used Bone Cave. Figure 5.15 shows the differential frequency of the various sources as tools (N=8) or as debitage (N=38). These data must be interpreted with some caution due to the extremely small sample sizes, especially for the tools. When the sources are ordered according to their estimated distance from Bone Cave, a simple model of stone tool use at the site is suggested. In the case of an embedded lithic procurement strategy (Binford 1979), raw material from distant sources is generally used and discarded in the process of residential mobility toward another source (Ingbar 1994). The debitage distribution at Bone Cave behaves much as expected for a highly mobile group utilizing direct procurement (Gramly 1980; Close 1996), with abundance inversely correlated with distance to the site. The tools exhibit a dramatically different distribution. The distribution of the tools favors the more distant and unknown sources. While more than 62 percent of the debitage sample was sourced to the three closest sources, no tools were from these sources. In contrast, the two most distant sources comprise 25 percent of the obsidian tool assemblage, while no debitage was recovered from these sources.

Several behavioral and sampling factors would be expected to produce this type of distribution. There are no significant physical differences between the various obsidians present in the sample, reducing the likelihood that the prehistoric groups were preferentially selecting certain sources. Instead, research on Great Basin mobility patterns suggest that sources were more likely encountered as part of an embedded procurement pattern (Binford 1979; Skinner 1995) and therefore reflect seasonal movements focused on non-lithic resources (Jenkins, Skinner et al. 1999). Given the vast distribution of the sources, encompassing multiple Northern Great Basin drainage basins, it seems unlikely that all of the sources represent the extent of a single seasonal round for a single group. Great Basin groups were highly mobile, but this range covers thousands of square miles. Groups in the Great Basin ethnographically and archaeologically centered their seasonal movements around individual drainage basins (Aikens 1993), although this may underestimate the level of mobility during the Early Archaic period.

If the five closest sources, McKay Butte, Big Obsidian flow, Obsidian Cliffs, Unknown X, and Quartz Mountain are all considered "local" sources, then the assemblage at Bone Cave resembles the pattern at many quarry sites where the debitage is predominantly local, while the discarded tools are from distant sources (Gramly 1980). The faunal and lithic analyses (later in this chapter) clearly indicate that the site was used primarily as a rabbit processing site, and not as a primary lithic reduction location. Assuming that the groups that occupied Bone Cave were not selecting certain obsidians for specific attributes such as color, then the majority of the tools nearing or reaching the end of their use-lives would be greatest for tools produced at distant sources (Ingbar 1994). The amount of lithic raw material a group can transport is limited (Close 1996), and if they are conducting activities requiring obsidian, it is unlikely that groups would still carry larger bifaces or cores from distant sources into an area rich in local sources. On the other hand, they may have recently collected raw material from the local sources that would result in more debitage. There is probably a underestimated frequency of debitage from the distant sources, but it is present as small resharpening flakes that would not have met the minimum size requirements for XRF analysis. Further discussion of stone tool use at Bone Cave is presented in the conclusion.

Obsidian Hydration Analysis

Geologists during the early 1950s documented the conversion of natural volcanic glass, obsidian, into perlite through the absorption of water. These researchers also noted that the hydrated portion of the cross-section produced an increase in the indices of refraction termed strained birefringence caused by the increased surface density (Tremaine 1989). The dating potential was first presented to the archaeological community with the discovery that the thickness of the hydration band of obsidian artifacts correlates with the age of the artifact (Friedman and Smith 1960), although the potential problems of both environmental variables and archaeological context were quickly realized (Evans and Meggers 1960). Aside from the problems with the method, obsidian hydration has the potential to provide at least a relative date for a specific cultural event; the flaking of an obsidian artifact. The technique has become extremely widespread in the 40 years since its introduction. Researchers from all over the world have used the technique to obtain relative dates as well as to attempt to calculate absolute dates based on a defined hydration curve (Trembour 1983; Stevenson, Sheppard et al. 1996; Jenkins, Skinner et al. 1999).

The basic premise of the technique requires the removal of a small thin section from the margin of the obsidian artifact or geological sample. Upon removal, the section is affixed to a glass slide and ground down to the proper thickness of approximately 30 microns (µm). The sample is then observed under a birefringent light microscope under low power. If sufficient time has elapsed since the surface was first exposed, then hydration rims can be measured that typically vary between 1 µm for recent exposure to up to 30 µm for extremely old artifacts from Africa (Skinner 1995; Skinner 1999).

Time is not the only variable affecting the rate of hydration. In fact, one study lists twenty environmental and physical factors that significantly affect the hydration rate during induced hydration experiments in controlled laboratory settings. Three of these variables have been shown to affect the hydration rates in archaeological contexts (Stevenson, Mazer et al. 1998). These include temperature, soil chemistry, and relative humidity, (Clark et al. 1976 in Tremaine 1989:15). Although the exact effects of pH and soil chemistry are debated, it is clear that the pH of the soil can alter water absorption, especially in extremely acidic or alkali conditions (Jackson 1984), and the decomposition process of obsidian itself can alter the pH (Stevenson, Mazer et al. 1998).

Relative humidity can also greatly influence hydration. Most buried artifacts are subject to fairly constant 100 percent relative humidity and should hydrate faster that surface artifacts exposed to 30-100 percent relative humidity, except that surface artifacts are generally exposed to greater temperatures, minimizing some of the differences caused by different relative humidity (Friedman, Trembor et al. 1994). Temperature is another significant factor in establishing hydration rates (Stevenson, Mazer et al. 1998). Stevenson et al. (1998) argue that it is necessary to measure the average effective temperature for a full year at various depths within an archaeological site. Others claim that the short-term temperature variability has the greatest impact on hydration rates (Ridings 1996; Jones, Sheppard et al. 1997).

Temperature, relative humidity, soil chemistry, and other environmental factors create some justified suspicion in the comparison of hydration results between different sites, and even between different areas of the same site. No two sites exhibit exactly the same environmental conditions and therefore are likely produce different hydration rates if the implications of many of the induced hydration experiments are correct.

Recently, many problems associated with obsidian hydration dating have been overcome, generating greater confidence in the technique (Green 1998). Some researchers argue that with more accurate optical methods, and hydration rates determined for individual specimens that relative as well as some absolute dates independent of other dating methods might be possible (Ambrose 1998). Given all of the potential problems, the hydration data from the Northern Great Basin, particularly the upper Deschutes drainage has proved remarkably consistent for the individual sources, producing relative dates for the region (Skinner 1995). For this reason, the following analysis will include a comparison of Bone Cave hydration measurements by source with those of two other regional sites that produced obsidian artifacts from pre-Mazama contexts.

In addition to the environmental variables, each chemical obsidian source exhibits its own specific hydration rate (Glascock, Braswell et al. 1998). While individual sources hydrate fairly consistently under the same conditions, in order to conduct comparisons in multiple source assemblages, different source material must be converted to a standard hydration rate based on experimentally defined hydration rates (Tremaine 1993). In an area such as the Northern Great Basin, relative dating requires that each hydrated specimen also undergo characterization analysis due to the large numbers of chemically distinct sources (Skinner 1995). Even approximate hydration rates are almost nonexistent for Oregon with the exception of the upper Deschutes Basin. As will be discussed later, the presence of obsidian artifacts in clear context below Mazama ash allows for a rough estimate of age relative to the eruption of Mt. Mazama (Skinner 1995).

Bone Cave Hydration Analysis

Initially 47 artifacts were selected for hydration and XRF analysis from Bone Cave including all obsidian tools (N=8) and two randomly selected flakes from each level in Units 1 and 4. These units were chosen in order to compare assemblages between the front and rear of the chamber. Flakes with a surface area of less than 0.8 cm^2 were not eligible due to minimum size requirements for characterization analysis (the potential bias this created is discussed in the preceding section dealing with the XRF analysis). Eleven flakes from the original sample were either not obsidian or did not possess visible hydration rims and replacements were selected giving a total of 45 successfully analyzed specimens (See Appendix 2 for complete hydration analysis results). The hydration analysis was conducted by Craig Skinner of Northwest Research Obsidian Studies Laboratory in Corvallis, Oregon.

Disturbance Pattern

Before presenting the relative age assessment of the Bone Cave assemblage, there is one underrated application of obsidian hydration that can provide information about site context. With few exceptions, artifacts within a single unit should be exposed to similar environmental circumstances. Obviously variables such as chemical differences between strata and exposure to fire can alter hydration rates, but these factors should not affect the ordering of hydration rates within a unit. If the archaeological deposits are intact and undisturbed, then the thickness of the hydration rim should correlate with depth. If the deposits have been disturbed such as the looting at Bone Cave, then a correlation would not be expected.

Although the hydration sample from Bone Cave was relatively small, eight pieces of debitage sourced to McKay Butte were analyzed from various levels of Unit 1. The disturbed nature of the sediments in this unit were clearly evident by the presence of historic debris more than a meter below the surface, and no correlation between hydration rim thickness and depth was expected. As shown in Figure 5.16 the hydration values do not increase with depth; in fact, both the largest and smallest hydration thicknesses were recovered from the first two levels, clearly revealing the mixed nature of the deposits. Similar analysis of the hydration measurements of other sources in both units produced similar patterns, but sample sizes were considerably smaller. No intact deposits were encountered during the project, and the disturbance evident from the stratigraphic

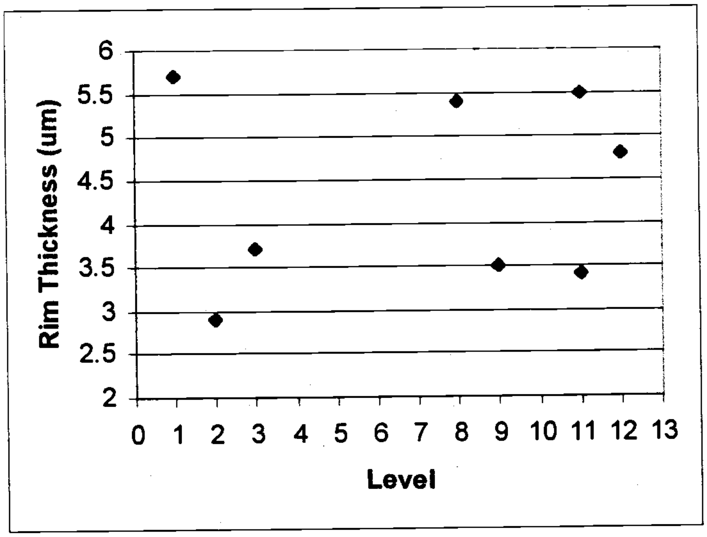

Figure 5.16: McKay Butte hydration values from Unit 1.

distribution of McKay Butte artifacts in Unit 4 prevents any diachronic analysis. The obsidian hydration and XRF analysis will consider the entire analyzed assemblage (n=59) as a single analytical unit.

Site Chronology

The recent INFOTEC pipeline project conducted obsidian hydration analysis of numerous artifacts from pre- and post-Mazama context within the upper Deschutes Basin (Skinner 1995). While other projects have certainly incorporated obsidian hydration, the pipeline project conducted the first extensive hydration analysis on artifacts from clear pre-Mazama context. Skinner (1995) was able to define approximate hydration rim values corresponding to the eruption of Mt. Mazama. This is a critical time break that coincides with the approximate boundary between the Early and Middle Archaic for much of the Northern Great Basin (Oetting 1994). Three sources in particular, Newberry Volcano, McKay Butte, and Unknown X, have distinctive ranges of hydration values that are considered to predate the Mazama eruption.

One of the most telling aspects of the Bone Cave assemblage is the apparent absence of Newberry Volcano obsidian. Hydration and stratigraphic analysis of Newberry Volcano obsidian artifacts has show that this flow was not exploited prior to the eruption of Mt. Mazama, and that the thickest hydration rim values for the source are around. This source almost completely replaces the use of McKay Butte and Unknown X, whose hydration rims generally have a large minimum corresponding with the Mazama event instead of a large maximum value, throughout the upper and lower Deschutes Basins in post-Mazama contexts (Skinner 1995). If any significant post-

Mazama occupation occurred at Bone Cave, obsidian from the Newberry source would have likely shown up in the source composition of the site.

The hydration ranges for the five upper Deschutes sources, McKay Butte, Obsidian Cliffs, Quartz Mountain, Unknown X, and the Big Obsidian Flow chemical group, closest to Bone Cave are shown in Figure 5.17. These are the five sources with the best estimates of a Mazama ashfall rim correlation (Skinner 1995).

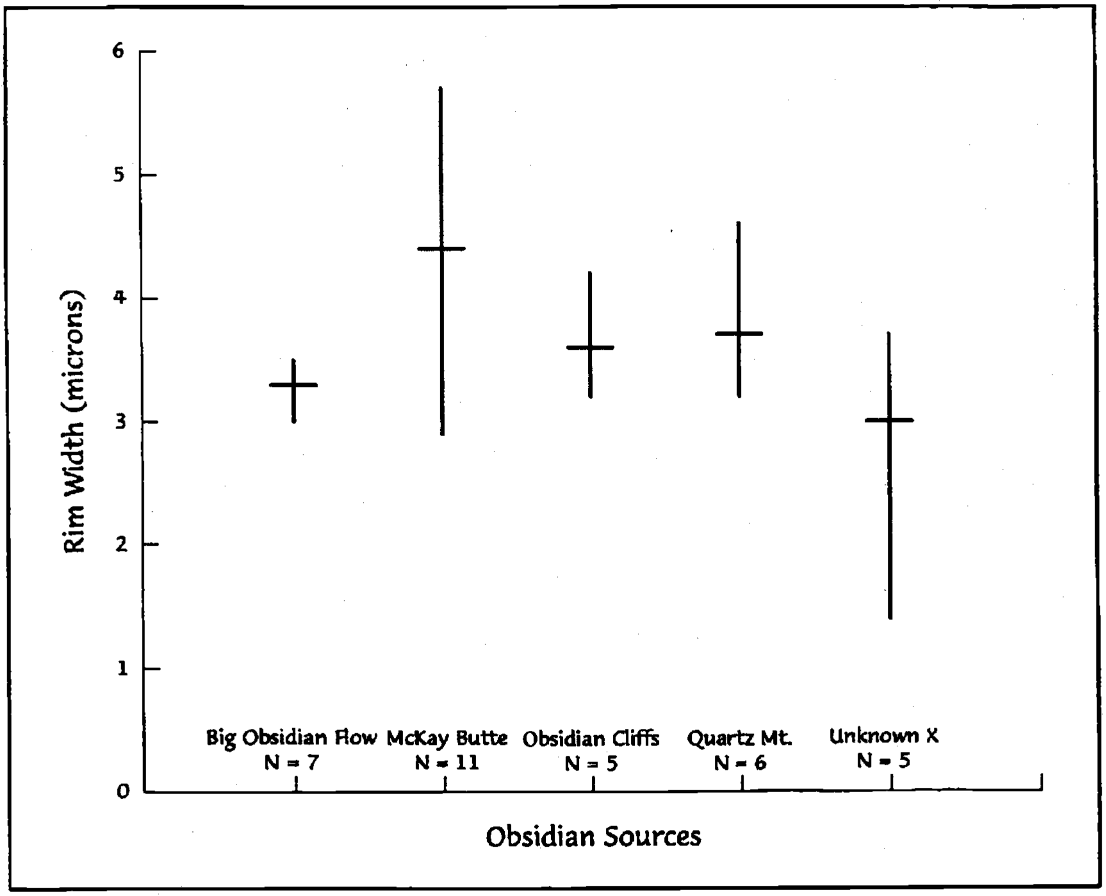

Figure 5.17: Hydration rim measurements from Bone Cave artifacts from the five upper Deschutes sources.

McKay Butte is located in the Eastern Cascade foothills of the upper Deschutes drainage. The hydration analysis of the pipeline project produced a distinctly bimodal distribution for McKay Butte hydration values. Larger rims related to pre-Mazama use of the source and smaller values, which occured in sites along the lower Deschutes, probably resulting from scavenging of previously worked material by Late Archaic groups while seasonally inhabiting the upper Deschutes Basin. Obsidian hydration rim measurements for pre-Mazama McKay Butte artifacts ranged from 3.3 to 8.7 μm and practically no post-Mazama artifacts from this source were recovered in the upper Deschutes (Skinner 1995). Other researchers have also noted a primarily pre-Mazama use for McKay Butte obsidian in the upper Deschutes Basin (Pettigrew 1998). The hydration rims for McKay Butte artifacts from Bone Cave show a distinctive pre-Mazama pattern. With the exception of one sample with a rim of 2.9, μm the hydration rims range from 3.4 to 5.7 μm and average 4.5 μm (see Figure 5.18). Hydration rates can vary substantially with temperature (Ridings 1996; Stevenson, Mazer et al. 1998). The buried artifacts within Bone Cave likely experienced a consistently low temperature that

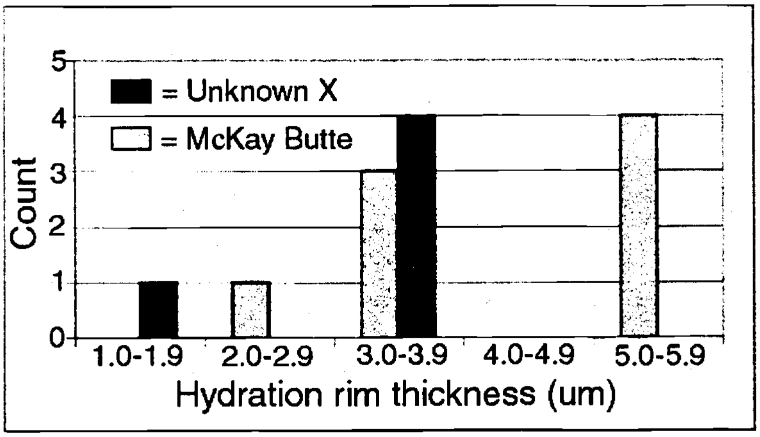

Figure 5.18: Distribution of McKay Butte and Unknown X hydration values.

did not undergo warming during the warmer periods that open sites are susceptable to. All of these samples, including the 2.9 µm reading, may actually represent pre-Mazama artifacts due to the likelihood of reduced hydration rates within the consistently cool lava tube compared to the samples from open sites analyzed in the pipeline project.

Unknown X, a yet undiscovered obsidian source presumed to be in the vicinity of the Newberry and McKay Butte flows, was heavily used almost exclusively in pre-Mazama times (Skinner 1995). This extremely slow-hydrating source was possibly buried by massive Mazama ashfall, limiting its use to the Early Holocene. The Unknown X samples from the same sites used to determine the approximate rate for McKay Butte shows a considerably smaller hydration rim for the dating of the Mt. Mazama eruption which may be as small as 2.5 µm. Four out of five of the Unknown X samples from Bone Cave measure between 3.2 and 3.7 µm (average = 4.5 µm), fitting well within pre-Mazama expectations (see Figure 5.18). The single reading of 1.4 microns could have easily resulted from either an occasional late period occupation of the site that scavenged older material, natural breakage of the sample, or the temperature influence mentioned above for McKay Butte.

The Big Obsidian Flow chemical group is another source that hydrates at a slower rate, and the limited sample from the pre-Mazama pipeline sites speculatively suggest a hydration measurement corresponding to the Mazama ashfall of 2.5 to 3.4 µm (Skinner 1995). The seven samples from the Big Obsidian Flow chemical source analyzed from Bone Cave all measured from 3.0 to 3.5 µm, averaging 3.3 µm. This is almost identical to, if not slightly larger than, the pre-Mazama pattern found in the pipeline project.

The five samples from Bone Cave originating from the Obsidian Cliffs source range from 3.2 to 4.2 µm with an average of 3.6 µm. The pre-Mazama pipeline sample from Obsidian Cliffs also consisted of five specimens that ranged from 4.8 to 7.6 µm. Skinner (1995) estimates the Mazama ashfall at approximately 4.5 µm. While the Bone Cave sample contains smaller hydration rims, both samples are too small to conclude anything other that that they are reasonably close to the estimate for the Mazama ashfall.

The pipeline project produced only one probable pre-Mazama reading on Quartz Mountain obsidian that measured 6.0 µm, but two other samples from a pre-Mazama site in the Newberry Caldera measured 2.5 and 2.9 µm suggesting a slow hydration rate for the source (Skinner 1995). The Bone Cave samples range from 3.2 to 4.6 µm with an average of 3.7 µm. Once again, these are small samples, but a pre-Mazama pattern is certainly suggested.

The two Silver Lake/Sycan Marsh samples both yielded rim values 0.4 µm less than the rough estimate for the correlation with the Mazama ashfall. There were five additional sources that yielded successful hydration measurements, but do not have estimated hydration rates or Mazama estimates. The sample from Brooks Canyon and both samples from Cougar Mountain yielded rims of 3.4 and 3.7 µm respectively. The remaining five readings come from three different unknown sources, Unknowns 1-3. The measurements from these sources vary from 3.2 to 5.2 µm. Assuming that these five sources hydrate at rates similar to other central Oregon sources, then the assessment of a pre-Mazama occupation seems reasonable.

Bone Cave represents a rare instance in archaeology when a completely disturbed site can still yield convincing chronological data. While some questions still remain about the validity of comparing hydration rim measurements of samples from different sources, the pre-Mazama/Early Holocene pattern seen elsewhere in the upper Deschutes Basin is certainly apparent in the Bone Cave assemblage.

Faunal Analysis

Faunal remains constituted by far the most abundant class of artifacts recovered from the excavation of Bone Cave. The vast majority of the bones are the remains of small mammals. While the obsidian studies suggest that the site predated the Mazama ashfall, the bone exhibited exceptional preservation, leading to the assumption that it may be the result of more recent natural deaths and possibly coyote accumulation that became mixed throughout the sediments during looting activities. The following analysis consists of a small sample sent to Deborah Olson in Pullman, Washington to determine if any of the bone accumulation resulted from cultural processes and to determine general species diversity and examine possible cultural modification (the letter report is included as Appendix 3).

The sample analyzed included all of the faunal remains recovered from alternate levels of Unit 4 (Levels 2, 4, 6, and 8). The high density of extremely small unidentifiable bone fragments encountered during screening discouraged collection of the fragments under 8mm in size. Without the small fragments, 3877 bones and bone fragments were analyzed from the four levels.

The faunal assemblage contained very limited species diversity. Over 57 percent of the remains were identified to genus and more than 34 percent to the family level. The majority of the remains are of three species of rabbit: hare or jackrabbit (*Lepus sp.*), cottontail (*Sylvilagus nuttalli*), and pygmy rabbit (*Sylvilagus idahoensis*). Other taxa present include *Canis sp.*, pronghorn antelope (*Antilocapra americana*), deer (*Odocoileus sp.*), a very small number of unidentified rodent bones, and a single humerus fragment from a duck (Cygininae). Level 1 (not included in this analysis) also contained a single snake vertebra and possible bat maxilla fragment. The rabbit taxa dominate the assemblage, accounting for 91.1 percent of the sample by count. The small species diversity itself suggests human cultural accumulation of the faunal assemblage.

Fifty-eight specimens exhibited direct cultural modification in the form of butchering cut marks, fractures associated with marrow removal, and one possible tool fragment. Of the 31 fragments with cut marks, only 5 were on rabbit specimens. The cut marks were mostly located on fragments of long bones. More than half of the cut specimens came from Level 6, which contained the largest faunal sample.

The bone breakage patterns provide further evidence of cultural activity. The medium-sized mammal bones appear to have been fractured in an attempt to extract marrow, some exhibiting impact fractures and negative flake scars resulting from striking the bone with a tool. While carnivore gnawing can sometimes produce similar fracture patterns, none of the other attributes associated with carnivore accumulation such as stained, polished, or pitted bones, or rounded and thinned fractured surfaces (Schmitt and Juell 1994) are present. Almost all of the rabbit remains appear broken, and long bone fragments seem more numerous than can be accounted for by the number of epiphyses. Notably rare in the assemblage are vertebra and vertebral fragments.

The pattern of burnt bone also suggests human cultural activity. Natural burns are extremely unlikely within the site due to the lack of plant debris accumulation. It is possible that historic fires on top of the site sediments may have charred some of the bone in the upper levels, but the majority of burning appears on limb bones with almost no burning of cranial or axial bones. Natural or historic fires would have burnt all skeletal elements equally. Some of the long bones show evidence of burning while meat was still intact.

One possible bone awl fragment was noted in the faunal assemblage. It is a medium-sized mammal metatarsal shaft fragment with the distal portion fractured to a point. The sides and the point are rounded and polished, although no macroscopic striae were observed.

The faunal assemblage appears to have resulted primarily from human exploitation of large numbers of rabbits and occasional larger mammals such as deer and antelope. Excavations at two sites in the Christmas Lake Valley, the eastern-most sub-basin of the Fort Rock Basin, by Oetting (1994) revealed a similar faunal assemblage interpreted as the remains of rabbit processing sites associated with Early Holocene rabbit drives. Site 35LK1881 contained a buried feature hearth feature, extensive lithic debitage, and almost ten thousand identifiable faunal remains. Approximately 98 percent of the faunal assemblage was identified as one of same three rabbit species found in the Bone Cave assemblage. The four radiocarbon dates predate the Mazama ashfall, ranging from 8080 to 9120 B.P. ± 120 years.

The excavation of site 35LK2076 revealed four smaller charcoal features over a 20 square meter area. A smaller lithic assemblage, but a similar faunal assemblage as the above site was also recovered. Three radiocarbon dates from charcoal samples were 8780 ± 120 B.P., 8780 ± 200 B.P. and 10,020 ± 370 B.P. These sites were interpreted as the remains of organized or repeated rabbit processing events that may have resembled Great Basin ethnographic accounts of rabbit drives (Oetting 1994).

Food resources and fresh water sources are widely scattered in the High Lava Plains, and have likely remained so since at least the Early Holocene. The organized hunting and processing of large numbers of rabbits may have provided the resource density required to support the population that inhabited Bone Cave. The sheltered site may have been an ideal location for rabbit processing in the early spring when a small snow pack inside the front chamber could have been the only significant water source in the area.

Modern Debris

In addition to the lithics and faunal remains, modern trash was recovered from almost every excavation level. While this provides crucial evidence as to the extent of site sediment disturbance, all of the historic items appear less than 20 or 30 years old, and are therefore not analyzed as historic artifacts.

A wide variety of items were recovered including large amounts of clear and brown glass, a shotgun shell, 22 caliber bullets and casings, beer bottle tops, a large nail, a plastic straw, a plastic beef jerky package, a beer can pull-tab, cigarette butts, and a foil Hallmark™ wrapper. Units 1 and 2 contained the most interesting assortment of historic debris. Two boards were discovered in Unit 1, one of which appeared to have been part of a screen that may have been used in the looting of the site. The boards extended more than 50 cm below the surface of the unit. A large concentration of beer cans, beer bottles, a milk carton, a cigarette wrapper, and *Coke Classic*™ cans were recovered from 50 cm to 70 cm below the surface in Unit 2, immediately above the isolated human remain fragment found in the unit. The presence of the *Coke Classic*™ cans indicates that the looting activities responsible for at least the last disturbance of the human remains occurred within the last 15 years.

The presence of historic debris in the lowest level of all units excavated, with the exception of Unit 1, clearly reveals the disturbance of all of the excavated sediments. Dark patches found in Units 3 and 4 were originally though to possibly represent intact middens until multiple historic artifacts were recovered from the interior of these patches with no sign of intrusive sediments.

Chapter 6: Synthesis and Conclusion

Excavations were conducted at Bone Cave to determine the extent of site disturbance and examine the contribution of the site to the understanding of regional archaeology. More than 10 m^3 were excavated from six 1-x-2 meter test units distributed throughout the front chamber of the lava tube. Work at the site ceased at the request of the consulting Native American Tribes upon the recovery of isolated of an isolated human bone fragment and two human teeth. Only one unit had reached bedrock and no undisturbed deposits were encountered.

The lack of an undisturbed sample for comparison prohibited the examination of looter behavior in detail. An understanding of their effect on archaeological deposits might aid in the further interpretation of looted sites. Aside from eliminating most contextual information, the site disturbance at Bone Cave most likely affected the tool assemblage, especially the recovery of formal diagnostic tools.

Analysis of the lithic debitage provided valuable information about the general pattern of stone tool use at the site. No differences in the lithic assemblage were found between the front, center, and rear of the chamber, allowing for the entire debitage sample to be treated as a single analytical unit. Of the five major raw material types that all showed similar reduction stages, obsidian comprised more than 92 percent of the debitage. Late-stage bifacial reduction and tool rejuvination seem to have been the primary lithic activities conducted at the site, with no indication of early-stage core reduction. The limited tool assemblage includes mostly small, well-worked bifacial fragments that support the conclusions made about the debitage assemblage.

Obsidian characterization and obsidian hydration studies proved extremely valuable. Thirteen chemically distinct obsidian sources were recovered from an XRF sample of only 49 obsidian flakes and tools. The vast majority of the debitage originated from the nearby sources of Obsidian Cliffs, McKay Butte, Quartz Mountain, Unknown X, and the Big Obsidian Flow chemical group, while the tools were made from obsidian from unknown or distant sources such as Chickahominy and Whitewater Ridge. Unprocessed lithic material is unlikely to be transported great distances, but curated tools such as knives and projectile points, are often not discarded until highly mobile groups have moved to remote camps that are distant from the source (Ingbar 1994; Jenkins and Connolly 1994; Close 1996). As expected, the amount of debitage from a particular source roughly correlates with its distance from the site.

Important in the analysis of obsidian characterization results is an understanding of the mode of lithic procurement. There is no evidence of significant lithic trade in the Northern Great Basin (Minor and Toepel 1989), especially during the Early Holocene, and therefore the distribution of the obsidian sources may represent the extent of mobility for Bone Cave inhabitants (Skinner 1995). If obsidian sources were evenly distributed throughout the Northern Great Basin and Columbia Plateau, determination of the probable ethnic affiliation of Bone Cave occupants would involve demonstrating that the distribution of sources utilized extends south from the site into the Northern Great Basin, suggesting a Great Basin affiliation of the site inhabitants. Instead, the lower Deschutes Basin is lacking substantial obsidian sources, and in fact, the pattern of raw material use at sites in the upper Deschutes Basin is similar to the pattern found in lower Deschutes sites. Without the diagnostic tool assemblage, it becomes difficult to distinguish between a site occupation by groups from the Northern Great Basin, the lower Deschutes Basin, or a group indigenous to the upper Deschutes Basin.

Both the obsidian characterization and obsidian hydration analyses provide convincing evidence of a predominantly pre-Mazama (pre-6,800) occupation of the site. McKay Butte and Unknown X obsidian is rarely recovered from post-Mazama sites in the upper Deschutes Basin (Skinner 1995). These two sources account for nearly 40 percent of the XRF sample. The obsidian hydration rim measurements for all of the known sources are compatible with pre-Mazama measurements from two well-documented sites with pre-Mazama components (Skinner 1995). The lack of any, more recent, hydration rims suggests that the site may have been abandoned some time prior to 6,800 B.P.

The faunal analysis contributed perhaps the most valuable information about site function. Various rabbit species comprised more than 91 percent of the faunal assemblage, and there is clear evidence of butchering and cooking of the rabbits. Some larger mammals such as deer and antelope were present, and also show cut marks indicative of butchering practices. The overwhelming dominance of rabbit remains suggests that the site was used as a rabbit processing location. It is possible that the rabbits were collected through large rabbit hunts evident in the Early Holocene in the Fort Rock Basin (Oetting 1994), and well documented in the ethnographic literature from the Great Basin (Steward 1938; Wheat 1967; Fowler 1982; Fowler 1992). With limited and widely dispersed food resources, the rabbit drives may have provided the necessary resource density to support a population inhabiting the High Lava Plains, at least on a seasonal basis. A protected snow pack within the cave could have served as a water source during the spring in an area lacking any significant water for miles.

A thorough analysis of the cultural material from Bone Cave has addressed almost every research objective set forth. Often, disturbed sites such as Bone Cave are ignored, or worse, not protected from destructive activities without significant assessment. Intact sites can generally provide more information than similar looted sites, but if carefully studied, disturbed archaeological deposits can still reveal valuable information, and are certainly worth investigating.

BIBLIOGRAPHY

Adams, J. L. (1993). "Mechanisms of wear on ground stone surfaces." Pacific Coast Archaeological Society Quarterly **29**(4): 61-74.

Adovasio, J. M., R. Andrews, et al. (1977). "Perishable industries from Dirty Shame Rockshelter." Tebiwa(7): 1-22.

Adovasio, J. M. and R. L. Andrews (1986). The Numic speakers: not whence but when? Perishable Industries from Dirty Shame Rockshelter. R. L. Andrews, J. M. Adovasio and R. C. Carlisle. Eugene, Oregon. **34**.

Aikens, C. M. (1993). Archaeology of Oregon. Portland, U.S. Department of the Interior Bureau of Land Management.

Aikens, C. M., D. L. Cole, et al. (1977). "Excavations at Dirty Shame Rockshelter Southeastern Oregon." Tebiwa **4**: 1-29.

Aikens, C. M. and R. L. Greenspan (1988). "Ancient lakeside culture in the Northern Great Basin: Malheur Lake, Oregon." Journal of California and Great Basin Anthropology **10**(1): 32-61.

Aikens, C. M. and D. L. Jenkins (1994). Environment, climate, subsistence, and settlement: 11,000 years of change in the Fort Rock Basin, Oregon. Archaeological Researches in the Northern Great Basin: Fort Rock Archaeology Since Cressman. C. M. Aikens and D. L. Jenkins. Eugene, Department of Anthropology and State Museum of Anthropology, University of Oregon. **50:** 1-19.

Aikens, M. C. (1982). Archaeology of the Northern Great Basin: an overview. Man and Environment in the Great Basin. D. B. Madsen and J. F. O'Connell. Washington, D.C., Society for American Archaeology. **2:** 139-155.

Ambrose, W. R. (1998). Obsidian hydration dating at a recent age obsidian mining site in Papua, New Guinea. Archaeological Obsidian Studies Method and Theory. M. S. Shackley. New York, Plenum Press. **3:** 205-222.

Amick, D. S. (1993). "Toolstone use and distribution patterns among Western Pluvial Lakes Tradition points from Southern Nevada." Current Research in the Pleistocene **10**: 49-51.

Amick, D. S. and R. P. Mauldin (1997). "Effects of raw material on flake breakage patterns." Lithic Technology **22**(1): 18-32.

Andrefsky, W. J. (1994). "Raw-material availability and the organization of technology." American Antiquity **59**(1): 21-34.

Andrefsky, W. J. (1998). Lithics: Macroscopic Approaches to Analysis. Cambridge, Cambridge University Press.

Anteves, E. (1948). Climate change and pre-white man. In The Great Basin: With Emphasis on Glacial and Postglacial Time, Bulletin of the University of Utah Vol. 38, No. 20, University of Utah, Salt Lake City.

Baldwin, E. M. (1976). Geology of Oregon. Dubuque, Iowa, Kendall and Hunt.

Bamforth, D. B. (1986). "Technological efficiency and tool curation." American Antiquity **51**(1): 38-50.

Bamforth, D. B. (1991). "Technological organization and hunter-gatherer land use: a California example." American Antiquity **56**(2): 216-234.

Barber, R. L. and T. L. Holtzapple (1998). Dudley House Pit Excavations at Big Summit Prarie, Ochoco Mountians. Bend, Archaeological Society of Central Oregon.

Basgall, M. E. and M. A. Giambastiani (1995). Prehistoric Use of a Marginal Environment: Continuity and Change in Occupation of the Volcanic Tablelands, Mono and Inyo Counties, California. Davis, California, Center for Archaeological Research at Davis.

Baumler, M. F. and C. E. Downum (1989). Between micro and macro: a study in the interpretation of small-sized lithic debitage. Experiments in Lithic Technology. D. S. Amick and R. P. Mauldin. Oxford, BAR. **528:** 101-116.

Beck, C. and G. T. Jones (1993). "The multipurpose function of the Great Basin stemmed series points." Current Research in the Pleistocene **10**: 52-54.

Beck, C. and G. T. Jones (1997). "The Terminal Pleistocene/Early Holocene archaeology of the Great Basin." Journal of World Prehistory **11**(2): 161-236.

BECON (1982). Cultural Resource Reconnaissance and Assessment Within the City of Bend Sludge Disposal and Ultimate Effluent Pond Areas. Bend, BECON.

Bedwell, S. F. and L. S. Cressman (1972). "Fort Rock report: Prehistory and the environment of the pluvial Fort Rock Lake area of South-Central Oregon." : 1-25.

Bettinger, R. L. (1978). "Alternative adaptive strategies in the prehistoric Great Basin." Journal of Anthropological Research **34**: 27-46.

Bettinger, R. L. (1982). "The Numic spread: Great Basin cultures in competition." American Antiquity **47**(3): 485-503.

Bettinger, R. L. (1991). Hunter-Gatherers: Archaeological and Evolutionary Theory. New York, Plenum Press.

Bettinger, R. L. (1993). "Doing Great Basin Anthropology Recently: coping with variability." Journal of Archaeological Research **1**(1): 43-66.

Bettinger, R. L., M. G. Delacorte, et al. (1984). Visual sourcing of Central Eastern California obsidians. Obsidian Studies in the Great Basin. R. Hughes. Berkeley, Archaeological Research Facility, University of California Berkeley. **45:** 63-78.

Bettinger, R. L., J. F. O'Connell, et al. (1991). "Projectile points as time markers in the Great Basin." American Anthropologist **93**: 166-173.

Binford, L. R. (1967). "Smudge pits and hide smoking: the use of analogy in archaeological reasoning." American Antiquity **32**(1): 1-12.

Binford, L. R. (1979). "Organization and formation processes: looking at curated technologies." Journal of Anthropological Research **35**(3): 255-273.

Binford, L. R. (1980). "Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation." American Antiquity **45**(1): 4-20.

Bloomer, W. W. (1991). "Reduction assemblage models in the interpretation of lithic technology at the Tosawihi Quarries, North-Central Nevada." Journal of California and Great Basin Anthropology **13**(2): 204-216.

Boone, J. L. and E. A. Smith (1998). "Is it evolution yet? A critique of evolutionary archaeology." Current Anthropology **39**(Supplement): S141-S173.

Bouey, P. D. and M. E. Basgall (1984). Trans-Sierran exchange in Prehistoric California: the concept of economic articulation. Obsidian Studies in the Great Basin. R. Hughes. Berkeley, Archaeological Research Facility, University of California Berkeley. **45:** 135-172.

Broughton, J. M. and D. K. Grayson (1993). "Diet breadth, adaptive change, and the White Mountain faunas." Journal of Archaeological Science **20**: 331-336.

Broughton, J. M. and J. F. O'Connell (1999). "On evolutionary ecology, selectionist archaeology, and behavioral archaeology." American Antiquity **64**(1): 153-165.

Bryan, A. L. (1988). The relationship of the Stemmed Point and Fluted Point traditions in the Great Basin. Early Human Occupation in the Far Western North America: the Clovis-Archaic Interface. J. A. Willig, M. C. Aikens and J. L. Fagan. Carson City, Nevada, Nevada State Museum. **21:** 53-74.

Callahan, E. (1979). "The basics of biface knapping in the Eastern Fluted Point Tradition: a manual for flintknappers and lithic analysts." Archaeology of Eastern North America **7**(1): 1-180.

Cannon, W. J., C. C. Creger, et al. (1990). A wetlands and uplands settlement-subsistence model for Warner Valley, Oregon. Wetland Adaptations in the Great Basin. J. C. Janetski and D. B. Madsen. Provo, Utah, Bringham Young University: 173-182.

Carr, P. J. (1994). Technological organization and prehistoric hunter-gatherer mobility: examination of the Hayes site. The Organization of North American Prehistoric Chipped Stone Tool Technologies. P. J. Carr. Ann Arbor, Michigan: 35-44.

Clemmer, R. O. and O. C. Stewart (1986). Treaties, reservations and claims. Handbook of North American Indians: Great Basin. W. L. D'Azevedo. Washington D.C., Smithsonian Institution Press. **11:** 525-557.

Close, A. E. (1996). "Carry that weight: the use and transportation of stone tools." Current Anthropology **37**(3): 545-553.

Connolly, T. J. (1995). Human and Environmental Holocene Chronology in Newberry Crater, Central Oregon. Eugene, State Museum of Anthropology, University of Oregon.

Connolly, T. J. and D. L. Jenkins (1997). "Population dynamics on the Northwestern Great Basin periphery: clues from obsidian geochemistry." Journal of California and Great Basin Anthropology: 241-250.

Connolly, T. J., D. L. Jenkins, et al. (1993). Archaeology of Mitchell Cave (35WH122): a Late Period Hunting Camp in the Ochoco Mountains, Wheeler County, Oregon. Eugene, Department of Anthropology and Oregon State Museum of Anthropology, University of Oregon.

Cressman, L. S. (1948). "Odell Lake site: a new Paleo-indian campsite in Oregon." American Antiquity **13**(1): 57-58.

Davis, C. M. and S. A. Scott (1991). "The Lava Butte Site revisited." Journal of California and Great Basin Anthropology **13**(1): 40-59.

Dibble, H. L. and A. Pelcin (1995). "The effect of hammer mass and velocity on flake mass." Journal of Archaeological Science **22**: 429-439.

Earle, T. K. and J. E. Ericson (1977). Exchange systems in archaeological perspective. Exchange Systems in Prehistory. T. K. Earle and J. E. Ericson. New York, Academic Press: 3-12.

Evans, C. and B. J. Meggers (1960). "A new dating method using obsidian: part II, an archaeological evaluation of the method." American Antiquity **25**(4): 523-537.

Fagan, B. M. (1987). The Great Journey. New York, Thames and Hudson.

Fink, T. M. (1994). "Hantavirus pulmonary syndrome and Southwestern archaeologists: a protocol for risk reduction." Kiva **59**(3): 363-365.

Flenniken, J. J. (1985). Stone tool reduction techniques as cultural markers. Stone Tool Analysis: Essays in Honor of Don E. Crabtree. M. G. Plew, J. C. Woods and M. G. Pavisic. Albuquerque, University of New Mexico Press: 265-276.

Flenniken, J. J. and A. W. Raymond (1986). "Morphological projectile point typology: replication experiments and technological analysis." American Antiquity **51**(3): 603-614.

Fowler, C. S. (1982). Settlement patterns and subsistence systems in the Great Basin: the ethnographic record. Man and Environment in the Great Basin. D. B. Madsen and J. F. O'Connell. Washington, D.C., Society for American Archaeology. **2:** 121-138.

Fowler, C. S. (1992). In the Shadow of Fox Peak: an Ethnography of the Cattail-Eater Northern Paiutte People of Stillwater Marsh, U.S. Department of the Interior Fish and Wildlife Service, Region 1 Stillwater National Wildlife Refuge.

Fowler, D. D. (1980). "History of Great Basin anthropological research, 1776-1979." Journal of California and Great Basin Anthropology **2**(1): 8-36.

Fowler, D. D. (1986). History of research. Handbook of North American Indians: Great Basin. W. L. D'Azevedo. Washington D.C., Smithsonian Institution Press. **11:** 15-30.

Fowler, D. D. and C. S. Fowler, Eds. (1971). Anthropology of the Numa: John Wesley Powell's Manuscripts on the Numic Peoples of Western North America 1868-1880. Washington D.C., Smithsonian Institution Press.

Freidel, D. E. (1994). Paleolake shorelines and lake level chronology of the Fort Rock Basin, Oregon. Archaeological Researches in the Northern Great Basin: Fort Rock Archaeology Since Cressman. C. M. Aikens and D. L. Jenkins. Eugene, Department of Anthropology and State Museum of Anthropology, University of Oregon. **50:** 21-40.

Friedman, I. and R. L. Smith (1960). "A new dating method using obsidian: part I, the development of the method." American Antiquity **25**(4): 476-493.

Friedman, I., F. W. Trembor, et al. (1994). "Is obsidian hydration dating affected by relative humidity?" Quaternary Research **41**: 185-190.

Gaston, J. (1983). Alternative Cultural Resource Management Strategies: The Pendulum and the Pits. 9th International Congress of Anthropological and Ethnological Sciences, Vancouver, B.C.

Glascock, M. D., G. E. Braswell, et al. (1998). A systematic approach to obsidian source characterization. Archaeological Obsidian Studies Method and Theory. M. S. Shackley. New York, Plenum Press. **3:** 15-66.

Gould, R. A. and S. Saggers (1985). "Lithic procurement in Central Australia: a closer look at Binford's idea of embeddedness in archaeology." American Antiquity **50**(1): 117-136.

Gramly, R. M. (1980). "Raw materials source areas and "curated" tool assemblages." American Antiquity **45**(4): 823-833.

Grayson, D. K. (1977). "Paleoclimatic implications of the Dirty Shame Rockshelter mammalian fauna." Tebiwa **9**: 1-26.

Grayson, D. K. (1993). Ch. 9: The prehistoric archaeology of the Great Basin. The Desert's Past**:** 233-276.

Greeley, R. (1971). Geology of Selected Lava Tubes in the Bend Area, Oregon. Portland, Department of Geology and Mineral Industries.

Green, R. C. (1998). A 1990's perspective on method and theory in archaeological volcanic glass studies. Archaeological Obsidian Studies Method and Theory. M. S. Shackley. New York, Plenum Press. **3:** 223-236.

Hall, H. J. (1977). "A paleoscatological study of diet and disease at Dirty Shame Rockshelter, Southeast Oregon." Tebiwa **8**: 1-15.

Hampel, J. H. (1984). Technical considerations in X-ray fluorescence of obsidian. Obsidian Studies in the Great Basin. R. Hughes. Berkeley, Archaeological Research Facility, University of California Berkeley. **45:** 21-27.

Hanes, R. E. (1977). "Lithic tools of the Dirty Shame Rockshelter: typology and distribution." Tibiwa **6**: 1-24.

Hayden, B. and W. K. Hutchings (1989). Whither the billet flake? Experiments in Lithic Technology. D. S. Amick and R. P. Mauldin. Oxford, BAR. **528:** 235-258.

Hopkins, N. A. (1965). "Great Basin prehistory and Uto-Aztecan." American Antiquity **31**(1): 48-60.

Houser, M. (1996). A Prehistoric Overview of Deschutes County. Bend, Deschutes County Community Development Department.

Hughes, R. E. (1984). Obsidian sourcing in the Great Basin: prospects and problems. Obsidian Studies in the Great Basin. R. Hughes. Berkeley, Archaeological Research Facility, University of California Berkeley. **45:** 1-20.

Ice, D. M. (1962). Archaeology of the Lava Butte Site, Deschutes County, Oregon. Pullman, Washington State University, Pullman.

Ingbar, E. E. (1994). Lithic material selection and technological organization. The Organization of North American Prehistoric Chipped Stone Tool Technologies. P. J. Carr. Ann, Arbor, Michigan, Internation Monographs in Prehistory. **7:** 45-56.

Jackson, R. J. (1984). Current problems in obsidian hydration analysis. Obsidian Studies in the Great Basin. R. Hughes. Berkeley, Archaeological Research Facility, University of California Berkeley. **45:** 103-115.

Jenkins, D. L. (1998). "The University of Oregon's Fort Rock Basin prehistory project: 10 years of intensive research." Current Archaeological Happenings in Oregon **23**(3): 11-13.

Jenkins, D. L. and T. J. Connolly (1990). Archaeology of Indian Grade Spring: a Special Function Site on Stinkingwater Mountain, Harney County, Oregon. Eugene, Oregon State Museum Of Anthropology.

Jenkins, D. L. and T. J. Connolly (1994). Archaeological Excavations at the Paquet Gulch Bridge Site: a Pithouse Village in the Deschutes River Basin, Southwestern Columbia Plateau, Oregon. Eugene, Department of Anthropology and Oregon State Museum of Anthropology, University of Oregon.

Jenkins, D. L. and J. M. Erlandson (1996). "Olivella grooved rectangular beads from a Middle Holocene site in the Fort Rock Valley, Northern Great Basin." Journal of California and Great Basin anthropology: 296-302.

Jenkins, D. L., C. E. Skinner, et al. (1999). Obsidian chartacterization and hydration results of the Fort Rock Basin prehistory project. Northwest Anthropological Conference, Newport, Oregon.

Jennings, J. D. and E. Norbeck (1955). "Great Basin prehistory: a review." American Antiquity **21**(1): 1-11.

Jones, M., P. J. Sheppard, et al. (1997). "Soil temperature and obsidian hydration dating: a clarification of variables affecting accuracy." Journal of Archaeological Science **24**: 505-516.

Jones, S. (1997). The Archaeology of Ethnicity. New York, Routledge.

Kelly, R. L. (1983). "Hunter-gatherer mobility strategies." Journal of Anthropological Research: 277-306.

Kelly, R. L. (1988). "Coming into the country: Early Paleoindian hunting and mobility." American Antiquity **53**(2): 231-244.

Kelly, R. L. (1988). "The three sides of a biface." American Antiquity **53**(4): 717-734.

Kelly, R. L. (1995). The Foraging Spectrum. Washington D.C., Smithsonian Institution Press.

Kelly, R. L. (1997). "Late Holocene Great Basin prehistory." Journal of World Prehistory **11**(1): 1-49.

Kittleman, L. R. (1977). "Preliminary report on the geology of Dirty Shame Rockshelter Malheur County, Oregon." Tebiwa **5**: 1-22.

Kobayashi, H. (1982). The experimental study of bipolar flakes. Lithic Technology: Making and Using Stone Tools. E. Swanson. Paris, Mouton Publishers: 115-127.

Krebs, C. J. (1994). Ecology. New York, HarperCollins College Publishers.

Lawrence, R. A. (1979). Experimental evidence for the significance of attributes used in edge-damage analysis. Lithic Use-Wear Analysis. B. Hayden. San Francisco, Academic Press: 113-121.

Lohse, E. S. (1995). "Northern Intermountain West projectile point chronology." Tebiwa **25**: 3-51.

Magne, M. P. R. (1989). Lithic reduction stages and assemblage formation processes. Experiments in Lithic Technology. D. S. Amick and R. P. Mauldin. Oxford, BAR. **528**: 15-32.

Malstrom, K. L. (1996). "Edge attrition on obsidian flakes from wood scraping." Tebiwa **26**(1): 118-122.

Masten, R. A. (1985). A Cultural Resources Survey of the Bonneville Power Administration's Bend Area Support Project, Crook and Deschutes Counties, Oregon. Cheney, Washington, Eastern Washington University.

Matz, S. (1991). The Mazama Tephra-Falls: Volcanic Hazards and Prehistoric Populations. Corvallis, Oregon State University Department of Anthropology.

Mauldin, R. P. and D. S. Amick (1989). Investigating patterning in debitage from experimental bifacial core reduction. Experiments in Lithic Technology. D. S. Amick and R. P. Mauldin. Oxford, BAR. **528:** 67-88.

McBrearty, S., L. Bishop, et al. (1998). "Tools underfoot: human trampling as an agent of lithic artifact edge modification." American Antiquity **63**(1): 108-129.

Minor, R. and K. A. Toepel (1984). Lava Island Rockshelter: an Early Hunting Camp in Central Oregon. Pocatello, Idaho, Idaho Museum of Natural History.

Minor, R. and K. A. Toepel (1989). "Exchange items or Hunters' tools? Another look at the lanceolate bifaces caches in Central Oregon." Journal of California and Great Basin Anthropology **11**(1): 99-107.

Minor, R., K. A. Toepel, et al. (1988). The Inn of the Seventh Mountain Lithic Scatters: Post-Mazama Hunting Camps in the Cascade Foothills of Central Oregon. Eugene, Heritage Research Associates.

Monks, G. G. (1981). Seasonality studies. Advances in Archaeological Method and Theory. M. B. Schiffer, Academic Press. **4:** 177-240.

Morrow, C. A. and R. W. Jeffries (1989). Trade or embedded procurement?: a test case from Southern Illinois. Time, Energy and Stone Tools. R. Torrence. New York, Academic Press: 27-33.

Musil, R. R. (1995). Adaptive Transitions and Environmental Change in the Northern Great Basin: a View from Diamond Swamp. Eugene, University of Oregon.

Muto, G. R. (1971). A stage analysis of the manufacture of stone tools. Great Basin Anthropological Conference 1970 Selected Papers. C. M. Aikens. Eugene, University of Oregon Museum of Natural History. **1:** 109-118.

Nelson, F. W. J. (1984). X-ray fluorescence analysis of some Western North American obsidians. Obsidian Studies in the Great Basin. R. Hughes. Berkeley, Archaeological Research Facility, University of California Berkeley. **45:** 27-62.

Nelson, M. C. (1991). The study of technological change. Archaeological Method and Theory. M. B. Schiffer. New York, Academic Press. **3:** 57-100.

O'Brien, M. J. (1996). Preface and Acknowledgements. Evolutionary Archaeology: Theory and Application. M. J. O'Brien. Salt Lake City, University of Utah Press: xiii-xv.

O'Connell, J. F. (1982). Some thoughts on prehistoric archaeology in the Great Basin. Man and Environment in the Great Basin. D. B. Madsen and J. F. O'Connell. Washington, D.C., Society for American Archaeology. **2:** 227-240.

Oetting, A. C. (1989). Villages and Wetlands Adaptations in the Northern Great Basin: Chronology and Land Use in the Lake Abert-Chewaucan Marsh Basin-Lake County, Oregon. Eugene, Department of Anthropology and Oregon State Museum of Anthropology, University of Oregon.

Oetting, A. C. (1990). Aboriginal settlement in the Lake Abert-Chewaucan Marsh Basin, Lake County, Oregon. Wetland Adaptations in the Great Basin. J. C. Janetski and D. B. Madsen. Provo, Utah, Bringham Young University: 183-206.

Oetting, A. C. (1992). "Lake and marsh-edge settlements on Malheur Lake, Harney County, Oregon." Journal of California and Great Basin Anthropology **14**(1): 110-129.

Oetting, A. C. (1994). Chronology and time markers in the Northwestern Great Basin: the Chewaucan Basin cultural chronology. Archaeological Researches in the Northern Great Basin: Fort Rock Archaeology Since Cressman. C. M. Aikens and D. L. Jenkins. Eugene, Department of Anthropology and State Museum of Anthropology, University of Oregon. **50:** 41-62.

Oetting, A. C. (1994). Early Holocene rabbit drives and prehistoric land use patterns on Buffalo Flat, Christmas Lake Valley, Oregon. Archaeological Researches in the Northern Great Basin: Fort Rock Archaeology Since Cressman. C. M. Aikens and D. L. Jenkins. Eugene, Department of Anthropology and State Museum of Anthropology, University of Oregon. **50:** 155-169.

Ozbun, T. L. (1991). "Boulders to bifaces: initial reduction of obsidian at Newberry Crater, Oregon." Journal of California and Great Basin Anthropology **13**(2): 147-159.

Patterson, L. W. (1990). "Characteristics of bifacial-reduction flake-size distribution." American Antiquity **55**(3): 550-558.

Pelcin, A. (1997). "The effect of indentor type on flake attributes: evidence from a controlled experiment." Journal of Archaeological Science **24**: 613-621.

Pelcin, A. W. (1997). "The effect of core morphology on flake attributes: evidence from a controlled experiment." Journal of Archaeological Science **24**: 749-756.

Pelcin, A. W. (1997). "The formation of flakes: the role of platform thickness and exterior platform angle in the production of flake initiations and terminations." Journal of Archaeological Science **24**: 1107-1113.

Peterson, N. V., et al. (1976). Geology and Mineral Resouces of Deschutes County Oregon. Portland, Department of Geology and Mineral Industries.

Pettigrew, R. M. (1996). Prehistory chapter. A Prehistoric Overview of Deschutes County. M. Houser. Bend, Deschutes County Community Development Department. **HPF 9516:** 14-27.

Pettigrew, R. M. (1998). Final Technical REport of Cultural Resource Studies Pelton-Round Butte Hydroelectric Project FERC No. 2030. Eugene.

Pettigrew, R. M. and R. L. Spear (1984). Archaeological Investigations of Two Sites (35DS56 and 57) on the Cascade Lakes Highway, Deschutes County, Oregon. Eugene.

Prentiss, W. C. and E. J. Romanski (1989). Experimental evaluation of Sullivan and Rozen's debitage typology. Experiments in Lithic Technology. D. S. Amick and R. P. Mauldin. Oxford, BAR. **528:** 89-100.

Ridings, R. (1996). "Where in the world does obsidian hydration dating work?" American Antiquity **61**(1): 136-148.

Rondeau, M. F. (1996). When is an Elko? Stone Tools: Theoretical Insights into Human Prehistory. G. Odell. New York, Plenum Press: 229-243.

Rotell, D. A., C. E. Skinner, et al. (1998). A preliminary report from the Malheur National Forest obsidian characterization project: insights on prehistoric use of Strawberry Mountain Obsidian. Great Basin Anthropological Conference.

Rozen, K. C. and A. P. I. Sullivan (1989). "The nature of lithic reduction and lithic analysis: stage typologies revisited." American Antiquity **54**(1): 179-184.

Schmitt, D. N. and K. E. Juell (1994). "Toward the identification of coyote scatological faunal accumulations in archaeological contexts." Journal of Archaeological Science **21**: 249-262.

Schneider, J. S. (1993). "Milling implements: biases and problems in their use as indicators of prehistoric behavior and paleoenvironment." Pacific Coast Archaeological Society Quarterly **29**(4): 5-21.

Scott, S. A. (1991). "Problems with the use of flake size in inferring stages of lithic reduction." Journal of California and Great Basin Anthropology **13**(2): 172-179.

Scott, S. A., C. M. Davis, et al. (1986). "The Pahoehoe site: a lanceolate biface cache in Central Oregon." Journal of California and Great Basin Anthropology **8**(1): 7-23.

Shackley, M. S. (1996). Range and mobility in the early hunter-gatherer Southwest. Early Formative Adaptations in the Southern Southwest. B. J. Roth. Madison, Wisconsin, Prehistory Press. **25:** 5-18.

Shea, J. J. and J. D. Klenck (1993). "An experimental investigation of the effects of trampling on the results of lithic microwear analysis." Journal of Archaeological Science **20**: 175-194.

Sheets, P. D. (1994). "Tropical time capsule." Archaeology **1994**(July/August): 30-33.

Shott, M. J. (1989). "Bipolar industries: ethnographic evidence and archaeological implications." North American Archaeologist **10**(1): 1-24.

Shott, M. J. (1994). "Size and form in the analysis of flake debris: review and recent approaches." Journal of Archaeological Method and Theory **1**(1): 69-110.

Shott, M. J. (1996). "An exegesis of the curation concept." Journal of Anthropological Research **52**(3): 259-280.

Shott, M. J. (1996). "Stage versus continuum in the debris assemblage from production of a fluted biface." Lithic Technology **21**(1): 6-22.

Sidrys, R. and J. Kimberlin (1979). "Use of Mayan obsidian sources through time: trace-element data from El Balsamo, Guatemala." Journal of Field Archaeology **6**: 116-122.

Skinner, C. (1999). Introduction to Obsidian Characterization Studies, http://www.obsidianlab.com/info_xrf.html.

Skinner, C. (1999). Introduction to Obsidian Hydration Studies, http://www.obsidianlabs.com/info_oh.html.

Skinner, C. E. (1995). Obsidian characterization studies. Archaeological Investigations PGT-Pg&E Pipeline Expansion Project Idaho, Washington, Oregon, and California. M. J. Moratto. Fresno, Infotec Research. **5:** 4.1-4.54.

Skinner, C. E. (1995). Obsidian hydration studies. Archaeological Investigations PGT-Pg&E Pipeline Expansion Project Idaho, Washington, Oregon, and California. M. J. Moratto. Fresno, Infotec Research. **5:** 5.1-5.42.

Smith, D. G., R. L. Bettinger, et al. (1994) Serum albumin phenotypes at Stillwater: implications for population history in the Great Basin.

Smith, E. A. (1983). "Anthropological applications of optimal foraging theory: a critical review." Current Anthropology **24**(5): 625-651.

Stevenson, C. M., J. J. Mazer, et al. (1998). Laboratory obsidian hydration rates: theory, method and application. Archaeological Obsidian Studies Method and Theory. M. S. Shackley. New York, Plenum Press. **3:** 181-204.

Stevenson, C. M., P. J. Sheppard, et al. (1996). "Advances in the hydration dating of New Zealand Obsidian." Journal of Archaeological Science **23**: 233-242.

Steward, J. H. (1938). Basin-Plateau Aboriginal Sociopolitical Groups. Washington D. C., University of Utah Press (1970).

Sullivan, A. P. I. and K. C. Rozen (1985). "Debitage analysis and archaeological interpretation." American Antiquity **50**(4): 755-779.

Sutton, M. Q. (1986). "Warfare and expansion: an ethnohistoric perspective on the Numic spread." Journal of California and Great Basin Anthropology **8**(1): 65-82.

Synder, S. L. (1981). "Medicine Creek: pre and post-Mazama occupation in the Cascades." Tebiwa **23**: 1-13.

Thomas, D. H. (1973). "An emperical test for Steward's model of Great Basin settlement patterns." American Antiquity **38**(2): 155-176.

Thomas, D. H. (1978). "Arrowheads and atlatl darts: how the stones got the shaft." American Antiquity **43**(3): 461-472.

Thomas, D. H. (1981). "How to classify projectile points from Monitor Vally, Nevada." Journal of California and Great Basin Anthropology **3**(1): 7-43.

Thomas, D. H. (1986). "Points on points: a reply to Flenniken and Raymond." American Antiquity **51**(3): 619-627.

Toepel, K. A. and R. L. Greenspan (1985). "Fish remains from an "open" archaeological site in the Fort Rock Basin, South-Central Oregon." Journal of California and Great Basin Anthropology **7**(1): 109-117.

Tremaine, K. J. (1989). Obsidian as a Time Keeper: an Investigation in Absolute and Relative Dating. Anthropology. Sonoma, California, Sonoma State University: 119.

Tremaine, K. J. (1993). Temporal ordering of artifact obsidians: relative dating enhanced through the use of accelerated hydration experiments. There Grows a Green Tree: Papers in Honor of David A. Fredrickson. G. White, P. Mikkelsen, W. R. Hildebrandt and M. E. Basgall. Davis, Center for Archaeological Research at Davis. **11:** 265-275.

Trembour, F. W. (1983). Appendix 10-A. Obsidian hydration study of prismatic blade fragments from the Cambio site. Archaeology and Volcanism in Central America. P. D. Sheets. Austin, University of Texas Press: 224-226.

Tuohy, D. R. (1987). "A comparison of pressure and percussion debitage from a Crabtree obsidian stoneworking demonstration." Tebiwa **23**: 23-30.

Tykot, R. H. (1998). Mediterranean Islands and multiple flows: the sources and exploitation of Sardinian obsidian. Archaeological Obsidian Studies Method and Theory. M. S. Shackley. New York, Plenum Press. **3**: 67-82.

Walthall, J. A. (1998). "Rockshelters and hunter-gatherer adaptation to the Pleistocene/Holocene transition." American Antiquity **63**(2): 223-238.

Webster, L. D. and K. A. Hays-Gilpin (1994). "New trails for old shoes: sandals, textiles, and baskets in Basketmaker culture." Kiva **60**(2): 313-327.

Weisler, M. I. and D. A. Clague (1998). Characterization of archaeological volcanic glass from Oceania: the utility of three techniques. Archaeological Obsidian Studies Method and Theory. M. S. Shackley. New York, Plenum Press. **3**: 103-128.

Wheat, M. M. (1967). Survival Arts of the Primitive Paiutes. Reno, University of Nevada Press.

Whiting, B. B. (1950). Paiute Sorcery. New York, Reprinted by Johnson Reprint Corporation, 1964.

Wilde, J. D. (1989). "Interpreting late prehistoric use of a desert marsh: the Tule Springs Hearth site, Alvord Basin, Southeastern Oregon." Journal of California and Great Basin Anthropology **11**(2): 215-230.

Willig, J. A. (1981). Pole-and-Thatch Structures in the Great Basin: Evidence from the Last 5000 Years. Department of Anthropology. Eugene, University of Oregon: 23.

Willig, J. A. and C. M. Aikens (1988). The Clovis-Archaic interface in Far Western North America. Early Human Occupation in the Far Western North America: the Clovis-Archaic Interface. J. A. Willig, M. C. Aikens and J. L. Fagan. Carson City, Nevada, Nevada State Museum: 1-40.

Wilson, K. M. (1996). "Obsidian flake edge-wear as a result of trampling in different site matrices." Tebiwa **26**(1): 123-128.

Yocum, C. and V. Brown (1971). Wildlife and Plants of the Cascades: Covering Most of the Common Wildlife and Plants of the Pacific Northwest and the Area of the Lava Beds. Healdsburg, California, Naturegraph Publishers.

Young, D. and D. B. Bamforth (1990). "On the macroscopic identification of used flakes." American Antiquity **55**(2): 403-409.

Young, D. C. J. (1995). "A model of potential marsh productivity and implications for Paleoindian land use, Warner Valley, Oregon." Current Research in the Pleistocene **12**: 115-116.

Young, D. C. J. (1998). Late Holocene Landscapes and Prehistoric Land Use in Warner Valley, Oregon. Anthropology. Reno, University of Nevada: 193.

Appendices

Appendix 1

Obsidian Characterization Data

Northwest Research Obsidian Studies Laboratory

Table A-1. Results of XRF Studies: Bone Cave, Deschutes County, Oregon

	Specimen			Trace Element Concentrations											Ratios		
Site	No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/Chemical Type
Bone Cave	1	1		64	23	133	64	44	166	4	204	120	NM	0.32	44.7	57.2	Quartz Mountain *
			±	13	7	4	7	4	7	4	95	47	NM	0.11			
Bone Cave	2	2		66	35	168	70	39	201	13	491	134	NM	0.54	57.7	38.2	McKay Butte *
			±	14	7	5	7	4	7	3	95	47	NM	0.11			
Bone Cave	3	3		76	23	113	49	55	125	9	207	133	NM	0.33	38.6	57.0	Cougar Mountain? *
			±	11	6	4	7	4	7	3	95	47	NM	0.11			
Bone Cave	4	4		86	29	162	70	44	218	9	783	203	NM	1.05	59.0	43.9	McKay Butte
			±	8	4	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	5	5		137	30	82	44	61	387	18	629	235	NM	0.86	41.2	45.5	Brooks Canyon? *
			±	12	5	4	7	4	8	3	96	47	NM	0.11			
Bone Cave	6	6		66	26	145	68	39	212	14	339	126	NM	0.51	60.9	52.3	McKay Butte *
			±	10	4	4	7	3	7	3	95	47	NM	0.11			
Bone Cave	7	7		77	20	139	80	37	244	8	558	151	NM	0.70	61.1	42.6	Unknown X *
			±	10	5	4	7	3	7	3	95	47	NM	0.11			
Bone Cave	8	8		95	15	69	216	46	359	19	1457	285	NM	1.55	56.3	34.5	Basalt *
			±	9	4	4	7	3	7	2	97	47	NM	0.11			
Bone Cave	9	9		79	19	146	68	51	179	10	268	131	NM	0.54	59.6	67.5	Quartz Mountain *
			±	10	4	4	7	3	7	3	95	47	NM	0.11			
Bone Cave	10	10		53	20	95	126	21	104	8	261	159	NM	0.43	37.7	57.9	Obsidian Cliffs *
			±	9	4	4	7	3	7	2	95	47	NM	0.11			
Bone Cave	11	11		71	12	60	197	36	333	20	1227	235	NM	1.25	58.1	33.4	Basalt *
			±	11	5	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	12	12		82	28	119	48	58	351	18	705	259	NM	1.14	47.1	52.4	Big Obsidian Flow *
			±	9	4	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	13	13		103	38	152	76	43	178	10	287	132	NM	0.52	56.8	61.6	Quartz Mountain *
			±	10	4	4	7	3	7	3	95	47	NM	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Table A-1. Results of XRF Studies: Bone Cave, Deschutes County, Oregon

	Specimen			Trace Element Concentrations											Ratios		
Site	No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/Chemical Type
Bone Cave	14	14		72	22	163	73	41	205	11	500	154	NM	0.72	61.1	48.5	McKay Butte
			±	9	4	4	7	3	7	3	96	47	NM	0.11			
Bone Cave	15	15		103	15	87	220	44	364	15	1641	311	NM	1.85	60.0	36.2	Basalt
			±	9	4	4	7	3	7	2	97	47	NM	0.11			
Bone Cave	16	16		53	14	154	71	37	207	11	483	166	NM	0.79	59.5	54.5	McKay Butte
			±	9	4	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	17	17		78	17	53	172	42	311	10	1019	212	NM	1.08	57.7	35.1	Basalt *
			±	10	5	4	7	3	7	3	96	47	NM	0.11			
Bone Cave	18	18		24	5	2	15	6	223	ND	153	66	NM	0.00	20.8	9.9	Not Obsidian
			±	10	5	3	7	4	7	ND	95	48	NM	0.11			
Bone Cave	19	19		118	21	125	52	58	346	14	442	179	NM	0.67	46.5	51.1	Big Obsidian Flow *
			±	10	5	4	7	4	7	3	95	47	NM	0.11			
Bone Cave	20	20		69	13	84	139	17	121	7	291	112	NM	0.22	38.1	31.6	Obsidian Cliffs *
			±	12	6	4	8	4	7	4	95	47	NM	0.11			
Bone Cave	21	21		111	14	71	185	40	318	15	789	170	NM	0.81	58.9	34.5	Basalt *
			±	13	6	4	8	4	8	3	96	47	NM	0.11			
Bone Cave	22	22		96	26	141	71	36	191	11	426	115	NM	0.39	55.6	33.5	McKay Butte *
			±	11	6	5	7	4	7	3	95	47	NM	0.11			
Bone Cave	23	23		48	17	82	99	14	96	7	213	94	NM	0.09	29.7	23.9	Obsidian Cliffs *
			±	12	6	4	8	4	8	4	95	47	NM	0.11			
Bone Cave	24	24		82	17	102	50	24	150	10	304	76	NM	0.14	58.6	22.1	McKay Butte? *
			±	15	8	6	8	5	8	5	95	47	NM	0.11			
Bone Cave	25	25		54	23	150	66	40	205	17	498	153	NM	0.68	58.3	46.3	McKay Butte
			±	9	4	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	26	26		105	15	71	210	47	362	16	1900	342	NM	2.03	58.8	34.3	Basalt
			±	8	3	3	7	3	7	2	97	47	NM	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Table A-1. Results of XRF Studies: Bone Cave, Deschutes County, Oregon

	Specimen			Trace Element Concentrations											Ratios		
Site	No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/Chemical Type
Bone Cave	27	27		97	25	123	48	53	340	17	614	227	NM	0.99	48.7	52.8	Big Obsidian Flow *
			±	10	4	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	28	28		87	17	62	190	44	354	17	1417	290	NM	1.60	56.5	36.4	Basalt *
			±	8	3	3	7	3	7	2	97	47	NM	0.11			
Bone Cave	29	29		93	15	71	214	46	376	18	3109	535	NM	3.48	60.0	35.3	Basalt
			±	7	3	3	7	3	7	2	99	48	NM	0.11			
Bone Cave	30	30		90	20	78	217	47	377	22	1970	363	NM	2.13	57.6	34.6	Basalt
			±	8	3	3	7	3	7	2	97	47	NM	0.11			
Bone Cave	31	31		79	21	120	51	55	344	15	745	271	NM	1.19	46.6	52.0	Big Obsidian Flow
			±	8	3	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	32	32		109	27	142	54	52	373	18	734	252	NM	1.13	48.4	50.2	Big Obsidian Flow *
			±	8	3	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	33	33		61	26	128	52	54	345	13	427	176	NM	0.71	49.8	55.4	Big Obsidian Flow *
			±	10	4	4	7	4	7	3	95	47	NM	0.11			
Bone Cave	34	34		48	21	149	69	41	217	12	661	218	NM	1.14	58.4	56.1	McKay Butte
			±	7	3	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	35	35		82	24	151	54	57	400	19	884	344	NM	1.66	48.2	60.1	Big Obsidian Flow?
			±	8	3	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	36	36		60	15	85	112	17	99	9	299	141	NM	0.34	36.3	41.6	Obsidian Cliffs *
			±	8	4	4	7	3	7	2	95	47	NM	0.11			
Bone Cave	37	37		51	25	133	65	40	182	12	221	137	NM	0.60	61.8	89.5	Quartz Mountain
			±	8	3	4	7	3	7	2	95	47	NM	0.11			
Bone Cave	38	38		50	14	86	125	17	109	13	322	176	NM	0.49	35.9	52.4	Obsidian Cliffs
			±	8	4	3	7	3	7	2	95	47	NM	0.11			
Bone Cave	39	39		58	27	121	76	42	239	14	498	169	NM	0.76	55.9	50.8	Unknown X *
			±	9	4	4	7	3	7	2	95	47	NM	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Table A-1. Results of XRF Studies: Bone Cave, Deschutes County, Oregon

Site	Specimen No.	Catalog No.		Trace Element Concentrations											Ratios		Artifact Source/Chemical Type
				Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	
Bone Cave	40	40		64	20	139	62	41	195	13	508	156	NM	0.72	59.4	47.6	McKay Butte
			±	8	4	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	41	41		57	22	128	83	42	260	14	1019	286	930	1.58	57.2	50.0	Unknown X
			±	7	3	3	7	3	7	2	97	47	15	0.11			
Bone Cave	42	42		96	20	77	39	61	419	20	631	341	684	1.51	44.4	76.1	Unknown 1
			±	7	3	3	7	3	7	2	96	47	14	0.11			
Bone Cave	43	43		64	22	118	35	56	309	16	1089	416	862	1.95	45.4	57.1	Chickahominy?
			±	6	2	3	7	3	7	1	97	48	13	0.11			
Bone Cave	44	44		62	23	131	43	50	271	11	799	308	904	1.59	52.6	63.6	Unknown 2
			±	7	3	3	7	3	7	2	96	47	13	0.11			
Bone Cave	45	45		69	31	142	68	43	188	8	546	224	956	1.20	59.3	70.8	Quartz Mountain
			±	7	2	3	7	3	7	2	96	47	14	0.11			
Bone Cave	46	46		73	25	132	64	42	182	8	534	282	963	1.60	58.4	94.2	Quartz Mountain
			±	7	2	3	7	3	7	2	96	47	13	0.11			
Bone Cave	47	47		69	21	121	42	45	268	16	911	344	981	1.79	51.7	62.5	Unknown 2
			±	7	2	3	7	3	7	2	97	47	13	0.11			
Bone Cave	48	48		118	37	156	15	63	228	11	266	130	NM	0.58	64.8	73.4	Unknown 3
			±	9	4	4	7	3	7	3	95	47	NM	0.11			
Bone Cave	49	49		88	26	111	43	57	135	19	191	147	NM	0.40	39.6	72.8	Cougar Mountain? *
			±	10	5	4	7	3	7	2	95	47	NM	0.11			
Bone Cave	50	50		77	21	145	63	37	196	13	335	110	NM	0.34	53.7	37.7	McKay Butte *
			±	11	5	5	7	4	7	3	95	47	NM	0.11			
Bone Cave	51	51		93	26	129	73	41	254	4	332	111	NM	0.37	57.2	41.0	Unknown X *
			±	11	5	5	7	4	8	4	95	47	NM	0.11			
Bone Cave	52	52		91	27	165	72	36	222	9	351	124	NM	0.43	53.8	43.7	McKay Butte
			±	11	5	5	7	4	7	3	95	47	NM	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Northwest Research Obsidian Studies Laboratory

Table A-1. Results of XRF Studies: Bone Cave, Deschutes County, Oregon

	Specimen			Trace Element Concentrations											Ratios		
Site	No.	Catalog No.		Zn	Pb	Rb	Sr	Y	Zr	Nb	Ti	Mn	Ba	$Fe_2O_3^T$	Fe:Mn	Fe:Ti	Artifact Source/Chemical Type
Bone Cave	53	53		45	37	101	63	34	192	9	366	94	NM	0.25	56.4	27.7	McKay Butte? *
			±	15	6	5	8	4	8	4	95	47	NM	0.11			
Bone Cave	55	55		76	22	133	7	56	350	16	488	346	NM	1.08	31.9	71.2	Silver Lake/Sycan Marsh
			±	8	3	3	7	3	7	2	96	47	NM	0.11			
Bone Cave	56	56		80	20	149	49	49	289	12	872	302	NM	1.66	56.1	60.9	Unknown 2
			±	7	3	3	7	3	7	2	96	47	NM	0.11			
Bone Cave	57	57		49	24	130	76	36	248	15	608	160	NM	0.72	57.5	40.1	Unknown X *
			±	9	4	4	7	3	7	2	96	47	NM	0.11			
Bone Cave	58	58		100	32	140	10	56	371	18	468	306	NM	0.91	31.4	63.4	Silver Lake/Sycan Marsh *
			±	8	3	4	7	3	7	2	95	47	NM	0.11			
Bone Cave	59	59		39	18	118	88	27	128	6	328	104	NM	0.24	45.6	29.9	Whitewater Ridge *
			±	8	4	4	7	3	7	2	95	47	NM	0.11			
NA	RGM-1	RGM-1		35	25	147	103	26	214	7	1668	283	784	1.90	68.7	36.6	RGM-1 Reference Standard
			±	6	2	3	7	3	7	1	97	47	13	0.11			

All trace element values reported in parts per million; ± = analytical uncertainty estimate (in ppm). Iron content reported as weight percent oxide.
NA = Not available; ND = Not detected; NM = Not measured.; * = Small sample.

Appendix 2

Obsidian Hydration Data

Northwest Research Obsidian Studies Laboratory

Table B-1. Obsidian Hydration Results and Sample Provenience: Bone Cave, Deschutes County, Oregon

Site	Specimen No.	Catalog No.	Unit	Depth	Artifact Type[A]	Artifact Source	Hydration Rims Rim 1	Rim 2	Comments[B]
Bone Cave	1	1	Unit 1	0-10	DEB	Quartz Mountain *	3.7 ± 0.1	NM ± NM	--
Bone Cave	2	2	Unit 1	0-10	DEB	McKay Butte *	5.7 ± 0.1	NM ± NM	REC
Bone Cave	3	3	Unit 1	10-20	DEB	Cougar Mountain? *	3.7 ± 0.1	NM ± NM	--
Bone Cave	4	4	Unit 1	10-20	DEB	McKay Butte	2.9 ± 0.0	NM ± NM	--
Bone Cave	5	5	Unit 1	20-30	DEB	Brooks Canyon? *	3.4 ± 0.0	NM ± NM	--
Bone Cave	6	6	Unit 1	20-30	DEB	McKay Butte *	3.7 ± 0.1	NM ± NM	--
Bone Cave	7	7	Unit 1	30-40	DEB	Unknown X *	3.7 ± 0.1	NM ± NM	--
Bone Cave	8	8	Unit 1	30-40	DEB	Basalt *	NM ± NM	NM ± NM	--
Bone Cave	9	9	Unit 1	40-50	DEB	Quartz Mountain *	3.2 ± 0.1	NM ± NM	--
Bone Cave	10	10	Unit 1	40-50	DEB	Obsidian Cliffs *	3.3 ± 0.1	NM ± NM	--
Bone Cave	11	11	Unit 1	50-60	DEB	Basalt *	NM ± NM	NM ± NM	--
Bone Cave	12	12	Unit 1	50-60	DEB	Big Obsidian Flow *	3.3 ± 0.1	NM ± NM	--
Bone Cave	13	13	Unit 1	60-70	DEB	Quartz Mountain *	4.4 ± 0.1	NM ± NM	REC
Bone Cave	14	14	Unit 1	60-70	DEB	McKay Butte	NA ± NA	NM ± NM	REC; UNR
Bone Cave	15	15	Unit 1	70-80	DEB	Basalt	NM ± NM	NM ± NM	--
Bone Cave	16	16	Unit 1	70-80	DEB	McKay Butte	5.4 ± 0.1	NM ± NM	--
Bone Cave	17	17	Unit 1	80-90	DEB	Basalt *	NM ± NM	NM ± NM	--
Bone Cave	18	18	Unit 1	80-90	DEB	Not Obsidian	NM ± NM	NM ± NM	--
Bone Cave	19	19	Unit 1	90-100	DEB	Big Obsidian Flow *	3.0 ± 0.1	NM ± NM	--
Bone Cave	20	20	Unit 1	90-100	DEB	Obsidian Cliffs *	3.9 ± 0.1	NM ± NM	--

[A] BIF = Biface; COR = Core; DEB = Debitage; EMP = Edge Modified Piece; PPT = Projectile Point; UTF = Utilized Flake

[B] See text for explanation of comment abbreviations

NA = Not Available; NM = Not Measured; * = Small sample

Table B-1. Obsidian Hydration Results and Sample Provenience: Bone Cave, Deschutes County, Oregon

Site	Specimen No.	Catalog No.	Unit	Depth	Artifact Type ^{A}	Artifact Source	Hydration Rims		Comments ^{B}
							Rim 1	Rim 2	
Bone Cave	21	21	Unit 1	100-110	DEB	Basalt *	NM ± NM	NM ± NM	--
Bone Cave	22	22	Unit 1	100-110	DEB	McKay Butte *	5.5 ± 0.1	NM ± NM	--
Bone Cave	23	23	Unit 1	110-120	DEB	Obsidian Cliffs *	4.2 ± 0.1	NM ± NM	--
Bone Cave	24	24	Unit 1	110-120	DEB	McKay Butte? *	4.8 ± 0.1	NM ± NM	DFV
Bone Cave	25	25	Unit 4	0-10	DEB	McKay Butte	4.8 ± 0.1	NM ± NM	--
Bone Cave	26	26	Unit 4	0-10	DEB	Basalt	NM ± NM	NM ± NM	--
Bone Cave	27	27	Unit 4	10-20	DEB	Big Obsidian Flow *	3.3 ± 0.1	NM ± NM	--
Bone Cave	28	28	Unit 4	10-20	DEB	Basalt *	NM ± NM	NM ± NM	--
Bone Cave	29	29	Unit 4	20-30	DEB	Basalt	NM ± NM	NM ± NM	--
Bone Cave	30	30	Unit 4	20-30	DEB	Basalt	NM ± NM	NM ± NM	--
Bone Cave	31	31	Unit 4	30-40	DEB	Big Obsidian Flow	3.4 ± 0.1	NM ± NM	--
Bone Cave	32	32	Unit 4	30-40	DEB	Big Obsidian Flow *	3.4 ± 0.1	NM ± NM	--
Bone Cave	33	33	Unit 4	40-50	DEB	Big Obsidian Flow *	3.5 ± 0.1	NM ± NM	--
Bone Cave	34	34	Unit 4	40-50	DEB	McKay Butte	5.5 ± 0.1	NM ± NM	--
Bone Cave	35	35	Unit 4	50-60	DEB	Big Obsidian Flow?	3.3 ± 0.1	NM ± NM	--
Bone Cave	36	36	Unit 4	50-60	DEB	Obsidian Cliffs *	3.3 ± 0.1	NM ± NM	--
Bone Cave	37	37	Unit 4	60-70	DEB	Quartz Mountain	3.3 ± 0.1	NM ± NM	--
Bone Cave	38	38	Unit 4	60-70	DEB	Obsidian Cliffs	3.2 ± 0.1	NM ± NM	DFV
Bone Cave	39	39	Unit 4	70-80	DEB	Unknown X *	3.3 ± 0.1	NM ± NM	--
Bone Cave	40	40	Unit 4	70-80	DEB	McKay Butte	NA ± NA	NM ± NM	REC; NVH

^{A} BIF = Biface; COR = Core; DEB = Debitage; EMP = Edge Modified Piece; PPT = Projectile Point; UTF = Utilized Flake
^{B} See text for explanation of comment abbreviations
NA = Not Available; NM = Not Measured; * = Small sample

Northwest Research Obsidian Studies Laboratory

Table B-1. Obsidian Hydration Results and Sample Provenience: Bone Cave, Deschutes County, Oregon

Site	Specimen No.	Catalog No.	Unit	Depth	Artifact Type[A]	Artifact Source	Hydration Rims		Comments[B]
							Rim 1	Rim 2	
Bone Cave	41	41	Unit 3	80-90	BIF	Unknown X	1.4 ± 0.1	NM ± NM	Same rim on BRE
Bone Cave	42	42	Unit 4	0-10	BIF	Unknown 1	3.5 ± 0.1	NM ± NM	--
Bone Cave	43	43	Unit 4	20-30	BIF	Chickahominy?	4.4 ± 0.1	NM ± NM	--
Bone Cave	44	44	Unit 4	30-40	EMP	Unknown 2	5.2 ± 0.1	NM ± NM	Same rim on BRE
Bone Cave	45	45	Unit 4	50-60	BIF	Quartz Mountain	4.6 ± 0.1	NM ± NM	Same rim on BRE
Bone Cave	46	46	Unit 6	20-30	UTF	Quartz Mountain	3.2 ± 0.1	NM ± NM	--
Bone Cave	47	47	Unit 2	70-80	COR	Unknown 2	3.9 ± 0.1	NM ± NM	--
Bone Cave	48	48	Unit 1	30-40	DEB	Unknown 3	3.2 ± 0.1	NM ± NM	--
Bone Cave	49	49	Unit 1	50-60	DEB	Cougar Mountain? *	3.7 ± 0.1	NM ± NM	--
Bone Cave	50	50	Unit 1	70-80	DEB	McKay Butte *	NA ± NA	NM ± NM	REC; UNR
Bone Cave	51	51	Unit 1	80-90	DEB	Unknown X *	3.2 ± 0.1	NM ± NM	REC
Bone Cave	52	52	Unit 1	80-90	DEB	McKay Butte	3.5 ± 0.1	NM ± NM	--
Bone Cave	53	53	Unit 1	100-110	DEB	McKay Butte? *	3.4 ± 0.1	NM ± NM	--
Bone Cave	54	54	Unit 1	110-120	DEB	Too small for XRF	3.7 ± 0.1	NM ± NM	--
Bone Cave	55	55	Unit 4	0-10	DEB	Silver Lake/Sycan Marsh	4.6 ± 0.1	NM ± NM	--
Bone Cave	56	56	Unit 4	10-20	DEB	Unknown 2	4.6 ± 0.1	NM ± NM	--
Bone Cave	57	57	Unit 4	20-30	DEB	Unknown X *	3.3 ± 0.0	NM ± NM	--
Bone Cave	58	58	Unit 4	20-30	DEB	Silver Lake/Sycan Marsh *	4.6 ± 0.1	NM ± NM	--
Bone Cave	59	59	Unit 4	10-20	PPT	Whitewater Ridge *	NA ± NA	NM ± NM	NVH

[A] BIF = Biface; COR = Core; DEB = Debitage; EMP = Edge Modified Piece; PPT = Projectile Point; UTF = Utilized Flake

[B] See text for explanation of comment abbreviations

NA = Not Available; NM = Not Measured; * = Small sample

Abbreviations and Definitions Used in the Comments Column

1SO - (1 Surface Only). Hydration was observed on only one surface or side of the thin section.

A, B, C - 1st, 2nd, and 3rd cuts, respectively.

BEV - (Beveled). Artifact morphology or cut configuration resulted in a beveled thin section edge.

BRE - (BREak). The thin section cut was made across a broken edge of the artifact. The resulting hydration measurements may provide approximate chronological information about the age of the break relative to its time of manufacture.

DES - (DEStroyed). The artifact or flake was destroyed in the process of thin section preparation. This sometimes occurs during the preparation of extremely small items, such as pressure flakes.

DFV - (Diffusion Front Vague). The diffusion front, or the visual boundary between hydrated and unhydrated portions of the specimen, are poorly defined. This can result in less precise measurements than can be obtained from sharply demarcated diffusion fronts. The technician must estimate the hydration boundary when a vague diffusion front appears as a relatively thick, dark line or a gradation in color or brightness between hydrated and unhydrated layers.

DIS - (DIScontinuous). A discontinuous or interrupted hydration rind was observed on the thin section.

HV - (Highly Variable). The hydration rind exhibits variable thickness along continuous surfaces. This variability can occur with very well-defined bands as well as those with irregular or vague diffusion fronts.

IRR - (IRRegular). The surfaces of the thin section (the outer surfaces of the artifact) are uneven and measurement is difficult.

NOT - (NOT obsidian). Petrographic characteristics of the artifact or obsidian specimen indicate that the specimen is not obsidian.

NVH - (No Visible Hydration). No hydration rind was observed on one or more surfaces of the specimen. This does not mean that hydration is absent, only that hydration was not observed. Hydration rinds smaller than one micron often are not birefringent and are difficult to see and accurately measure using optical microscopy.

OPA - (OPAque). The specimen is too opaque for measurement and cannot be further reduced in thickness.

PAT - (PATinated). This description is usually noted when there is a problem in measuring the thickness of the hydration rind, and refers to the unmagnified surface characteristics of the artifact, possibly indicating the source of the measurement problem. Only extreme patination is normally noted.

REC - (RECut). More than one thin section was prepared from an archaeological specimen. Multiple thin sections are made if preparation quality on the initial specimen is suspect or obviously poor.

UNR - (UNReadable). The optical quality of the hydration rind is so poor that accurate measurement is not possible. Poor thin section preparation is not a cause.

WEA - (WEAthered). The artifact surface appears to be damaged by wind erosion or other mechanical action.

Appendix 3

Faunal Analysis Letter Report

Analysis of Selected Sample of Faunal Remains from Bone Cave

By
DEBORAH OLSON
May 1999

A small sample of faunal remains recovered from Bone Cave was analyzed. Faunal material from four levels of a single excavation unit, Unit 4, was chosen for analysis. The four levels chosen were level 2, 4, 6, and 8. The faunal sample from these four levels consists of a total of 3877 bones and bone fragments. This report presents the techniques and definitions employed for this analysis in addition to a brief summary of the results of the analysis.

Techniques of Analysis

All the recovered faunal remains were examined and identified to the most specific taxonomic level possible (e.g. genus and species). However, when this is not possible and identification is only possible to class level (i.e., mammal, fish, bird and reptile), the mammal remains are categorized by size to maximize the identified portion of the remains. These generalized mammalian size classes are based on the weight and corresponding body sizes of living animals. There is some overlap in the weight ranges which delineate the size classes, since the weight ranges in the definitions are purposefully broad and contain recorded extremes rather than averages. These mammalian size classes only apply to land mammals.

Four classes of mammal are employed for most analyses. These size classes are defined as follows (Olson 1983).

- Large: large ungulates that range in weight from 900 kg (a large male bison) to 225 kg (a small elk); taxa represented include bison, horse, cattle, moose and elk.
- Medium: small ungulates and large carnivores that range in weight from 270 kg (a large caribou) to 22.5 kg (a small white-tailed deer); taxa represented include caribou, deer, mountain sheep, mountain goat, domestic sheep and goats, bear, wolf, and mountain lion.
- Small: most carnivores, large rodents, and rabbits that range in weight from 27 kg (a large beaver) to 0.7 kg (a small cottontail or marten); taxa represented include coyote or dog, bobcat, river otter, raccoon, marten, beaver, porcupine, marmot, muskrat, rabbit, and hare.

The fourth category, medium/large, is used for analysis when bone fragments that can not be assigned with assurance to either the medium or large size categories. The undetermined remains consist of those that cannot be assigned to a size class but are most likely mammal.

Information on both burning, and natural and cultural modifications to the specimen is recorded. Four degrees or intensity of burning are recognized and recorded: unburned (1), partially burned (2), burned (3), and calcined (4). Partially burned is that bone which has sustained some exposure to heat which produces a color change (usually to red) or some partial charring. Burned bone specimens are completely charred. Calcined bone is that bone which has been burned to such a degree that the organic portion has been destroyed leaving only the inorganic, or mineral, fraction. Calcined bone is white to gray in color, blocky in appearance, and fairly regular in size. Calcined bone preserves better than unburned bone in certain environments, such as forests with acidic soil. Either cultural or natural forces can cause all of the three burned categories.

Other modifications noted in analysis include both natural or nonhuman modifications (e.g., weathering and gnawing by carnivores or rodents), and cultural modifications caused by humans (i.e., impact fractures, cut marks, tools, and sawing). Natural modifications often occur with other natural modifications (e.g., bone that is weathered and gnawed by carnivores) or with cultural modifications e.g., a bone tool with carnivore gnawing). Several types of natural modifications were observed and recorded in this analysis, including gnawing by carnivores, gnawing by rodents, weathering, root etching, mineralization, and calcium carbonate deposits. Indicators of gnawing by carnivores consist of crenulated edges, pitting and punctures, tooth scoring, chipping back edges (particularly long bones), and scooping out bones (Binford 1981).

Weathering is a complex process by which newly deposited bone decomposes into its constituent parts. The rate at which any given bone weathers is dependent on taxa, skeletal element, environment, and duration on exposure. Both surface and subsurface bone weathers. Often weathered bone shows longitudinal cracking, which produces splinters, flakes, or exfoliation (peeling off layers) of the outer surface. Weathered bone is rounded and eroded appearing, as well. Each of these characteristics represents a different stage in the weathering process. In this analysis, the remains are characterized as exfoliated and weathering splinters in addition to generalized weathering.

Cultural modifications to the remains in this analysis include historic saw cuts, cut marks, impact fractures and splinters, and tool manufacture and use. Most of these cultural modifications are associated with butchering activities. The identified bone tool fragments are described in a separate section.

Breaking a bone to extract the marrow produces distinctive bone debris. Long bones are broken in a variety of ways, but the end products are the same. At the point of impact bone flakes (i.e., impact fractures) and negative flake scars are produced. The bone flakes produced have the same attributes of stone flakes. During marrow extraction, bone may splinter in a manner consistent with green bone fractures, as well. The resultant splinters are distinctive from weathering splinters.

Cut marks identified on the bone are the result of various butchering activities: skinning, disarticulation or dismemberment, filleting or meat removal, and bone breakage for marrow extraction. Each of these activities results in cut marks that are more or less unique to that activity. For example, skinning cut marks occur in two locations: circling the lower fore and hind limbs, and on the head, especially around the antlers and on the mandible (Binford 1981:107). Cuts associated with dismemberment are located at or near points of articulation. For example, removing the head would result in cuts on the occipital condyle (Binford 1981:107-109). Filleting cut marks on long bones are short and at an oblique angle to the long axis of the bone, and are located near articular end and areas of muscle attachment (Binford 1981:128-133). Prior to breaking a long bone for marrow, the bone is cleaned. This involves removing any meat and tendons (cut marks identical to filleting cut marks) and removing the periosteum by scraping the bone producing scratches or striations parallel to the long axis of the bone (Binford 1981:134-135).

For this analysis, the data have been quantified using only the number of identified specimens (NISP) and bone weight. NISP is the actual number of bones and bone fragments that have been identified to a particular taxon, and theoretically, represents the maximum number of animals in a sample (Grayson 1979). This NISP value is a real number generated during identification and is represented by the number variable.

Results of Analysis

A total of 3877 bones and bone fragments were analyzed from four levels in Unit 4. The bulk of the sample has been identified to genus (57.6%) and family (34.5%) and fifteen taxa were identified in the sample (Table 1). The sample is dominated by rabbit remains which constitute 91.1% of the remains. The rabbit remains include at least two species of *Sylvilagus*, the mountain cottontail *S. nuttalli* and the much smaller pygmy rabbit *S. idahoensis*. The *Lepus* or jackrabbit remains were not identified beyond genus. At least three species of *Lepus* inhabit the region: *L. americanus* the snowshoe hare, *L. townsendi* the whitetail jackrabbit, and *L. californicus* the blacktail jackrabbit. Other identified cultural fauna include *Canis* (dog or coyote), *Odocoileus* (deer), *Antilocapra americana* (pronghorn antelope) and a single proximal humerus from a duck (Cygininae). Rodent remains make up a very small percentage of the sample (0.5%). These rodent remains are considered to be intrusive or non cultural.

Table 1. Summary of Analyzed Faunal Sample

Taxon	**NISP**	**% of NISP**	**Weight (g)**	**% of weight**
Rodent undetermined	14	0.4	0.2	0.01
Peromyscus sp. (deer mouse)	2	0.1	0.1	0.00
Perognathus parvus (pocket mouse)	1	0.0	0.0	0.00
Thomomys sp. (pocket gopher)	3	0.1	0.4	0.02
Leporidae (rabbit family)	1338	34.5	172.7	11.0
Sylvilagus sp. (cottontail)	1700	43.8	546.8	34.9
Lepus sp. (hare or jackrabbit)	496	12.8	359.9	22.9
Canis sp. (dog or coyote)	7	0.2	6.8	0.4
Antilocapra americana (pronghorn)	10	0.3	19.4	1.2
Odocoileus sp. (deer)	15	0.4	26.0	1.7
Small mammal	6	0.2	2.8	0.1
Medium mammal	184	4.7	392.9	25.0
Medium/large mammal	83	2.1	39.4	2.5
Undetermined mammal	17	0.4	1.7	0.1
Cyginiae (duck family)	1	0.0	0.1	0.00
Total	**3877**	**100.0**	**1569.2**	**99.8**

The burned remains constitute a very small portion of the sample (12.1%). Of these burned remains the partially burned fragments are the most numerous (n=329). Several of the partially burned remains exhibit a pattern of burning that indicates they were exposed to a heat source while flesh was still on the bone. The other burned remains consist of 104 burned remains and 37 calcined remains.

Likewise, very few of the remains show any modifications natural or cultural. Natural modifications were the most frequently observed with 119 specimens that have been gnawed, 102 specimens that show weathering and a single specimen with gnawing and weathering. Three of the gnawed bone fragments exhibit the characteristics of gnawing by rodents. One specimen appears to have been ingested and passed through the digestive tract of a carnivore. Twenty-six bones and bone fragments are considered to be recently deposited since these fragments appear to be greasy with no weathering.

Only 58 bones and bone fragments have direct cultural modifications, although it is inferred that human behavior is responsible for the deposition and overall appearance of the faunal sample. These direct cultural modifications are cut marks associated with butchering, fractures associated with breaking a bone for marrow extraction, and use as tools. Thirty-one bone fragments have cut marks associated with butchering. Five cut marks were observed on rabbit remains. The remaining cut marks were observed on medium size mammal bone fragments. All of the rabbit and the majority of the medium mammal cut marks were located on long bones. Twenty-one of the observed cut marks occurred in level 6. Four were observed in levels 2 and 4, and only 2 were observed on material from level 8.

Although the majority of the rabbit and large game animal remains are broken, twenty-six of the medium mammal remains exhibit breakage patterns associated with marrow extraction. Twenty-four are impact fractures and two are long bone splinters that appear to have been broken during butchering.

A single possible bone tool was identified in the sample. The possible tool fragment is a medium mammal metatarsal shaft fragment with the distal end broken in a point. The very tip of this point is broken off flat in a manner consistent with use. No use or polishing striae are visible macroscopically, but the sides of the point are very rounded and smooth. It is possible that this bone fragment represents an expediency tool, probably an awl.