GEOARCHAEOLOGY, PALEOECOLOGY, AND HOLOCENE SUBSISTENCE CHANGE ON THE UPPER SNAKE RIVER PLAIN, IDAHO

A Dissertation

by

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ABSTRACT

This dissertation presents new data on geochronology, site formation processes, projectile-point typology, and lithic technological organization in the Intermountain West's Snake River Plain and Bonneville Basin, relating diachronic change in lithic artifacts to paleoenvironmental changes.

This research is divided into three related articles, first focusing on site formation processes at the Pioneer site of southeastern Idaho. This study provides an example of the archaeological and paleoclimatic value of studying alluvial stratigraphic sequences in arid environments. Stratigraphic analyses were used to date mid-late Holocene archaeological horizons, as well as contribute to the late Quaternary geomorphic history of the Big Lost River drainage. There is also evidence of a high-energy erosional event at ~3800 years ago indicating a large middle Holocene flood.

Next, this dissertation updates the geochronology of strata from Veratic Rockshelter, southeastern Idaho, to contribute to the diagnostic projectile point typology of the upper Snake River Plain. Results indicate that Western Stemmed Tradition points at Veratic are younger and more morphologically diverse than previously thought. In addition, Elko point forms coeval with Northern Side Notched points are found to pre-date the classic age range of Elko. Finally, an analysis of dart point variability shows a distinct drop in diversity during the late Holocene.

This research concludes with a comparison of lithic assemblages from Veratic and Bonneville Estates (eastern Nevada) rockshelters, focusing on how paleoecological "crises" affected subsistence, lithic technological organization and raw material procurement. Results show that changes in aridity during the Holocene correspond with relative changes in raw material preference, ground stone use, bifacial stage of reduction, and formal vs. informal tools use at both sites. However, increased variability in raw material preference at Bonneville Estates potentially relates to the harsher, more variable and patchy ecological conditions of the Bonneville Basin compared to the more homogenous sagebrush steppe of the Snake River Plain.

Ultimately, this dissertation provides geoarchaeological and geochronogical contexts for important Snake River Plain archaeological sites, providing a better understanding of prehistoric subsistence and mobility for the Snake River Plain and neighboring regions and the relation of these adaptations to climatic change.

DEDICATION

To my parents, John and Teresa, my brother Alex, and to my wonderful wife Marion.

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The site formation study of the Pioneer site (Chapter II) was initiated and funded by the Idaho National Laboratory CRM department under supervision from the United States Department of Energy Idaho Operations Office (contract # DE-AC07-05ID14517). I would specifically like to thank the tireless efforts of INL archaeologists Clayton Marler, Hollie Gilbert, Brenda Pace, Julie Braun-Williams, and Christina Olsen, who initiated the Pioneer project and got me involved in Idaho archaeology, as well as the efforts of the rest of the CRM staff who made this possible, and the Department of Energy staff for overseeing my excavation permit. I would also like to thank the Shoshone-Bannock tribes of the Fort Hall Reservation for their support and excavation assistance, as well as the efforts of Kelly Graf, Marti Brooks, Jessi Halligan, Adam Burke, Cameron Brizzee, and the Texas A&M 2012 field school for their help with field work. I would also like to thank the reviewers of my article in *Geoarchaeology* as well as editor Gary Huckleberry who helped me greatly improve the quality of this manuscript, and the University of Arizona Accelerator Mass Spectrometry Laboratory for processing AMS dates.

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Contributors

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The AMS dating for Chapter II was performed by Arizona AMS Laboratory. AMS dates used in Chapter III were provided by Beta Analytic as well Doug Kennett at Penn State in conjunction with the W. M. Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory at UC Irvine. Plant identifications of dated charcoal from Chapter III were provided by David Rhode at the Desert Research Institute. Some of the provenience data in Chapter III were provided in the original Veratic Rockshelter site report and field notes originally developed by Earl Swanson (Swanson 1972), and made available by the Idaho Museum of Natural History. Age ranges of strata from Bonneville Estates in Chapter IV were provided by Professors Ted Goebel and Kelly Graf at Texas A&M University, who also provided the basic quantities and provenience information for the Bonneville Estates assemblage. Some of the XRF data in Chapter IV was collected by Aria Holmes, a student in the Department of Anthropology at Texas A&M.

All other work conducted for the dissertation was completed by the student independently.

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CHAPTER I

INTRODUCTION*

Changes in climate have had a major influence on past human societies, with both abrupt and gradual environmental shifts shown to trigger "crises" that directly affect human population size, technology, and subsistence change (Aimers and Hodell 2011; deMenocal 2001; Kelly et al. 2013; Munoz et al. 2010). This fact is apparent among agricultural and industrial societies (Aimers and Hodell 2011; deMenocal 2001; Zhang et al. 2011), but it is also an important factor of change in foraging populations where so much depends on the frequency and predictability of plant and animal resource patches (Binford 1980; Kelly 1995; Kelly et al. 2013; Louderback et al. 2010; Surovell 2009). The arid Intermountain West of North America is an ideal area to study the affects of climate and environmental change on human groups, as highly variable elevations, hydrographies, and vegetation communities could have led to varying frequencies and magnitudes of cultural change through time.

However, proving a causal link between past environmental and prehistoric culture changes is difficult to do, and slight environmental differences, even in the same regions, may have led to variable degrees of cultural adaptation. Additionally, the geochronological context of paleoecological and archaeological materials is of utmost

*Parts of this chapter are reprinted with permission from: 1) "Geochronology and Geomorphology of the Pioneer Archaeological Site (10BT676), Upper Snake River Plain, Idaho" by Joshua L. Keene, 2016. *Geoarchaeology: An International Journal* 31(4):282-303, Copyright 2016 by John Wiley and Sons, and 2) "A Diachronic Perspective on Projectile Point Morphology from Veratic Rockshelter, Idaho" by Joshua L. Keene, (available online May 2016). *Quaternary International*, Copyright 2016 by Cambridge University Press.

importance in establishing correlations between the timing of cultural and climatic change. This dissertation uses geoarchaeological methodologies to establish secure temporal contexts for lithic assemblages from stratified sites on the Snake River Plain, Idaho, then uses this context to discuss diachronic change in human subsistence and mobility in relation to ecological factors, comparing records between the Snake River Plain and adjacent Bonneville Basin to the south. The problems addressed in this dissertation are addressed below.

I.1 Themes of Research

I.1.1 Geochronology and Site Context in the Intermountain West

The aridity of the Intermountain West of North America poses a serious challenge to understanding chronological contexts of archaeological sites, as it has led to an overwhelming occurrence of un-stratified surface assemblages (Beck and Jones 1997). Multi-component assemblages from intact, buried contexts provide the most precise chronological controls; however, in the Intermountain West's Great Basin these come almost exclusively from cave and rockshelter settings (e.g. Aikens 1970; Graf 2007; Jenkins et al. 2012; Jennings 1957; Thomas et al. 1983) and less frequently alluvial contexts, in particular vertically accreted overbank flood deposits (Aikens and Greenspan 1988; Davis and Rusco 1987; Davis and Schweger 2004; Hicks 2004; Irwin and Moody 1978; Rusco et al. 1987).

However, in the Intermountain West alluvial activity is usually marked by abrupt transitions from long-term dry conditions to high-energy flood events which carve out arroyos and erode cultural deposits (Waters 1991) or form rapidly anastomosing braided systems, jumbling artifacts, as in the deepest layers of the Sunshine locality in Nevada where camel bones were redeposited with Paleoarchaic artifacts within gravelly channel deposits (Beck and Jones 2009; Huckleberry 2001). Alluvial fans are also prone to mixing through braided flash-flood events and colluvial activity, and furthermore can rapidly bury a site under 10s of meters of sediment (Huckleberry 2001). Despite these issues, alluvial contexts (in particular, vertically accreted overbank flood deposits) are still among the most ideal for the preservation of multi-component open-air archaeological sites in arid settings (Goebel et al. 2003; Huckleberry 2001; Waters 1992:138), as seen at a few multi-component open-air sites in the Intermountain West (Aikens and Greenspan 1988; Davis and Rusco 1987; Davis and Schweger 2004; Hicks 2004; Irwin and Moody 1978; Rusco et al. 1987).

The upper Snake River Plain region of southern Idaho, a major component of the Intermountain West's Great Basin Desert (Grayson 1993), is no exception to these factors of archaeological site formation and preservation, with most multi-component, stratified sites found in rockshelters or caves (eg. Gruhn 1961; Gruhn 2006; Henrikson 2003; Lohse 1989; Miller 1972; Miller 1982; Swanson and Sneed 1971) or in alluvial settings on the periphery of the plain (Davis 2005; Green 1972; Green et al. 1998; though see Holmer and Ringe 1986; Lohse and Sammons 1994; Plew and Woods 1985; Powers 1966; Schneider 2002; Swanson et al. 1964; Swanson and Dayley 1968). In addition, very few Snake River Plain sites are reliably dated using current geoarchaeological or radiocarbon methods.

Establishing proper geochronological context is a crucial part of understanding diachronic changes in lithic technology, and is a cornerstone of the diachronic analyses of paleoclimate and lithic technological organization presented in this dissertation. However, many stratified sites in the Great Basin and Snake River Plain were excavated prior to the development of modern techniques for AMS dating and geoarchaeological methods of stratigraphic excavation and artifact provenience. For this reason, a number of recent studies focus on establishing the geochronological context of artifacts recovered from newly excavated sites, as well as for previously excavated sites when possible. The geochronological context for the Pioneer and Veratic Rockshelter sites presented in this dissertation (Chapters II and III) was established through analyses of site formation processes and by AMS dates of organic materials from relatively secure stratigraphic associations with cultural components. Only by pinpointing the chronologies of archaeological assemblages from stratified multi-component sites does it become possible to establish accurate typologies of diagnostic artifacts, and understand human population change and adaptation through time as reflected by changes in lithic technology.

I.1.2 Diachronic Change and Lithic Technology

Projectile-point typologies have long been an important tool used by archaeologists to assign chronometric ages to archaeological components without datable geological contexts. Thomas' Monitor Valley/Gatecliff Rockshelter chronology for the central Great Basin (1981), for example, provided a much-needed standardization of projectile-point variability using metric attributes. However, it is becoming increasingly apparent that different regions of the Intermountain West have variations in form and chronology inconsistent with Thomas' key (e.g. Bettinger 1999; Holmer and Ringe 1986; Schmitt and Madsen 2005). Most recently, Smith et al. (2013b) suggested that, based on benchmark sites with established chronologies, the Great Basin has at least five areas with distinct projectile-point chronologies. These inter-regional differences go beyond merely affecting chronologies; they also have implications for understanding culture change and regional cultural interactions throughout the Holocene in the Intermountain West. However, as previously mentioned, to establish these chronologies for specific regions, it is crucial to have stratified, well-dated benchmark sites with occupations containing diagnostic points spanning much of the Holocene. Reaching this goal was a major component of this dissertation.

I.1.3 Lithic Technological Organization and Paleoecology

High-resolution Great Basin proxy records provide a detailed record of past climate fluctuation (Adams et al. 2008; Goebel et al. 2007; Louderback and Rhode 2009; Madsen et al. 2001; Mensing et al. 2013), making it possible to compare changes in prehistoric technological organization with fluctuations in temperature, aridity, and ecological zone change on a millennial scale or better. Recent archaeological studies have focused on the transition from the cool and wet terminal Pleistocene/early Holocene to the hot and dry middle Holocene, correlating changes in climate with the archaeological record of mobility and subsistence (Duke 2011; Elston and Zeanah 2002;

Elston et al. 2014; Goebel 2007; Madsen et al. 2015a). Mobility, specifically residential mobility, was the primary adaptive tool prehistoric populations utilized to respond to the changing availability of patchy resources (Kelly 1992), and organization of technology was clearly tied to this subsistence-settlement pattern, providing a means to understand and quantify basic human adaptation (e.g. Andrefsky 1994; Bleed 1986; Cowan 1999; Elston and Zeanah 2002; Kelly and Todd 1988; Parry and Kelly 1987; Smith 2011). As climate change has the potential to affect resource patch size, frequency, and predictability (Kelly 1995; Surovell 2009), it has also potentially affected mobility and subsistence strategies amongst prehistoric populations. Archaeological proxies for analyzing such changes include artifact-assemblage variability (Elston and Zeanah 2002; Goodyear 1993), formal/informal tool production (e.g. Andrefsky 1994; Bleed 1986; Cowan 1999; Kelly and Todd 1988; Parry and Kelly 1987), and toolstone procurement based on geochemical analysis (e.g. Duke 2011; Hughes 1986; Jones et al. 2003, 2012; Page and Duke 2015; Smith 2011). In this dissertation, I contribute to these topics through a comparison of lithic assemblages from two rockshelters in the Intermountain West, comparing diachronic changes in technological organization and inferred residential mobility with the paleoclimatic record of the Holocene.

I.2 Geographic Setting

The focal sites of this study are the Pioneer and Veratic Rockshelter sites on the upper Snake River Plain in southern Idaho, and Bonneville Estates Rockshelter in the neighboring Bonneville Basin to the south in eastern Nevada. While both regions are broadly similar in climate, ecology, and culture history, differences in topography, and lithic resource distribution, as well as geographic separation have the potential to heterogeneously affect how human populations in these two neighboring regions adapted to changing climatic conditions during he Holocene.

The Bonneville Basin, which once contained the massive Pleistocene Lake Bonneville, is a large enclosed basin located in the eastern Great Basin of eastern Nevada and western Utah. The basin and range topography of the area includes wide, flat-floored valleys with smaller north to south trending mountain ranges with a basin and range vegetative system consisting of broad lowland shadscale zones between 1200-1800 masl (10-40 cm annual precipitation), limited upper valley and mountain foothill sagebrush and grass steppe zones between 1500-1870 masl (20-58 cm annual precipitation), higher pinyon juniper zones between 1730-2300 masl (41-51 cm annual precipitation), upper limber pine and bristlecone aspen/fir zones between 2300-2900 masl (51-64 cm annual precipitation), and subalpine conifers and alpine herbaceous tundra between 2900-3600 masl (64-102 cm annual precipitation) (Billings 1951; Grayson 2011; Louderback 2007; Lull and Ellison 1950; Madsen 2000). Limited wetland vegetation also exists at perennial lakes which contain cattails, bulrushes, and sedges (e.g. Louderback and Rhode 2009). Generally, this “island-like” morphology results in lower faunal species diversity that are more prone to extirpation due to climatic fluctuation (Brown 1971; Grayson 1993; Madsen 2000). Though relatively constant throughout the year, the basin and range topography causes annual precipitation rates to vary geographically between ~155 cm in upland areas and ~13 cm on the basin floors, with slightly higher rainfall in the spring (Currey 1991; Madsen 2000). Mean temperatures are also highly variable based on elevation, with average high and low temperatures of ~26.5 to -2.9° C for the valley floor around Wendover, NV and 14.5 to -7.2° C in the alpine uplands around Brighton, UT (Madsen 2000; National Climatic Data Center 1997).

The upper Snake River Plain, located ~100 km north of the northern extent of the Bonneville Basin, consists of a long, broad trough following the Snake River in southeastern Idaho ~100 km wide, with a gradual increase in slope from west to east ranging between 1300-1700 masl and lacking the basin and range topography of the Bonneville Basin. The Snake River Plain is fed by numerous rivers from the surrounding Rocky Mountains, forming the ~26,000 square km Snake River Aquifer. In the area near Veratic Rockshelter, a number of streams flow into the "Pioneer Basin," an enclosed basin that once contained the Pleistocene Lake Terreton (Nace et al. 1956). Vegetation is fairly uniform across the plain, consisting primarily of sagebrush steppe with perennial grasses and riparian zones containing predominantly willows, cottonwoods and sedges (Plew 2000). As it is surrounded by mountain ranges, upland vegetation zones comparable in composition and elevation range to the Bonneville Basin exist around the periphery, including pinyon-juniper zones, ponderosa pine, and mountain mahogany woodlands (Plew 2000). Rainfall on the plain is consistently low (20-23 cm), with most precipitation occurring in the winter. Seasonal temperatures vary between average summer high temperatures of 38° C and average low winter temperatures of -7° C (Idaho Department of Water Resources 1978; Plew 2000).

I.3 The Study Sites

The Pioneer, Veratic Rocksheler, and Bonneville Estates Rockshelter sites are ideal for this study as all are multicomponent sites with large assemblages of lithic tools from dated contexts, providing precise chronological control typically not available with most other sites in the region. Furthermore, Bonneville Estates and Veratic both have roughly similar occupation histories, and both contain records relating to every major climatic phase of the Holocene, allowing for a direct comparison of the two. Moreover, these sites are from neighboring sub-regions of the Intermountain West – the western Bonneville Basin and the Snake River Plain – allowing for comparison of environmental and technological variability in two closely related areas both marked by relatively arid conditions.

I.3.1 Pioneer

Pioneer (10BT676) is a Holocene-age open-air site located along the Big Lost River in the upper Snake River Plain of southern Idaho on land managed by the Idaho National Laboratory (INL). The Pioneer archaeological site was initially recorded in the 1980s as a large-scale, high-density surface artifact scatter indicative of a prehistoric residential site. Surface artifacts were present in an area spanning more than 1 km along the Big Lost River and consisted of a mix of diagnostic early to late Holocene bifacial points as well as protohistoric and historic debris. Following a limited surface survey and cut bank sampling project performed by an ISU field school in 2005, block excavations were performed between 2010-2013 by myself, INL archaeologists, and a

Texas A&M archaeology field school as part of this dissertation project. These excavations revealed an open air, stratified site with dense obsidian scatters, burn features, and large artiodactyl remains dating from the middle/late Holocene transition (~3900 cal B.P.) to the protohistoric period (~100 cal B.P.) within eight distinct stratigraphic horizons.

I.3.2 Veratic Rockshelter

Veratic Rockshelter, a south-facing shallow overhang located on the northern boundary of the upper Snake River Plain, was originally excavated by Earl Swanson, Jr. and colleagues in the early 1960s as part of the Birch Creek archaeological survey project (Swanson 1972). Swanson's excavations were cutting-edge for their time, applying stratigraphic and radiocarbon techniques to establish the context of over 400 diagnostic projectile points and 1100 other lithic artifacts from 13 components that ranged from 500 to more than 10,000 radiocarbon years ago (^{14}C B.P.). To complete this study, it was necessary to review and organize the extant lithic artifact collections and notes from Swanson's original excavation, currently housed at the Idaho Museum of Natural History, Idaho State University, to identify lithic artifacts and datable organic samples with known stratigraphic provenience. New AMS dates were acquired on original charcoal samples (see Chapter III) to better clarify the geochronological context of components at the site, providing better age ranges for archaeological materials from known contexts.

I.3.3 Bonneville Estates Rockshelter

Bonneville Estates Rockshelter is a large, south-facing rockshelter located in the eastern Great Basin on the western edge of the Bonneville Basin in the Lead Mine Hills at the Bonneville paleoshoreline (1600 m asl). Excavations undertaken by Ted Goebel, Kelly Graf, Bryan Hockett, and David Rhode between 2000-2009 revealed a well-stratified site almost continuously occupied from 12,900 cal B.P. until the historic period. Though a full report of the site is not yet published, the shelter's geochronology has been well established with over 130 AMS dates on hearth charcoal, bone, coprolites, perishable artifacts, and plant material from 20 identifiable strata (Albush 2010; Goebel et al. 2007; Graf 2007; Hockett 2015; Smith et al. 2013b). Collections for the site are currently housed at Texas A&M University by the Center for the Study of the First Americans, where I was able to identify and analyze lithic tools and points from known stratigraphic contexts.

I.4 Research Questions and Organization

This dissertation is separated into a series of related but independent chapters with the common themes of geochronology, lithic technology, and paleoecology in the Snake River Plain and Bonneville Basin. The following chapters focus on four research questions:

1) What is the geochronological context of lithic assemblages from the stratified Pioneer and Veratic Rockshelter sites?

2) Using updated ages from Veratic Rockshelter and new dates from Pioneer, how does projectile point form and variability change throughout the Holocene on the upper Snake River Plain, and how does this compare to observed typologies for neighboring regions of the Intermountain West?
3) Based on dated assemblages from Veratic and Bonneville Estates Rockshelters, how did diachronic changes in lithic technological organization and lithic procurement during the Holocene on the Snake River Plain compare to the neighboring Bonneville Basin?
4) How were similarities and differences in subsistence and technological organization influenced by paleoclimatic variability both through time and between the two regions?

In Chapter II, I present a site formation study of the Pioneer archaeological site. Based on block excavations performed as part of this dissertation project, this chapter details the sequence of multiple episodes of fluvial deposition, erosion, and pedogenesis at the site for the past ~7200 cal yr. B.P., relating this to periods of occupation by hunter-gatherers during the mid-late Holocene. The depositional sequence is then compared with local and regional paleoclimatic records providing a potential correlate between periods of deposition and flooding at the site and climatic fluctuations and possibly volcanic activity on the upper Snake River Plain. Though only indirectly applicable to the lithic analyses of Chapters III and IV, this section demonstrates the importance and effectiveness of geoarchaeological assessments of stratified archaeological sites both for understanding prehistoric culture change and paleoclimatic variation. This component of my dissertation was published in *Geoarchaeology: An International Journal* (Keene 2016a).

Chapter III re-evaluates the chronology of archaeological assemblages previously excavated from Veratic Rockshelter in southern Idaho using new AMS dates obtained as part of this dissertation on existing charcoal samples collected during the original excavations in the 1960s. These new ages are then used to look at changes in raw material preference, morphology, and variability of 390 diagnostic projectile point forms ranging in age from ~10,000 cal B.P. to ~500 cal B.P. Specifically, in this Chapter I discuss the updated age and morphological variability of Western Stemmed projectile points form the oldest occupation at the site; compare and contrast the morphology and ages of Elko and Northern Side Notched points at Veratic to determine whether they represent variations on a single form, or distinct projectile point styles indicating simultaneous Northern Side Notched and long-chronology Elko points during the early-middle Holocene; and compare the relative chronological distribution of several diagnostic dart point forms, including Elko corner and eared, Northern Side Notched, Humboldt, Stemmed Indented Base, and Salmon River points to update the upper Snake River Plain typology and determine if point variability changes through time. This component of my dissertation was published in *Quaternary International* (Keene 2016b).

In Chapter IV, I compare and contrast lithic assemblages from six components with broadly similar ages from Bonneville Estates and Veratic Rockshelters, focusing on the relationship between relative changes in diversity of raw material preference, artifact type, and point forms between the two sites throughout the Holocene. Differences in technological organization between the two sites are then compared with existing paleoclimatic proxy records to see how climatic changes through time as well as differences in paleoecological regimes between the two regions may have differentially influenced subsistence and procurement patterns at both sites. This component of my dissertation has been submitted for review and has not yet been accepted for publication.

Finally, in Chapter V, I conclude by summarizing the results of each chapter, discussing the strengths and weaknesses of the techniques used, the greater implications to hunter-gatherer research in the Intermountain West and Snake River Plain specifically, and possible avenues of future investigation. It is my intention that this research not only provide geoarchaeological and geochronogical contexts for important Snake River Plain archaeological sites, but also provide a better understanding of prehistoric subsistence and mobility for the Snake River Plain and neighboring regions and the relation of these adaptations to climatic change and ecological crises.

CHAPTER II

GEOCHRONOLOGY AND GEOMORPHOLOGY OF THE PIONEER ARCHAEOLOGICAL SITE (10BT676), UPPER SNAKE RIVER PLAIN, IDAHO, U.S.A*

II.1 Introduction

The aridity of the Intermountain West of North America poses a challenge to understanding chronological contexts of archaeological sites, as it has led to an overwhelming occurrence of un-stratified surface assemblages (Beck and Jones 1997). Assemblages from intact, buried contexts provide the most precise chronological controls, which in the Intermountain West's Great Basin and Snake River Plain come almost exclusively from cave and rockshelter settings (Aikens 1970; Graf 2007; Jenkins et al. 2012; eg., Jennings 1957; Thomas et al. 1983). Such sites, however, are uncommon and often have complex or mixed stratigraphy. Moreover, an over-reliance on rockshelters has potentially biased the archaeological record in favor of a specific site type and geologic/geographic setting. Buried and stratified open-air sites are more difficult to find in the Intermountain West (Beck and Jones 1997), and although they do occur occasionally in stratified contexts, it is most often as single or mixed-component sites buried in shallow eolian deposits (Bonstead 2000; Galm and Gough 2001; Helzer 2004; Jenkins 1994; Kelly 1999; Madsen 2005; Mehringer and Cannon 1994; e.g.,

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O'Connell 1975; Oetting 1994a; Oetting 1994b; Oetting 1989; O'Neill 2004; Pinson 2004; Raven and Elston 1989; Simms 1999; Wingard 1999). These are prone to wind erosion and lack continuous long-term deposition, increasing the likelihood of palimpsest surfaces. Multi-component sites within stratified eolian deposits are even rarer (Connolly 1999; Dugas et al. 1995; Jenkins et al. 2004; Jenkins 2004; Mehringer and Cannon 1994; Moessner 2004; Rusco and Davis 1987), but are still potentially prone to similar issues of site preservation.

Alluvial sites are ideal for site preservation, providing valuable data for reconstructing site formation and archaeological context (Hoffecker et al. 2014; eg. Pitulko et al. 2014; Wriston 2003). However, in the Intermountain West alluvial activity is usually marked by abrupt transitions from long-term dry conditions to high-energy flood events which carve out arroyos and erode cultural deposits (Waters 1991) or form rapidly anastomosing braided systems, jumbling artifacts, as in the deepest layers of the Sunshine locality in Nevada where camel bones were redeposited with Paleoarchaic artifacts within gravelly channel deposits (Beck and Jones 2009; Huckleberry 2001). Alluvial fans are also prone to mixing through braided flash-flood events and colluvial activity, and furthermore can rapidly bury a site under 10s of meters of sediment (Huckleberry 2001). Despite these issues, alluvial contexts (in particular, vertically accreted overbank flood deposits) are still among the most ideal for the preservation of multi-component open-air archaeological sites in arid settings (Goebel et al. 2003; Huckleberry 2001; Waters 1992:138), as seen at a few multi-component open-air sites in the Intermountain West (Aikens and Greenspan 1988; Davis and Rusco 1987; Davis and Schweger 2004; Hicks 2004; Irwin and Moody 1978; Rusco et al. 1987).

The upper Snake River Plain region of southern Idaho, a major component of the Intermountain West's Great Basin Desert (Grayson 1993), is no exception to these factors of archaeological site formation and preservation, with most multi-component, stratified sites found in rockshelters or caves (eg. Gruhn 1961; Gruhn 2006; Henrikson 2003; Lohse 1989; Miller 1972; Miller 1982; Swanson and Sneed 1971). Although sites in alluvial settings are not uncommon (Davis 2005; Green 1972; Green et al. 1998; Holmer and Ringe 1986; Lohse and Sammons 1994; Plew and Woods 1985; Powers 1966; Schneider 2002; Swanson et al. 1964; Swanson and Dayley 1968), nearly all are on the periphery of the Snake River Plain and not in the open desert (though see Holmer and Ringe 1986). In addition, very few Snake River Plain sites are reliably dated using current geoarchaeological or radiocarbon methods. Recent excavations at the Pioneer site, however, provide a rare opportunity in arid western North America to study not only an intact, open-air, multi-component archaeological site in a buried alluvial context in the open desert, but also an important late Quaternary geomorphological context of the region.

Pioneer (10BT676) is a Holocene-age open-air site located along the Big Lost River in the Snake River Plain of southern Idaho on land managed by the Idaho National Laboratory (INL). Despite its location in a high-elevation, sagebrush-steppe environment, over two meters of low-energy alluvial deposition during the past 7000 years (cal yr B.P.) provide an ideal geochronological context for investigating Holocene site-formation processes and hunter-gatherer subsistence and mobility. The Pioneer site has also provided a dated context chronicling a series of geomorphological and paleoecological events in the Pioneer Basin following the early/middle Holocene transition. Of particular interest is a period of rapid erosion around 3800 cal yr B.P., suggesting a major flood event. By identifying and dating paleosols developed within alluvial deposits forming terraces along the Big Lost River, this paper clarifies questions regarding site formation, archaeology, and paleoecology for one of only a few open-air archaeological sites in an arid alluvial setting on the Snake River Plain.

II.2 Geomorphology and Archaeological Contexts

The Pioneer Basin, as originally defined by Nace and colleagues (1956; 1975) and Butler (1968), is a hydrographic basin located on the northern boundary of the eastern Snake River Plain of southern Idaho. This basin consists of a series of sinks fed primarily by the Big Lost River, Little Lost River, and Birch Creek, as well as Crooked, Camas, and Medicine Lodge creeks, all of which flow from alluvial valleys of central Idaho's Basin and Range province to the northwest (Figure 2.1).

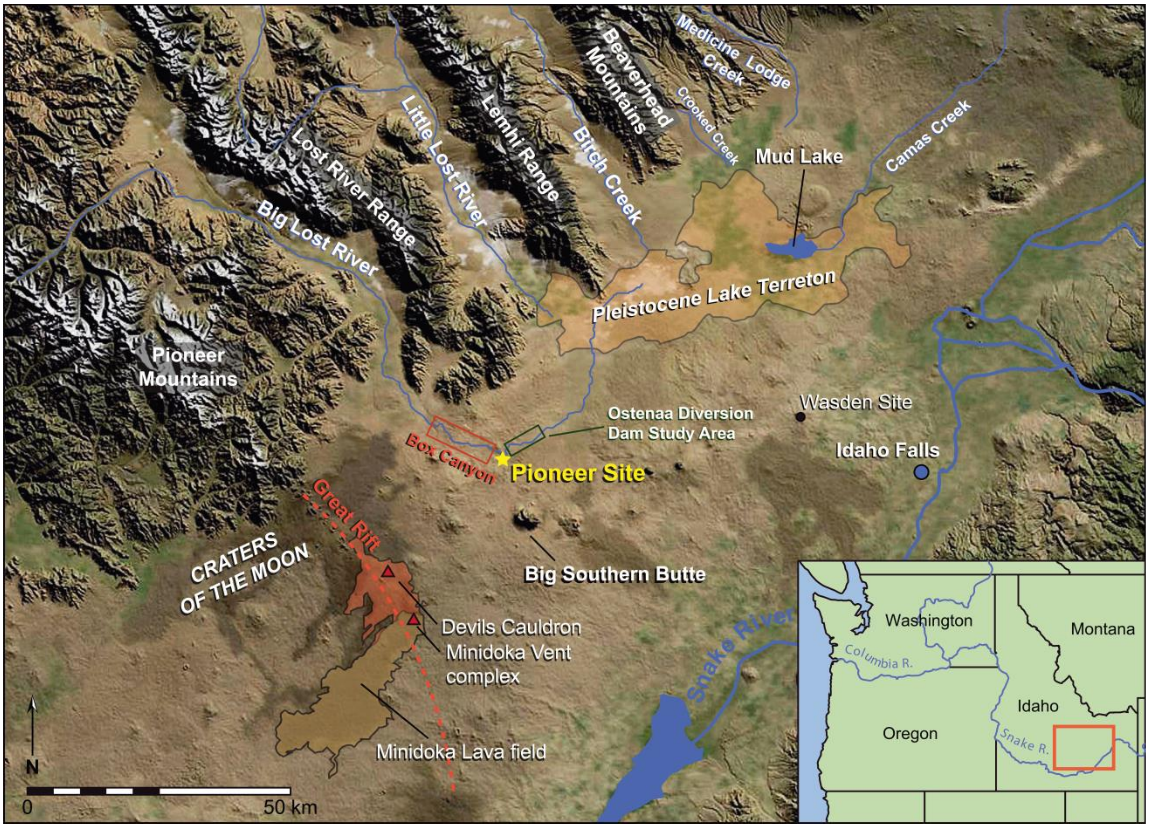

Figure 2.1. Location of the Pioneer site on the Big Lost River and surrounding area.

Early archaeological and geomorphological studies in the area focused on high-profile archaeological rockshelter and cave sites along Birch Creek to the north (Swanson et al. 1964; Swanson and Sneed 1971; Swanson 1972) and at the Wasden site to the east (Butler 1968; Butler 1972; Miller 1982). Swanson and Butler both used alternating episodes of deposition and stability in rockshelter settings as a coarse proxy for climate variation throughout the Holocene. Swanson (1972) in particular provided estimates for mesic and xeric fluctuation throughout the late Quaternary based on sedimentation rate, freeze-thaw related rockfall deposits, and alternating alluvial and eolian deposits observed in the stratigraphy of excavated rockshelters in Birch Creek Valley (e.g., Bison, Veratic, and Jacknife rockshelters). He produced estimates that generally conformed to Antev's (1948) Neothermal sequence, with a thermal maximum around ~8800 cal B.P. and a transition to cooler and wetter conditions around ~5800 cal yr B.P. based on the presence of wind-blown loess (arid) versus alluvial sandy loam (moist). He documented further arid episodes between 4500-4300 and 3400-2900 cal yr B.P., and a period of increased moisture between 2900-100 cal yr B.P., with a further increase around 700 cal yr B.P. (Swanson 1972). Similar assumptions were made by Butler (1972) based on sediments from archaeological deposits at the Wasden site, where he identified a "population crash" between ~8800-5800 cal yr B.P. correlating with a long period of increased aridity. Unfortunately, the relative sparseness and inaccuracy of radiocarbon dates used in these studies, combined with the possibly flawed assumption that rockfall only occurs during cold periods (see Farrand 2001), make these interpretations only broad estimates in need of testing.

More recent geomorphological and hydrologic research relates the development of facilities at the Naval Reactor Test Station, now known as the Idaho National Laboratory, a 2,225 km^2 nuclear-reactor testing and environmental laboratory, which encompasses the bulk of the Pioneer Basin and much of the original extents of pluvial Lake Terreton (Dechert et al. 2006; Forman 1997; Gianniny 2002; Hackett et al. 1995; Knudsen et al. 2002; Nace et al. 1956; Nace et al. 1975; Ostenaa et al. 1999; Ostenaa and O'Connell 2005).

Initial geomorphological studies by Nace and colleagues (1956) identified a series of sinks and ephemeral playas (prior to the historic diversion of water for irrigation in the early 1900s) representing remnants of a once extensive, shallow lake known as Lake Terreton (Figure 2.1). At its furthest extent, this lake covered an area of ~90 km^2 and included modern-day Mud Lake, but it never reached a depth greater than 8 meters at its highstand around 1460 masl. Sediment cores from Mud Lake and the Big Lost Trough indicate that Lake Terreton fluctuated during the Pleistocene, with highstands at ~120k-160k cal yr B.P., 80k-100k cal yr B.P., and 11k-22k cal yr B.P., the first and last of which roughly correlate with highstands of Lake Bonneville ~200 km to the south (Forman 1997; Gianniny 2002). During the Holocene, Terreton receded to the current limits of Mud Lake, though a freshwater-shell date suggests that Lake Terreton may have had a resurgence as recently as 710 ± 70 ^{14}C B.P. (545-761 cal yr B.P.) (Bright and Davis 1982). Radiocarbon dates from Mud Lake exposures also suggest a resurgence of Lake Terreton within the last thousand years (Forman 1997).

In addition to Lake Terreton, geomorphological studies have focused on the Big Lost River floodplain, an alluvial plain accompanying the largest river in the Pioneer basin, and neighboring overflow basins (Dechert et al. 2006; Gianniny et al. 1997; Hackett et al. 1995; Knudsen et al. 2002; Nace et al. 1956; Nace et al. 1975; Ostenaa et al. 1999; Ostenaa et al. 2002; Ostenaa and O'Connell 2005; Rathburn 1993). Upon reaching the Pioneer basin, the Big Lost River takes on a meandering form when not constricted by canyons and basaltic lava flows, with output decreasing significantly downstream due to infiltration into the Snake River Plain aquifer. Early studies (Butler

1968; Nace et al. 1956; 1975) described a series of gravelly terraces surrounding abandoned braided and anastomosing channels, with Nace et al. (1975) describing three alluvial terraces, providing relative ages for each based on the degree of weathering. Nace et al. (1975) assumed the least degraded braided channels were very recent, while the oldest terraces, marked by the presence of mima-mound-like formations on the surface (Tullis 1995), were oldest, dating to the Pleistocene. However, the large extent and thickness of these braided deposits indicate that they likely formed as a result of catastrophic floods, the last of which occurred either 20,000 (Cerling et al. 1994) or 50,000 (Knudsen et al. 2002) cal yr B.P. Ostenaa and O’Connell (2005) performed a GIS-based hydrologic/geomorphological study using high-resolution aerial photography combined with backhoe trenching to map the Big Lost River’s terrace sequence (Ostenaa et al. 1999; Ostenaa et al. 2002; Ostenaa and O'Connell 2005). In addition to clarifying the distribution of the previously mentioned Pleistocene gravel bars, the authors identified a series of ~1-3 m high terraces composed of sandy and silty overbank flood deposits, which they interpreted to have formed as early as the Pleistocene/Holocene transition and then sporadically throughout the Holocene.

Paleoflood studies by Ostenaa and colleagues (Ostenaa et al. 2002; Ostenaa and O'Connell 2005) of the lower Big Lost River downstream of the INL (aka INEEL) Diversion dam (located directly adjacent to Pioneer) (Figure 2.2) provide a strong basis for the terrace identifications used in this paper. In addition, they provide a basic chronology for Holocene and terminal Pleistocene terrace formation based on a total of 30 radiocarbon dates (Table 2.1) acquired from organic material removed via flotation from bulk sediment samples (Puseman and Ruggiero 2003) collected from four backhoe trench profiles transecting the Big Lost River (T4, 5, 6, & 9) (Ostenaa and O'Connell 2005) and four cleared cutbank profiles bordering terrace edges (BLR-2, 6, 7 & 8) (Ostenaa et al. 2002) (Figure 2.2).

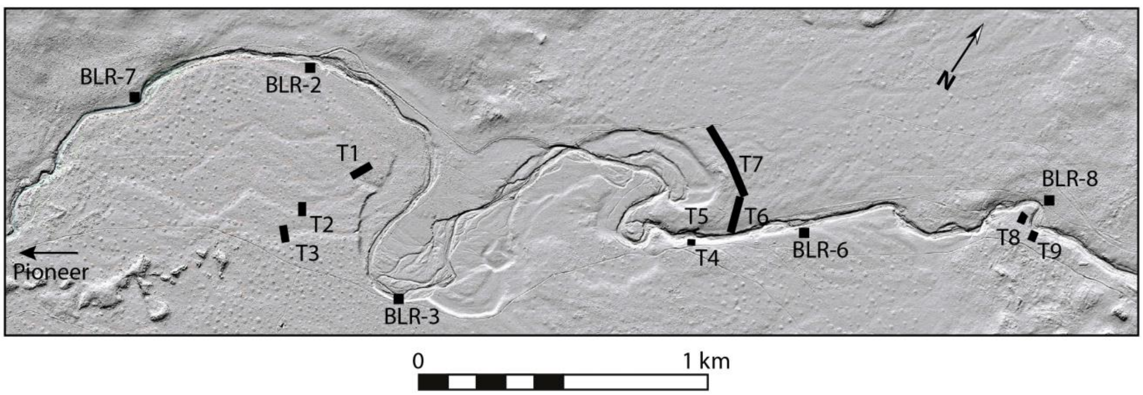

Figure 2.2. INL diversion dam study area and locations of geologic trenches and test profiles described by Ostenaa and colleagues (Ostenaa et al. 2002; Ostenaa and O'Connell 2005). Topographic imagery adapted from Ostenaa and O'Connell (2005: Plate 2).

Table 2.1. Radiocarbon dates from Ostenaa et al. testing projects (Ostenaa, 2002: Table 2; Ostenaa, 2005: Table 2-2)

Trench No.	Sample Depth (cm)	Material Dated	Lab No.	14C Age B.P. (± 1σ)	Calibrated Age B.P. (± 2σ)
T4	20-25	*Artemisia* charcoal	Beta-174101	520 ± 40	630-600; 560-510
	38-51	*Artemisia* charcoal	Beta-174102	1070 ± 40	1060-930
	50-60	*Artemisia* charcoal	Beta-174099	1130 ± 40	1160-950
	50-60	Conifer charcoal	Beta-174100	1980 ± 40	2000-1860
	140-155	*Chrysothamnus* charcoal	Beta-172812	6330 ± 40	7320-7200
T5	22-32	*Artemisia* charcoal	Beta-174103	780 ± 40	760-660
	110-132	Conifer charcoal	Beta-174104	1880 ± 40	1900-1720
T6	12-25	*Salicaceae* charcoal	Beta-174106	630 ± 40	660-540
	12-25	*Artemisia* charcoal	Beta-174105	830 ± 40	790-680
	95-105	snail shell	Beta-183387	10390 ± 50	12800-11940
	103-121	charcoal fragments	Beta-172813	3210 ± 40	3480-3360
	110-140	charcoal fragments	Beta-183388	2710 ± 40	2870-2760
	30-40	*Artemisia* charcoal	Beta-174107	620 ± 40	660-540
T9	35-45	*Populus* charcoal	Beta-183391	170 ± 40	290-250; 230-130; 110-70; 30-0
	105-115	Chrysothamnus charcoal	Beta-183392	130 ± 40	290-0
	105-115	*Artemisia* charcoal	Beta-183389	2610 ± 40	2730-2780
BLR-2	25-35	*Artemisia* charcoal	Beta-121217	350 ± 40	490-300
	35	*Artemisia* charcoal	Beta-122946	410 ± 40	520-420; 400-310
	80-90	Hardwood charcoal	Beta-121218	2370 ± 50	2750-2200
	80-111	bark	Beta-122947	1270 ± 50	1290-1070
	111-150	shell	Beta-122948	7550 ± 50	8370-8140
BLR-6	100-160	*Artemisia* charcoal	Beta-124711	9090 ± 120	10360-9870
BLR-7	40-60	*Artemisia* charcoal	Beta-124712	250 ± 50	470-250; 230-130; 30-0
	75-90	*Salicaceae* charcoal	Beta-124713	890 ± 40	970-700
BLR-8	11-29	*Artemisia* charcoal	Beta-124714	100 ± 50	520-310
	29-45	*Artemisia* charcoal	Beta-124715	1430 ± 70	1510-1180
	60-75	*Artemisia* charcoal	Beta-124716	1680 ± 90	1810-1390
	93-125	*Artemisia* charcoal	Beta-124717	1580 ± 50	1550-1340
	125-136	*Juniperus* charcoal	Beta-124718	2220 ± 50	2350-2110
	125-136	*Discus shineki* and *Stagnicola* shells	Beta-126509	2470 ± 50	2720-2360

Test sites chosen for the initial study (Ostenaa et al. 2002) were on the edges of terraces composed of fine-grained sand and silt considered to date to the Holocene. Two locations (BLR-3 and BLR-6) were considered to be late Pleistocene/early Holocene in age based on extensive carbonate accumulations near the surface and a single date of 10,360-9870 cal B.P. at BLR-6. The remaining three locations (BLR-2, 7, & 8) showed evidence of weakly developed modern soil horizons with a bracketing age range of ~400-800 cal yr B.P., which Ostenaa et al. (2002) suggest as the age range for a flood or multiple floods, resulting in the last significant period of deposition along the Big Lost River, referred to as the "400 year flood." In addition, paleosols at these three locations further indicated earlier episodes of deposition and soil formation between ~800 and 2500 cal yr B.P., with one date at BLR-2 suggesting an additional early Holocene horizon based on a date of ~8200 cal yr B.P. from freshwater shell.

Ostenaa and O'Connell (2005) provide an additional 16 radiocarbon dates, though their geochronology is somewhat problematic. While five correlating radiocarbon dates from the upper soil profiles of three trenches provide additional age estimates for deposition caused by the "400 year flood", most other dates were from disturbed or unreliable contexts. Three ages acquired on materials from below the modern soil horizon in trench T6 were reversed, ranging from ~12,000 to ~2800 cal yr B.P. In trench T4, two dates from the same bulk sample were nearly 1000 years apart, and in trench T9 two samples from 30-100 cm below the surface were practically modern, suggesting some form of mixing or redeposition of sediments. A single age of 7320-7200 cal yr B.P. from trench T4 potentially correlates to an early flood event stratigraphically below the modern soil horizon, but unfortunately none of the geological trenches were excavated deep enough to clearly expose this deposit. Five remaining ages ranging between 2780-930 cal yr B.P. are used to roughly date a sandy/silty stratum topped with a buried soil horizon seen at multiple locations, which they suggest represents a period of low deposition prior to the "400 year flood." Though potentially useful for identifying late Holocene paleosols, Ostenaa and O'Connell's (2005) chronology of terrace formation covers only the last 1000-2000 years, with few specific paleosols defined.

II.3 The Pioneer Site

The Pioneer archaeological site was initially recorded in the 1980s as a large-scale, high-density surface artifact scatter indicative of a prehistoric residential site. Artifacts were present in an area spanning more than 1 km along the Big Lost River (Figure 2.1) and consisted of a mix of diagnostic early to late Holocene bifacial points as well as protohistoric and historic debris, the latter resulting from its proximity to the Oregon Short Line (later Union Pacific) railroad grade. In addition, Goodale's Cutoff, an extension of the Oregon Trail, passed through the southern section of the Pioneer site, where remnants of the early 1900s Pioneer ghost town (Gilbert et al. 2009) are concentrated. Initial sub-surface testing by an Idaho State University field school in 2005 provided a stratigraphic sequence with buried archaeological material that was suspected to have spanned the Holocene.

Major objectives of the current Pioneer field study were: 1) to establish the geochronology of stratigraphic components at the site, providing ages for preserved archaeological materials; 2) to understand site-formation processes affecting the contexts of archaeological materials; and 3) to better understand the chronology of the Big Lost River's terrace system and its implications for the region's archaeological record.

Favorable geomorphic conditions for site preservation combined with the high density of archaeological artifacts dating back to Folsom times (12,800-11,680 cal yr BP, Collard et al. 2010), in the area surrounding Pioneer led INL archaeologists and me to organize a geoarchaeological project at Pioneer in 2010, aimed at revealing extensive stratified deposits with multiple paleosols and buried occupation surfaces with archaeological features. Block excavations followed between 2011-2013, revealing a dense, stratified, multi-component site with evidence of bison butchering, multiple hearth features, pottery usage, and an extensive lithic assemblage consisting of more than 300 modified stone tools and 32,000 flakes, the majority made from obsidian. In addition, variation in the composition of the site's archaeological components suggests intact occupational layers spanning the middle to late Holocene.

II.4 Methods

Sediments exposed in the stratigraphic profiles at the Pioneer site during 2011-2013 excavations were mapped and characterized using USDA techniques for field description (Soil Survey Staff 1993) (see Table 2.2) of all exposed stratigraphic profiles during the 2011-2013 excavation. Individual stata were identified and numbered based on differences in color, texture, and pedogenic structure, resulting in some cases in a single depositional unit being assigned to separate strata based on differing degrees of carbonate accumulation. The sediments were excavated in 5-cm levels within stratigraphic units. Sediment samples were collected from the east wall of the 2011 trench every 5 cm from the surface down to the base riverbed gravels (Figure 2.3). Soil horizons were identified and characterized according to soil structure, $CaCO_3$ content (based on degree of hydrochloric acid (HCl) effervescence), and carbonate stage based on quantity of carbonate nodules and inter-modular concretion (Birkeland 1999). The cultural sequence was divided into components based on associations with identified paleosols and stratigraphic positions of preserved hearth features and bone/lithic scatters.

Ages for strata were established through AMS radiocarbon dating of hearth-associated charcoal and burned bone (samples of large in-situ faunal remains associated with occupation surfaces), as well as traces of uncharred organic matter from middle Holocene deposits without artifacts. Radiocarbon samples were processed by the Arizona Mass Spectrometry Laboratory using standard pretreatment procedures that consisted of soaking in alternating HCl, distilled water, and diluted sodium hydroxide (Donahue et al. 1990). Bone was then treated using a modified version of Longin's technique (1971) in which acid was used to remove the apatite fraction, after which the remaining bone collagen was hydrolyzed. Calibrated ages were calculated using Calib software (Stuiver and Reimer 1993) and the IntCal13 calibration curve (Reimer et al. 2013).

Table 2.2. Stratigraphic profile descriptions from 2011 east wall profile and 2013 west wall profile at Pioneer (refer to Figures 2.3 and 2.6)

Soil #	Stratum #	Horizon	Depth (cm B.S.)	Description†
Modern	17	O1	0-5	Dry color: N/A. Structureless and loose organic surface horizon with an abrupt, clear lower boundary, 50% + roots, and no gravels. No carbonate accumulation, non-effervescent.
	16	A1	5-10	Sandy loam. Dry color: 2.5Y4/2. Structureless and loose, with abrupt, smooth lower boundary, ~50% roots, no gravels. No carbonate accumulation, non-effervescent.
	15	A2/Bk1	10-28	Loam. Dry color: 2.5Y4/2. Slightly hard with weak sub-angular blocky structure and abrupt, smooth boundary, ~10% roots, <1% gravels. Stage I carbonate accumulation, strongly effervescent.
	13	Bk2	28-34	Silt loam. Dry color: 10YR6/2. Hard, with strong angular blocky structure and an abrupt, wavy lower boundary, ~2% roots, <1% gravels. Stage II+ carbonate accumulation, violently effervescent.
P4	10	Ab2	34-54	Sandy loam. Dry color: 10YR5/2. Soft, with weak sub-angular blocky structure and gradual, smooth lower boundary, ~2% roots, <1% gravels. Stage I carbonate accumulation, slightly effervescent.
	9	Bkb2	54-72	Sandy loam. Dry color: 10YR5/2. Slightly hard, with medium sub-angular blocky structure and clear, smooth lower boundary, <1% roots, <1% gravels. Stage II carbonate accumulation, slightly effervescent.
P3	8	Bkb3	72-100	Sandy loam. Dry color: 10YR5/2. Very hard, with strong angular blocky structure and clear, wavy lower boundary, <1% roots, <1% gravels. Stage II+ carbonate accumulation, strongly effervescent.
	7	Bkb4	100-135	Sandy loam. Dry color: 10YR5/2. Hard, with weak sub-angular blocky structure and gradual, wavy lower boundary, <1% roots, <1% gravels. Stage I+ carbonate accumulation, strongly effervescent.
P2	5	Bkb5	135-165	Sandy loam. Dry color: 10YR6/2. Hard, with strong sub-angular blocky structure and clear, wavy lower boundary, <1% roots, <1% gravels. Stage II+ carbonate accumulation, violently effervescent.
	4F	Bkb6*	165-180**	Sandy loam. Dry color: 10YR6/2. Hard, with strong angular blocky structure and clear, wavy lower boundary, <1% roots, >60% pebbles/cobbles, few gravels (<10%). Stage II+ carbonate accumulation, slightly effervescent.
	4E	Bkb6*	165-180**	Sandy loam. Dry color: 2.5Y5/2. Hard, with weak sub-angular blocky structure and abrupt, wavy lower boundary, <1% roots, <2% gravels. Stage I carbonate accumulation, non-effervescent.
	4D	Bkb6*	165-180**	Sandy loam. Dry color: 10YR6/2. Hard, with strong angular blocky structure and clear, wavy lower boundary, <1% roots, >60% pebbles/cobbles, few gravels (<10%). Stage II+ carbonate accumulation, strongly effervescent.
	4C	Bkb6*	165-180**	Sandy loam. Dry color: 2.5Y5/2. Hard, with weak sub-angular blocky structure and abrupt, wavy lower boundary, <1% roots, <2% gravels. Stage I carbonate accumulation, non-effervescent.
	4B	Bkb6*	165-180**	Clay. Dry color: 2.5Y6/2. Very hard, with strong sub-angular blocky structure and abrupt, wavy lower boundary, no roots, no gravels. Stage II+ carbonate accumulation, violently effervescent.
	4A	Bkb6*	165-180**	Sandy loam. Dry color: 2.5Y5/2. Hard, with weak sub-angular blocky structure and abrupt, wavy lower boundary, <1% roots, <2% gravels. Stage I carbonate accumulation, non-effervescent.
P1	3F	Bkb7	180-232**	Sandy loam. Dry color: 10Y5/2. Extremely hard, with strong sub-angular blocky structure and abrupt, smooth lower boundary, <1% roots, no gravels. Stage II+/III carbonate accumulation (cementation), unknown effervescence.
	3E	Bkb7	180-232**	Fine sand. Dry color: 10Y5/2. Slightly hard, with weak sub-angular blocky structure and abrupt, wavy lower boundary, <1% roots, <1% gravels. Stage I carbonate accumulation (cementation), unknown effervescence.
	3D	Bkb7	180-232**	Loam. Dry color: 10Y5/2. Hard, with strong sub-angular blocky structure and abrupt, smooth lower boundary, <1% roots, <1% gravels. Stage II+/III carbonate accumulation (cementation), unknown effervescence.
	3C***	Bkb7	180-232**	Sandy clay. Dry color: 10Y5/2. Very hard, with medium sub-angular blocky structure and unknown lower boundary, <1% roots, <1% gravels. Stage II carbonate accumulation (cementation), unknown effervescence.
	3B	Bkb7	180-232**	Loam. Dry color: 2.5Y5/3. Hard, with medium angular blocky structure and clear, wavy lower boundary, <1% roots, <1% gravels. Stage II+ carbonate accumulation, violently effervescent.
	3A***	Bkb7	180-232**	Sandy loam. Dry color: 2.5Y5/3. Hard, with medium angular blocky structure and clear, wavy lower boundary, <1% roots, <1% gravels. Stage II carbonate accumulation, slightly effervescent.

Table 2.2 (cont.)

Soil #	Stratum #	Horizon	Depth (cm B.S.)	Description†
P1	2	C1	232-270	Loam. Dry color: 2.5Y5/2. Extremely hard and structureless with abrupt, smooth lower boundary, <1% roots, <1% gravels. No carbonate accumulation, very slightly effervescent. Laminated with horizontal organic staining, occasional thin lenses of coarse sand (<5%).
	1	C2	270-310	Coarse sand. Dry color: N/A. Loose and stuctureless with abrupt, irregular lower boundary (basalt bedrock). No carbonate accumulation, non-effervescent. Unsorted sand and gravels.

* = matrix.

**depth does not include sub-units

***3C and 3A may actually be the same stratum, but lack of extensive excavation into stratum 3C during 2013 season (Figure 3) prevented clear identification.

†Sediment descriptions based on USDA guidelines (Soil Survey Staff, 1993). Color determined with Munsell soil color charts. Carbonate stage based on Birkeland (1999). Particle size separates: Coarse sand: 1.0-0.5 mm, medium sand: 0.5-0.25 mm, fine sand:0.25-0.10 mm, very fine sand: 0.10-0.05 mm, silt: 0.05-0.002 mm, clay: >0.002 mm

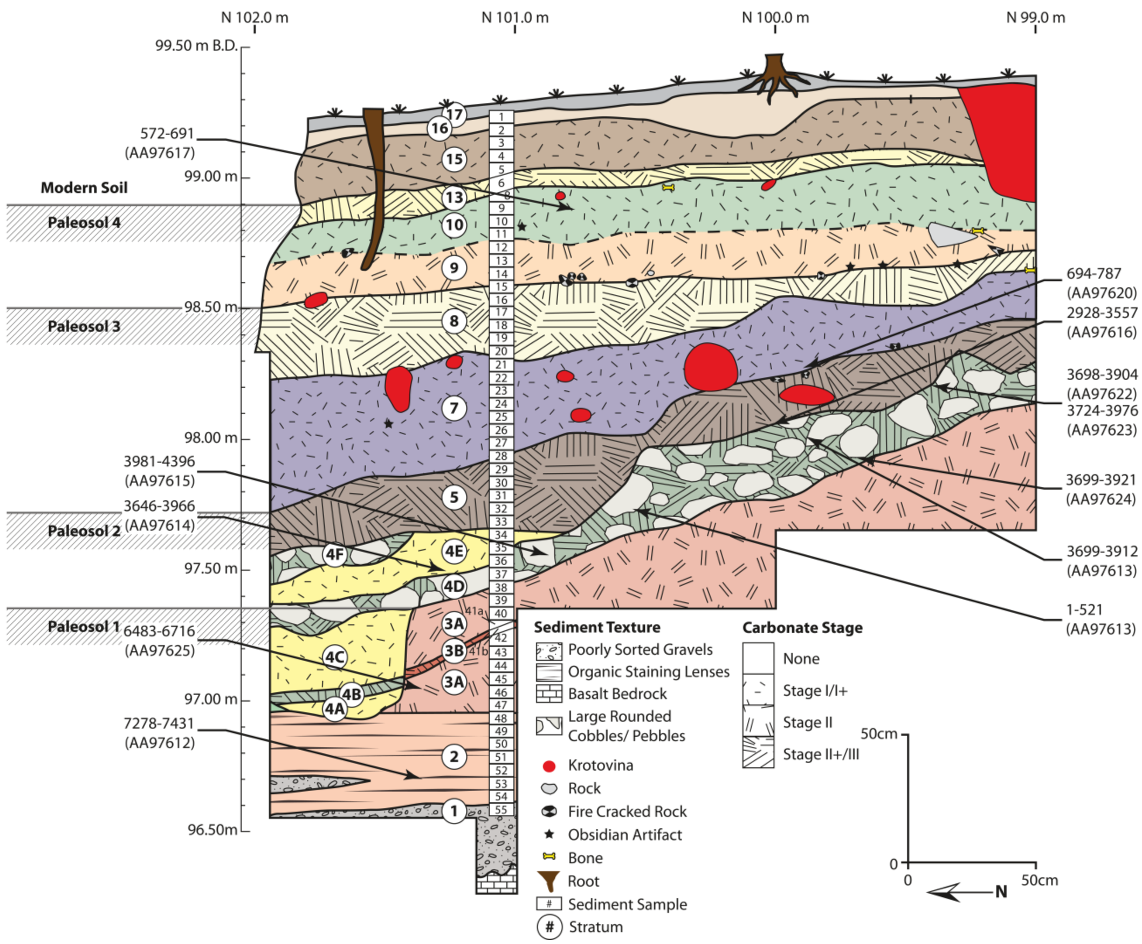

Figure 2.3. East wall profile of N99-N101, E42 (2011 excavation) showing approximate locations of AMS dates in cal yr B.P.

II.5 Results

II.5.1 Site Geomorphology

The Pioneer site is adjacent to the Big Lost River, which forms a meandering channel at this portion of its course (Figure 2.1). The river is currently dry most of the year due to modern irrigation practices upstream. The river meanders within a narrow valley about 300 m wide at this bend in the river, though this width varies, and the width of the active floodplain is only about 50 m wide. The valley is constrained by basaltic lava-flow formations to the north and south that are approximately 7 m above the channel bottom.

The 2011-2013 Pioneer excavations were situated on a flat alluvial terrace identified as the H1-2 Holocene terrace by Ostenaa and O’Connell (2005) (Figure 2.4), named as such because terrace H2 seemed to overlap the earlier, eroded terrace H1 visible only as a ~0.5-1.0 m high terrace riser occasionally located at the back of H1-2 terraces where they transition into the higher Pleistocene terraces (Ostenaa and O'Connell 2005). Generally, H1-2 is visible as only one clearly identifiable terrace surface, which is approximately 2.5 m above the base of the current river channel. While the channel margin has recently been altered somewhat by backhoe excavation to stabilize the cut bank of the current river bed, this did not affect the terrace itself, nor did it alter the elevation of the H1-2 terrace above the river channel. The excavation block intersects the cut bank, then extends from the channel to the south (magnetic) at a 45° angle (Figure 2.4).

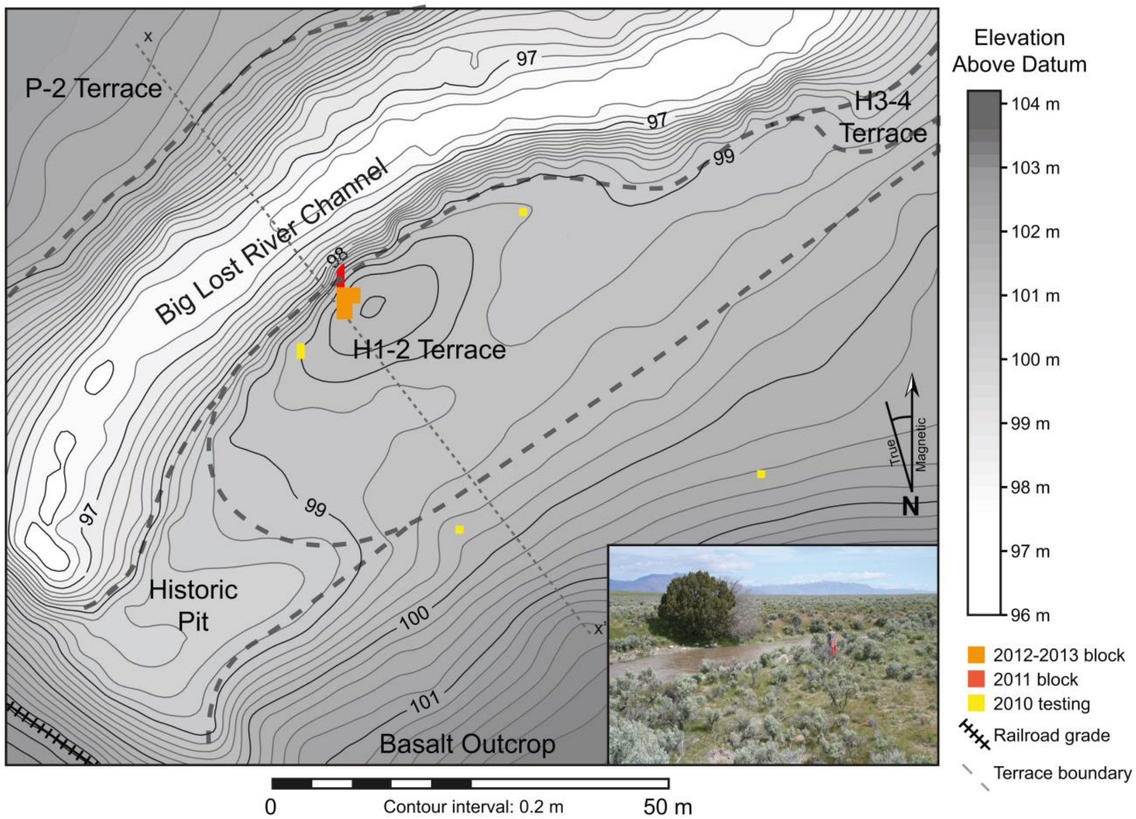

Figure 2.4. Topographic map of Pioneer site excavation block and surrounding terraces (x-x' refers to cross-section in Figure 2.6). Northward-facing inset photo shows Pioneer site in background, historic pit in foreground.

Adjacent to the H1-2 terrace, on the north side of the Big Lost River, is another higher terrace, approximately 3.5-4 m above the current river channel, composed of unconsolidated sands, gravels, and cobbles identified by Ostenaa and O'Connell (2005) as the P2 terrace (Figure 2.5). Lower terraces about 1-1.5 m above the current channel exist approximately 50 m east of the Pioneer excavation (identified as terrace H3-4 by Ostenaa and O'Connell 2005) (Figure 2.5).

II.5.2 Soils and Stratigraphy

The Pioneer archaeological site's stratigraphic profile can be generally characterized as a set of fine-grained deposits (fine loamy sand and even finer sediments) with two strata containing coarse sand and/or cobbles (Figures 2.3 and 2.6). With the exception of a few vertical sagebrush tap-roots, one of which extended to the base of the 2011 excavation, root activity was not an obvious source of bioturbation deeper than ~40 cm below the surface. Occasional rodent burrows were identified based on pockets of loose or discolored sediment. Stratigraphic layers were discerned, and five episodes of soil formation, referred to as Paleosols 1 to 5, were documented based on carbonate accumulation, sub-angular to angular-blocky ped development, and evidence of surface stability as indicated by archaeological features with charcoal, fire cracked rock (FCR), lithics, and bone scatters. Stratigraphic units and associated paleosols are described below. Specific sediment characterizations are provided in Table 2.2.

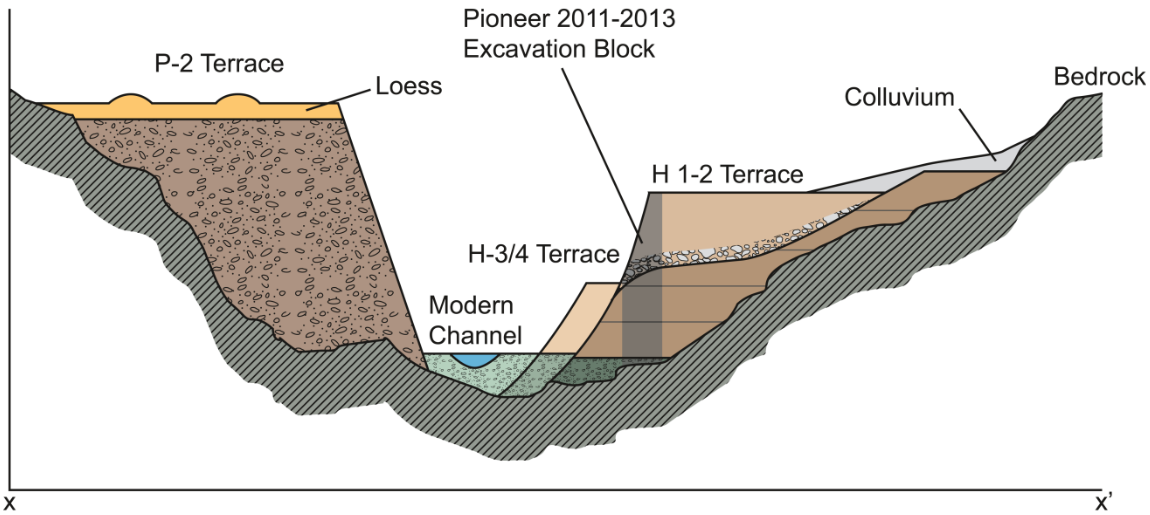

Figure 2.5. Representative profile of the Big Lost River terraces at Pioneer (not to scale) (x-x' shown in Figure 2.4).

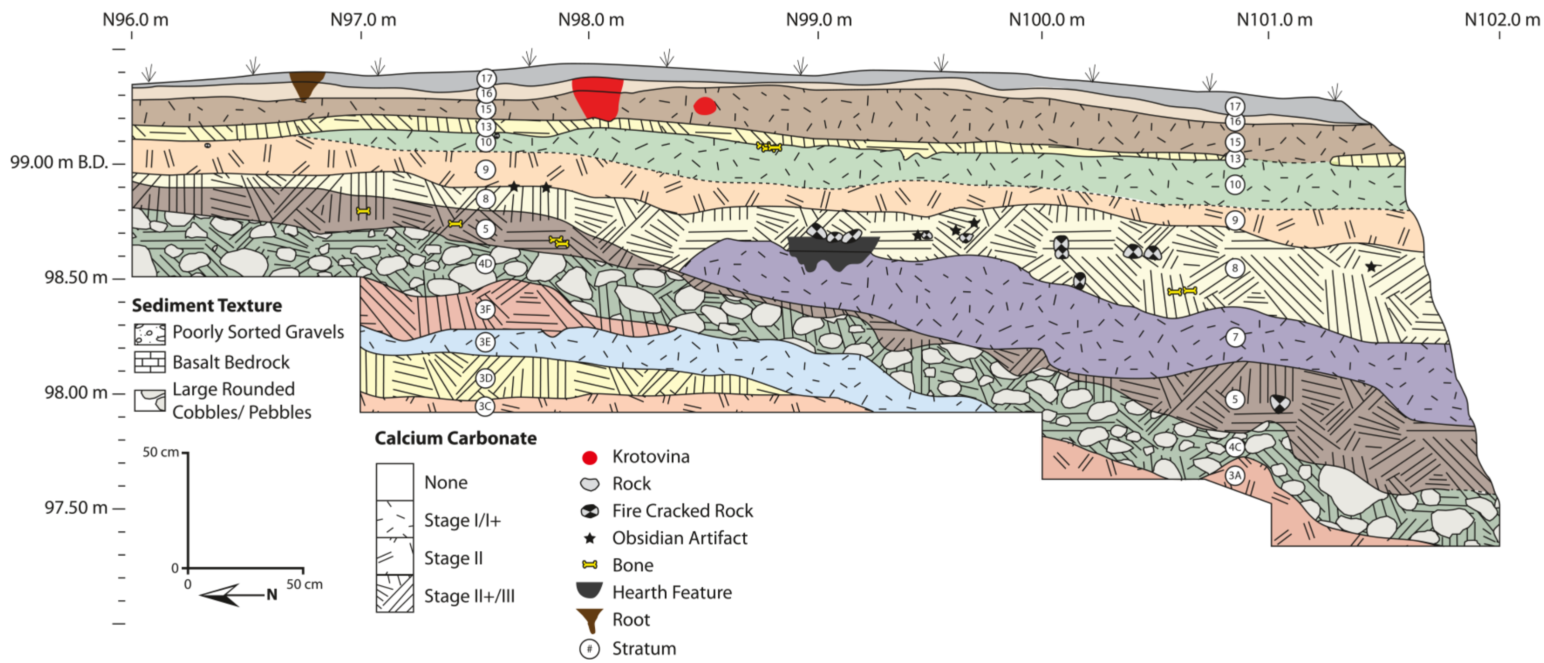

Figure 2.6. West wall profile of N96-N101, E42 (2011-2013 excavation).

II.5.2.1 Paleosol 1. Stratum 1 is at the base of the profile. It is a layer of loose, structureless, poorly sorted sand, gravels, and pebbles. This layer is ~30 cm thick and is underlain by basalt bedrock. The irregular and undulating shape of the bedrock surface as seen in various parts of the riverbed suggests the depth to the bedrock's upper boundary may be highly variable.

Stratum 1 is overlain by Stratum 2, which is composed of loam that represents the earliest known period of fine-grained alluvial deposition at Pioneer. This layer shows signs of laminar organic staining, and its upper boundary appears to be almost completely horizontal. Because excavations to this depth were limited, it is unclear how this boundary appears further from the cut bank. There is no substantive soil structure or HCl effervescence (carbonate content) associated with this stratum.

Stratum 3, originally thought to be a single layer of sandy loam, is sub-divided into six sub-strata of alternating layers of sandy loam, fine sand, loam, and sandy clay loam. These are horizontally bedded with a slight dip to the north toward the cut bank (<10°) and have alternating strong angular blocky and moderate sub-angular blocky soil structure, indicating multiple episodes of alluvial deposition and soil formation with carbonate stages ranging from I to II+/III. Stage II carbonate accumulation and an angular-blocky structure in lower Stratum 3A indicates this layer potentially contains evidence of a soil-formation episode, though the limited exposure and the unclear association with overlying 3C-3F sub-strata make this tentative (Figure 2.6). Stratum 3B is a very thin, 30-cm-long lens of loam with a slightly higher clay content and Stage II+ carbonate accumulation and is associated with the neighboring Stratum 4B to the north

(Figure 2.3), both of which may be part of a single, brief pedogenic episode. Paleosol 1 is developed into Strata 2 and 3 (shown in Figure 2.3, see also Table 2.2), which likely represents a series of at least two periods of stability and soil formation/calcium carbonate accumulation with stable surfaces at the top of Stratum 3D and at or above the top of Stratum 3F with carbonate stages ranging from I-III/IV (Table 2.2). However, the full extent of Stratum 3's sub-strata and soil-formation episodes are missing due to an unconformity between Stratum 3 and the overlying Stratum 4. Strata 1 and 2 are structureless, representing C horizons for this soil-formation episode (Table 2.2).

II.5.2.2 Paleosol 2. Stratum 4 is generally characterized as a 20-40-cm-thick layer of large, rounded basalt river cobbles (Figure 2.7). The northern-most meter of the east profile (Figure 2.3) shows a trench or channel containing multiple alternating cobble and sandy loam deposits (sub-Strata 4A-4F), though Stratum 4D extends across the entire block. Stratum 4D does not contain smaller pebbles, gravels, or coarse sand; it consists almost entirely of a matrix of secondary pedogenic carbonate (Stage II+) developed within sandy loam and large rounded pebbles and cobbles (generally between 5-10 cm in diameter), with no evidence of a fining-upward sequence. The base of Stratum 4 has a dip of about 30° to the north at the cut bank, gradually leveling, indicating an unconformity between Stratum 4 and the underlying strata.

Figure 2.7. View of Stratum 4D cobble layer in south wall of unit 99N E42.

Stratum 4 is partially overlain by Stratum 5, a thin deposit of sandy loam with moderate carbonate accumulation and a similar texture as the Stratum 4 matrix. This stratum is generally thinner to the south of the channel, though it is intermittent in places and its thickness varies. Stratum 5 also has a strong sub-angular blocky soil structure and Stage II+ carbonate morphology. Paleosol 2 (Figure 2.3, Table 2.2) formed during a period of stability at the surface of Stratum 5, forming a Bk horizon and partially cementing both Stratum 5 and the underlying Stratum 4 matrix. A Stratum 6 was originally identified but removed as it later appeared to represent the gradual contact between Strata 5 and 7.

II.5.2.3 Paleosol 3. Stratum 7 is a sandy loam bordering on a loamy sand with weak, sub-angular blocky soil structure and Stage I+ carbonate morphology. In places it is nearly 50 cm thick, and thins further from the cut bank, disappearing completely after ~3 m laterally. The upper boundary is somewhat wavy and gently dips (~10°) toward the cut bank to the north.

Stratum 8 is a sandy loam with a strong, angular blocky structure and increased carbonate accumulation (Stage II+). Like Stratum 7, Stratum 8 dips toward the river channel to the north, though at less of an angle (~5°) and with a straighter upper boundary marked by a significant concentration of archaeological material. While it becomes thinner at the southern end of the block, it does not disappear completely. Paleosol 3 developed in Stratum 8, forming a Bk horizon consisting of both Strata 7 and 8.

II.5.2.4 Paleosol 4. Stratum 9 is a sandy loam deposited on top of Stratum 8 after the development of Paleosol 3. It has moderate sub-angular blocky structure, Stage II carbonate morphology, and a smooth, slightly sloping (~5°) upper boundary. It is consistently ~20 cm thick and extends across the excavation block at Pioneer.

Stratum 10 is a sandy loam overlying Stratum 9. It is very similar in texture and color to Stratum 9, with the primary difference being the weaker sub-angular blocky structure and lower amounts of secondary calcium carbonate concretion (Stage I) in Stratum 10. The surface of Stratum 10 dips very gradually (~2°) to the north where it is 20-30 cm thick. This deposit, however, becomes thinner to the south, disappearing ~5 m to the south. Strata 9 and 10 are part of Paleosol 4. They are apparently part of the same depositional episode, but are distinguished based on differences in soil structure. The very weak sub-angular blocky structure of Stratum 10 indicates it to be a buried A or perhaps weakly developed Bw horizon overlying the moderately sub-angular blocky Stratum 9 Bk horizon. Strata 11, 12, and 14 were originally identified but later removed. Stratum 11 consisted of intermittent, thin deposits with carbonate accumulation later attributed to Stratum 13. Stratum 12 was a poorly developed sandy loam in between lenses of Strata 11 and 13 and most likely conforms with Stratum 10. Stratum 14 was identified elsewhere at the site, but was later found to be identical to Stratum 15, and the two were combined.

II.5.2.5 Modern Soil. Stratum 13 is a thin (5-10 cm) silty loam layer overlying Strata 9 and 10. It is nearly horizontal (< 2° dip to the north) and has a strong, angular blocky soil structure and calcium carbonate accumulation (Stage II+). It is overlain by Stratum 15, a weakly developed, sub-angular blocky loam with Stage 1 carbonate morphology and is generally horizontal and 15-20 cm thick. Above this is Stratum 16, which is a very thin (5-10 cm) layer of loose sandy loam with no soil development. This layer is overlain by Stratum 17, which is a thin (5-10 cm) layer consisting primarily of sagebrush and grass roots and debris. Strata 13-17 comprise the modern soil horizon with an O horizon

(Stratum 17), a thin A horizon (Stratum 16), a second A or weak B horizon (Stratum 15), and a more developed but thin Bk horizon (Stratum 13) (Table 2.2, Figure 2.3).

II.5.3 Radiocarbon Dating

Radiocarbon samples were collected from the 2011 excavation, and thus correlate with the stratigraphic profile in Figure 2.3. Radiocarbon ages are mostly in stratigraphic order, ranging from ~7300 to ~670 cal yr B.P. (Table 2.3). Stratum 2 has an associated date of 6,451 ± 45 ^{14}C B.P. (7278-7431 cal yr B.P.) (AA97612) run on non-cultural, uncharred organic matter. For the overlying stratum, a total of eight samples were dated, including six on bone and two on charcoal. Of these, four dates from within Stratum 4D (AA97614, AA97622, AA97623, and AA97624) and one date from the contact between Strata 4D and 3A (AA97613) overlap at 2σ, providing a pooled mean of 3539 ± 19 ^{14}C B.P. (3725-3889 cal yr B.P.). Another date on bone from Stratum 4D provides an age of 3,778 ± 53 ^{14}C B.P. (3981-4396 cal yr B.P.) (AA97615), while an age on charcoal from the contact between Strata 4D and 5 provides an age of 3,060 ± 120 ^{14}C B.P. (2928-3557 cal yr B.P.) (AA97616). The final date from Stratum 4D is anomalously young, dating to 315 ± 85 ^{14}C B.P. (0-521 cal yr B.P.) (AA97618). Strata 7-17 are not as well dated, though two dates, including one charcoal date and one bone date, suggest the base of Stratum 7 formed 836 ± 25 ^{14}C B.P. (694-787 cal yr B.P.) (AA97620), and Stratum 10 formed 716 ± 25 ^{14}C B.P. (572-691 cal yr B.P.) (AA97617).

II.5.4 Archaeological Stratigraphy

Excavations at Pioneer recovered dense concentrations of lithic artifacts and animal bones, numerous hearth features, diagnostic bifacial projectile points, ceramic sherds, and surficial historic debris. Lithic artifacts are overwhelmingly made from obsidian, most likely due to its nearby availability from Big Southern Butte 11 km to the south, though some artifacts (< 10%) are made from cryptocrystalline silicates or fine-grained volcanics, both of which are present in the river bed. The following briefly relates the artifacts to the stratigraphic sequence.

Strata 2 and 3 contain a limited number of artifacts, including scattered obsidian debitage and a single modified flake. Though a slight increase in flake density occurs near the Stratum 2/3 contact, the low number of artifacts indicates that they may be displaced via krotovina and other disturbances. This does not preclude, however, the possibility that middle Holocene cultural materials may be present elsewhere in un-tested areas at the site, as very little of these lower strata was tested.

Table 2.3. Radiocarbon dates from the 2011 block at Pioneer

Lab #	Cat #	Material	Strat	Northing	Easting	Elevation	d^{13}C	Fraction of Modern	^{14}C Age BP	Cal BP (2σ)
AA97612	2011-488	organic stained sediment	2	101.38	42.78	96.77	-25.2	0.4479 + 0.0025	6451 ± 45	7278-7431
AA97625	2011-483	organic stained sediment	3A	101.93	42.2	97.03	-26.3	0.4863 + 0.0026	5792 + 43	6483-6678 (p=0.98) 6685-6691 (p=0.01) 6704-6716 (p=0.01)
AA97615	2011-350	burned bone	4D	100.92	42.17	97.52	-20.6	0.6248 + 0.0042	3778 ± 53	3981-4299 (p=0.97) 4327-4354 (p=0.02) 4369-4385 (p=0.01) 4394-4396 (p<0.01)
AA97613*	2011-163	bone	3A/4D contact	99.75	42.4	97.91	-19.7	0.6458 + 0.0043	3512 ± 53	3641-3673 (p=0.05) 3677-3921 (p=0.95)
AA97614*	2011-460	bone	4D/4E contact	101.34	42.65	97.52	-18.8	0.6445 + 0.0042	3529 ± 53	3646-3663 (p=0.02) 3687-3930 (p=0.95) 3944-3966 (p=0.03)
AA97622*	2011-150	bone	4D/5 contact	99.43	42.46	98.02	-19.3	0.6442 + 0.0030	3532 ± 37	3698-3904
AA97623*	2011-151	bone	4D/5 contact	99.49	42.47	98.05	-19.1	0.6412 + 0.0030	3570 ± 38	3724-3754 (p=0.06) 3757-3795 (p=0.08) 3818-3976 (p=0.86)
AA97624*	2011-169	bone	4D	99.92	42.32	97.85	-19	0.6439 + 0.0030	3536 ± 37	3699-3912

Table 2.3. (Cont.)

Lab #	Cat #	Material	Strat	Northing	Easting	Elevation	$d^{13}C$	Fraction of Modern	^{14}C Age BP	Cal BP (2σ)
pooled mean of previous five dates			*4D*						*3539 ± 19*	*3725-3753 (p=0.13) 3759-3795 (p=0.20) 3818-3889 (p=0.66)*
AA97618	2011-339	charred wood	4D	100.48	42.7	97.61	-22.8	0.962 + 0.010	315 ± 85	1-24 (p=0.02)** 141-220 (p=0.09) 263-521 (p=0.88)
AA97616***	2011-117	charcoal	4D/5 contact	99.95	42.55	97.96	-26.9	0.684 + 0.010	3060 ± 120	2928-3510 (p=0.99) 3530-3557 (p=0.01)
AA97620	2011-080	charcoal	5/7 contact	99.86	42.32	98.19	-28.6	0.9012 + 0.0028	836 ± 25	694-787
AA97617	2011-226	charcoal	10	100.82	42.9	98.89	-26.4	0.9147 + 0.0029	716 ± 25	572-578 (p=0.02) 652-691 (p=0.98)

*used to create pooled mean value for stratum 4C

**Modern

***Inconsistent date not included in age estimate of Stratum 4D

Stratum 4D contains the deepest clear archaeological component at Pioneer. It consists of numerous obsidian and chert bifaces, modified flakes, and debitage as well as faunal remains and scattered fire-cracked rock (FCR) situated at the contact between Strata 4D and 5, and it presumably dates to ~3700 cal yr B.P. Two of these bifaces resemble "Beaverhead" variety dart-point preforms (Swanson 1972) and are likely un-notched Elko or Northern Side Notched points (Figure 2.8: a-b). Artifact and bone quantities drop to practically zero at depths greater than ~5 cm below the top of Stratum 4D, though occasional bone fragments are present within and at the base of Stratum 4D.

The top of Stratum 5, dating to between ~3700-750 cal yr B.P., yielded a single concentration of FCR associated with expedient tools and multi-directional cores, as well as a bifacial knife/preform, suggesting a possible hearth feature and processing area.

Stratum 7 contains a denser concentration of artifacts than do deeper strata, with an archaeological assemblage consisting of over 5000 pieces of debitage associated with charcoal indicating an age of ~750 cal yr B.P. This stratum contains a single Desert Side-Notched point (Figure 2.8d) and a re-worked stemmed-point base that resembles an unfinished Haskett point (Figure 2.8c).

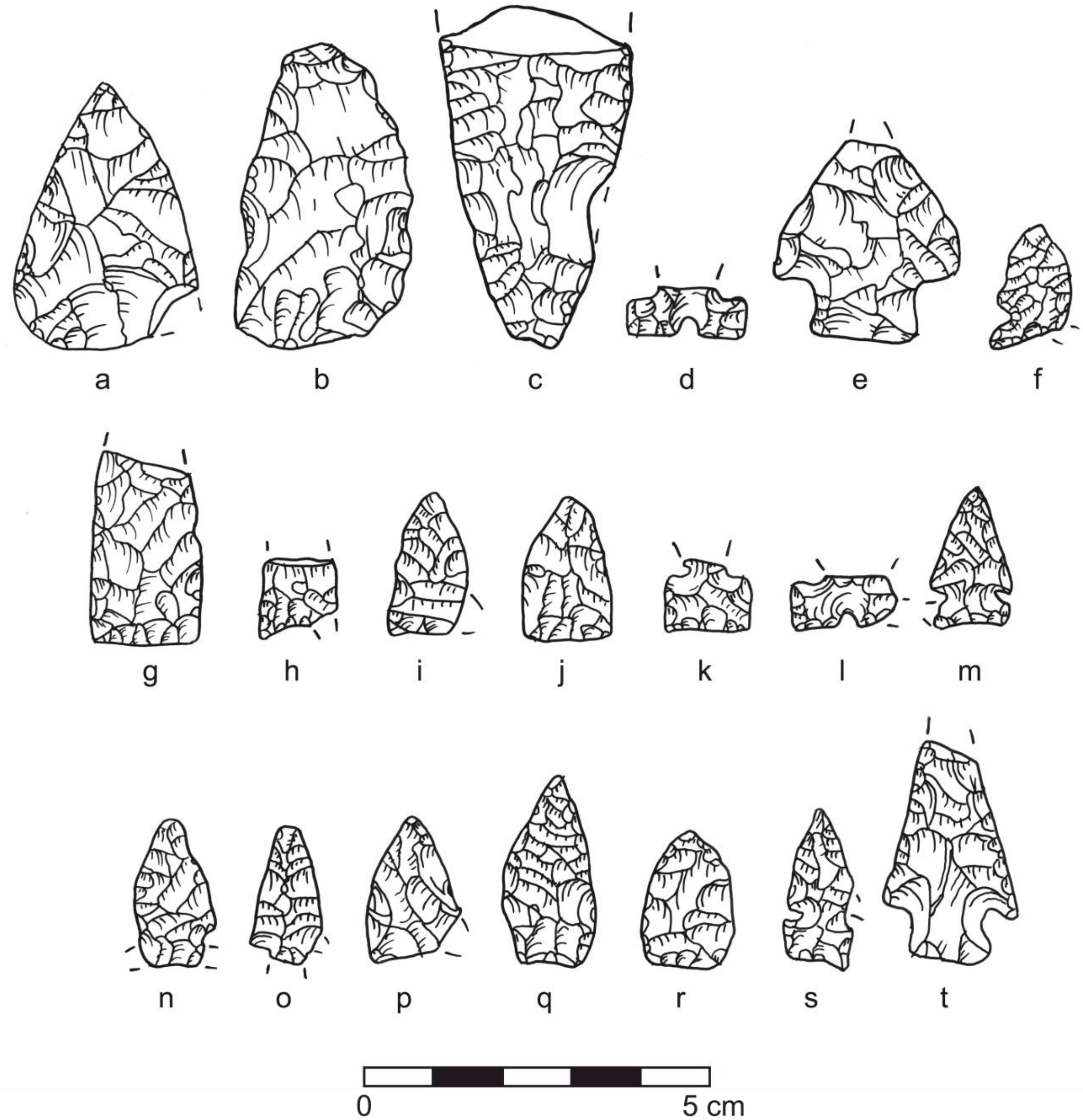

Figure 2.8. Diagnostic artifacts from Pioneer: a-b) Beaverhead preforms, Stratum 4; c) Stemmed point preform, Stratum 5; d) Desert Side-notched point, Sierra variety, Stratum 6; e) Elko point, Stratum 8; f) Avonlea point, Strata 9-10; g-j) Cottonwood triangular points, Strata 9-10; k) Desert Side-notched points, Stratum 9-10; l) Desert Side-notched, Sierra variety, Strata 9-10; m-o) Rosegate points, Strata 9-10; p-r) Cottonwood triangular points, Strata 13-17; s) Desert Side-notched point, Stratum 13-17; t) Elko point, Stratum 13-17.

Stratum 8 has the largest and densest concentrations of artifactual material in the site, situated primarily near the contact of Strata 8 and 9. Its age is ~750-630 cal yr B.P., and there are over 12,000 pieces of debitage, six concentrations of FCR (including one rock-oven feature), and six dense concentrations of lithic material and bone, and a single Elko style dart point (Figure 2.8e). Other artifacts include multiple bifaces, cores, modified flakes, one ground-stone fragment, and three ceramic sherds resembling Shoshone brown-ware.

Strata 9-10, unlike the lower horizons, have no obvious single occupation surface, making it difficult to differentiate between the two during excavation. There are no distinct hearth features, though a diffuse spread of FCR and charcoal around the center of the block was present, dated to ~630 cal yr B.P. Archaeological materials consist of faunal remains, bifacial tools, western-Shoshone-style ceramic sherds, and debitage. In addition, two Desert Side-Notched points (including one Sierra/Tri-Notched variety), one Avonlea point, three Rosegate points, and four Cottonwood triangular points were found (Figure 2.8f-o).

Strata 13-17 consist of a low-density concentration of scattered prehistoric/protohistoric and historic debris at or within 30 cm of the surface that post-dates ~630 cal yr B.P. Historic artifacts such as bullet shells, glass, and metal cans were found in association with lithic debitage, bifaces, Shoshoni brown-ware ceramic sherds, and surface hearth features both in the excavation block as well as across the surrounding terrace surface. These strata also contain the following diagnostic projectile points: one Desert Side-Notched point, three Rosegate points, five Cottonwood triangular points, and a single small Elko point or large Rosegate point (Figure 2.8p-t).

II.6 Discussion

The following discussion is organized into three sections. The first provides a chronology of geomorphological deposition, erosion, and soil-formation episodes at Pioneer in the context of human occupation of the site. Data from Pioneer, combined with existing data provided by Ostenaa and O'Connell (2005), are then used to interpret the sequence of Holocene terrace formation along the Big Lost River valley between the constricted box canyon upstream to the northwest and the playas downstream to the north. Third, possible explanations for the formation of the rounded cobble deposit of Stratum 4 and its potential association with a middle-Holocene flood event are discussed.

II.6.1 Site Formation Processes

The sediments from the 2011-2013 excavation are interpreted as alluvial deposits from the adjacent Big Lost River. The earliest period of fine-grained alluvial deposition (Stratum 2) began in the early-middle Holocene prior to ~7300 cal yr B.P., and occurred on top of an older, as yet undated, lateral channel deposit of coarse sands and gravels (Stratum 1, Figure 2.3). Lower Stratum 2 shows signs of horizontal, laminar organic staining, suggesting the area may have had extended periods with shallow standing water. The lack of carbonate accumulation suggests a period of deposition too rapid or too wet to allow Aridisol formation.

Extensive secondary $CaCO_3$ accumulation took place within Stratum 3A (Paleosol 1), indicating a period of stability beginning no earlier than ~6600 cal yr B.P., though the upper portions of this horizon were truncated by an erosional unconformity related to the deposition of Stratum 4. Following this period of stability and lasting until no later than ~3800 cal yr B.P., layers 3C-3F were deposited by overbank flooding. Additional layers above these also may have existed, but if once present, these were eroded, forming an unconformity between Strata 3A-3F and 4D. Strata 3C-3F have varying degrees of sandiness and alternate between strong and weak aridisol formation, indicating sporadic periods of variable stream flow followed by periods of stability (Paleosol 1). The low number and small size of flakes found in Strata 2-3 suggest possible downward displacement via bioturbation, and that the layers are not directly connected to human presence at the time the sediments were deposited. Limited presence of small rodent burrows throughout the profile likely explains this presence. However, this does not preclude the possibility that middle Holocene artifacts may be present in these deposits elsewhere in the site, as the sediments indicate a low-energy depositional environment (with the possible exception of Stratum 3E) and early-middle Holocene diagnostic points (i.e., Haskett, Humboldt, and Northern Side Notched forms) were found on the surface in the vicinity of the site by the 2005 ISU field school.

Following the deposition of Strata 3A-3F, much of these layers eroded and was capped with the large rounded basalt cobbles of Stratum 4 (Figure 2.7). While the presence of large cobbles may suggest a riverbed or lateral-bar deposit, only the northern-most portion of the profile resembles the edge of a channel, with alternating cobble and sandy-loam deposits. The rest of the profile shows that Stratum 4 matrix consists of sandy loam. This, coupled with underlying, intact, horizontally bedded loam strata that were not fully washed away, suggests a very rapid and short-term increase in river flow. This flow was intense enough to redistribute large cobbles ranging in size from 5-10 cm in diameter, suggesting a possible flood event. Furthermore, though some of the AMS radiocarbon dates from Stratum 4 could be from animal bone redeposited during this flood and not related to human activities, their age range show a very narrow range of time. Five overlapping radiocarbon dates from both the surface and base of Stratum 4D provide a pooled mean of 3539 ± 19 ^{14}C B.P. (3725-3889 cal yr B.P.), suggesting this layer was deposited over the course of ~150 years or less, with the possibility of a single rapid depositional episode as the cause.

This ~3800 cal yr B.P. event eroded portions of the underlying Strata 3A-3F, depositing large cobbles in its wake, but without fining-upward alluvial deposits as would be present in a regular riverbed resulting from more prolonged deposition. The “channel” shown in the northernmost profile (Figure 2.3) possibly represents subsequent, or prior, smaller floods that occurred shortly before or after the primary flood. This may represent the “Older Flood” event mentioned in a few sources (Butler 1978; Ostenaa and O'Connell 2005). The date for this occurrence is not well established, but a general age of 3000-4000 ^{14}C B.P. by Butler (1978) and 1000-2000 ^{14}C B.P. by Ostenaa and O’Connell (2005) may roughly coincide with the Stratum 4 event. A similar

“Pebble Lag” was deposited at the mouth of the Radioactive Waste Management (RWMC) facility “spreading area” basin < 1 km to the south, along with discontinuous lenses of sand and gravel. As these overlie the Pleistocene glacial outwash gravels, they are considered to date to some time during the Holocene and may also relate to the “Older Flood” event, though no direct dates are available (Dechert et al. 2006; Hackett et al. 1995)

Humans occupied the surface of Stratum 4 very shortly after this event, depositing a number of bifacial tools, FCR, and faunal remains directly on the surface of the cobbles. It is likely that these materials are in-situ and not redeposited by the flood, as they are almost exclusively isolated to within 5 cm of the boundary between Stratum 4D and Stratum 5, and obsidian flakes lack significant battering or other damage to their edges. They do not penetrate very deeply into the cobbles of Stratum 4D, and they occur in three discrete horizontal concentrations of flake and bone. In addition to multiple bone samples collected from Stratum 4D dated to ~3800 cal yr B.P., a single sample of charcoal collected from this surface dates to ~3200 cal yr B.P., suggesting human presence around 3800 cal yr B.P. and a potential later presence on the same surface at ~3200 cal yr B.P. The single Beaverhead A Elko/Bitterroot bifacial preform found in this horizon fits this time range, though the age range for this artifact form is very broad, ranging anywhere from ~8350-1100 cal yr B.P. (Holmer 2009; Swanson 1972)

There was a subsequent period of fine-grained sedimentation (Stratum 5) which deposited a thin layer of sandy loam above and between the cobbles in Stratum 4. An extended period of stability resulted in the development of Paleosol 2. Based on available ^{14}C measurements, it is unknown when and for how long this period of stability occurred, though charcoal from a feature resting at the top of Stratum 5 and dating to ~750 cal yr B.P. may provide an upper limiting age. During this period, humans appear to have occasionally used the site based on the isolated scatter of FCR and artifacts. The extremely limited sediment deposition or possible erosion during this period, however, means the time period between ~3200 and ~750 cal yr B.P. is not well represented in the stratigraphic profile.

Strata 7 and 8 likely formed as part of the same period of increased alluvial deposition, as shown by a similar texture and slight fining-upward nature in the two combined strata, with the only difference being the degree of soil formation within the Paleosols. Paleosols 3 and 4 began forming in rapid succession at or possibly just prior to ~750 cal yr B.P., with perhaps only 100 years of stability between them, based on dates of ~750 cal yr B.P. from the surface of Stratum 5/base of Stratum 7 and ~630 cal yr B.P. from within Stratum 10. During the period of stability following the deposition of Stratum 8, this surface was intensively occupied, though the presence of numerous artifacts and features throughout Strata 7-13 suggests the site was frequently revisited between a period of increased flooding 800-600 cal yr B.P. Flooding deposited a thick layer of sandy loam ranging from 0.5-1.0 m in thickness over a relatively short period of time. This appears to correlate both stratigraphically and chronologically with the "400 year flood" deposits (Ostenaa and O'Connell 2005). Increased stream flow likely resulted from higher precipitation, likely creating a favorable environment for hunter-gatherers.

The presence of Avonlea, Cottonwood, Rosegate, and Desert Side-Notched points in Strata 6/7 and 10 is consistent with the AMS radiocarbon dates from these deposits. The age range of 750-630 cal yr B.P. corresponds with the terminal age of Avonlea-style arrow points and the earliest known age of Desert Side-Notched and Cottonwood points in the area (~650 cal yr B.P.) (Holmer 2009). This, combined with an age range of 1650-100 cal yr B.P. for Rosegate points in the area (Holmer 2009), correlates with AMS age estimates for these horizons and suggests that users of these different point forms frequented the Pioneer site for over 100 years. The single Elko point found in Stratum 8 post-dates the standard terminal age of Elko (~1150 cal yr B.P.) (Holmer 2009) by roughly 400 years. Likewise, the possible un-ground Haskett fragment post-dates the latest known Haskett and Birch Creek points in the area (~8350 cal yr B.P.) (Holmer 2009) by nearly 8000 years. While these points were found in-situ with no evidence of post-depositional transport via bioturbation, the common presence of these forms on the surface in the immediate vicinity suggests that these points may have been collected and recycled by later occupants.

Following a short period of stability after the formation of Paleosol 4, the modern soil horizon began forming in sediments deposited sometime after ~600 cal yr B.P. Though radiocarbon ages are not available for these deposits, the mixed historic and prehistoric materials suggest humans continued to use the locality through the late prehistoric and protohistoric periods. The sediments in this uppermost horizon, though, appear somewhat mixed and loose, resembling a “plow zone,” though it was more likely the result of trampling by people or cattle, or the re-deposition of loose sediment as a result of nearby historic excavation activities. Rosegate, Cottonwood, and Desert Side-Notched points are present in this deposit and confirm a late-Archaic age, though again these may be mixed or re-deposited from slightly older sediments elsewhere at the site.

II.6.2 Holocene Big Lost River Terrace Formation

The Big Lost River terraces were defined as a series of gravelly bar and meander channels formed as a result of middle/late Pleistocene flooding and glacial melt (Cerling et al. 1994; Geslin et al. 1999; Gianniny et al. 1997; Knudsen et al. 2002; Nace et al. 1956; Nace et al. 1975). As defined by Ostenaa and O’Connell (2005), Pleistocene deposits near Pioneer can be split into three terraces. The P-1 and P-2 terrace deposits (4.0-4.5 m above channel) formed through high-energy floods and glacial melt. They resemble braided-stream deposits and consist of poorly sorted gravels and cobbles topped by eolian mima-mound formations that likely developed sometime in the late Pleistocene (Tullis 1995). The P-3 terrace formed in the late Pleistocene and is associated with the Big Lost River’s shift to a meandering stream, characterized by a heavily indurated surface soil formed in eolian and alluvial sediments, potentially correlating with BLR-3 and BLR-6 (Ostenaa et al. 2002; Ostenaa and O'Connell 2005)

It was not until recently that Holocene-age terraces were described along portions of the Big Lost River by Ostenaa and O’Connell (Ostenaa et al. 1999; Ostenaa et al. 2002; Ostenaa and O'Connell 2005). Though they are sporadic and only present on a relatively short stretch of the river between Lake Terreton’s bed to the north and the box canyon and lava flows to the northwest, these deposits tend to be fine-grained overbank flood deposits. These terraces are sporadic and range in width from a few meters to as much as 100 m wide in some places (Figure 2.5).

Based on the work presented here, sediment deposits within the earliest Holocene-aged terrace, H1 (2.5-3.0 m above channel), began forming just prior to ~7300 cal yr B.P. Alternating layers of slightly coarser or slightly finer sediments with bands of organic staining indicate variable discharge, with periods of very low energy flow and marshy conditions in the immediate area early on. This potentally correlates with early paleosols dated by Ostenaa and colleagues to 8370-8140 cal yr B.P. (BLR-2) and 7300-7200 cal yr B.P. (T4) (Ostenaa et al. 2002; Ostenaa and O'Connell 2005). Deposition continued until sometime between 6600 and 3800 cal yr B.P., at which time a high-energy alluvial episode occurred. This potentially corresponds to the “older flood” described by Ostenaa and O’Connell (2005), which partially eroded terrace H1 and deposited a layer of large rounded cobbles (Stratum 4) likely re-deposited from eroded P1-3 gravel deposits upstream.

Following the accumulation of a thin layer of Stratum 5 deposits over Stratum 4, there was a period of stability lasting until ~800 cal yr B.P., after which rapid alluvial deposition occurred, depositing alluvium over the remnants of terrace H1, forming terrace H2 (1.8-2.2 m above channel) and likely correlating with the “400 year flood” described by Ostenaa and colleagues (Ostenaa et al. 2002; Ostenaa and O'Connell 2005), the refilling of the playas and possibly even Lake Terreton to the north (Bright and Davis 1982; Forman 1997; Ostenaa et al. 1999), and potentially correlating with records of increased precipitation from nearby Birch Creek rockshelters ca. ~700 cal yr B.P.

(Swanson 1972). This deposition occurred over a period of at least 100 years, corresponding with a period of frequent habitation by prehistoric groups, and was probably the result of a period of increased precipitation, potentially correlating to the end of the Medieval Climatic Anomaly (MCA) (1150-700 cal yr B.P.) (RW.ERROR - Unable to find reference:264; Stine 1994). This period may also have correlated with the formation of the lower H3-4 terraces (1-1.8 m above channel) (Ostenaa and O'Connell 2005). It should also be noted that deposition did occur at other locations along the Big Lost River downstream of Pioneer between ~2800-800 cal yr B.P. based on data acquired by Ostenaa and colleagues (Ostenaa 2002; Ostenaa and O'Connell 2005), suggesting the lack of deposition at Pioneer during this period may be due to local differences in channel geomorphology.

II.6.3 The Pioneer Flood Event

Ostenaa and colleagues (Ostenaa et al. 2002; Ostenaa and O'Connell 2005) date a middle-Holocene Big Lost River flood event, referred to as the “Older Flood,” to approximately 2000-1000 cal yr B.P. They recognize that this is an estimated age, indicating that it may have occurred as much as 2000 years earlier, as suggested by Butler (1978). Ostenaa and O’Connell (2005) describe this flood as having been high enough to top the H1-2 terraces, based on the unconformity between these layers and the “400 year flood” deposition (Paleosols 2 and 3). Based on ages from Pioneer, it would appear that this flood is represented by Stratum 4 and therefore occurred between 3889-3725 cal yr B.P. It was potentially a large, instantaneous discharge intense enough to transport large cobbles, though it likely was limited to the lower Big Lost River trough. Given the available dating of this flood at the Pioneer site, the name "Pioneer Flood" event is used to distinguish it from others.

The most likely source for this flood is a precipitation or snowmelt event that was amplified by the constricted, 11 km long Box Canyon portion of the Big Lost River (Figure 2.1) to create a narrow but very high-energy flow of water downstream to the Pioneer area. The terminus of this canyon is only 4 km upstream of Pioneer, and the resulting localized flood could have eroded the H1 terrace and redeposited large round cobbles over a very short period of time. This event could also have overflowed into the RWMC spreading area directly to the south, creating the Holocene "pebble lag" deposits (Dechert et al. 2006; Hackett et al. 1995), though the lack of direct dates for these features makes this association tenuous. Due to the constricted nature of the canyon, higher rates of water velocity and transport are possible despite a relatively small increase in discharge. The late Pleistocene "Big Lost River Flood" that flowed through the same box canyon, as described by Rathburn (1993), despite its relatively small size, had the third-highest documented flood power on record after the Missoula and Bonneville floods.

The likely cause of the Pioneer flood event is a large accumulation of snow upstream followed by rapid snowmelt. It is not clear, however, what triggered this rapid snowmelt. There are no correlated features recorded upstream in the Mackay area, though studies of late Holocene deposits are scarce for this region. A potential correlate is the Carlson landslide, a moist landslide that originated in the Lost River Range ~80 km to the north that occurred ~3700 cal yr B.P. and contained a large amount of water (Shaller 1991). While the ultimate cause of this landslide was a gradual weakening of the substrate, the trigger for this event could potentially have been caused by intense precipitation. One possibility is that its timing corresponds to the onset of increased precipitation of the late Holocene, estimated to have occurred between ~3500-2800 cal yr B.P. based on ages from Gray's Lake (Beiswenger 1991) and Rattlesnake Cave (Bright and Davis 1982). However, large-scale climate change would not necessarily explain such an abrupt event, as abrupt snowmelt or flooding is still possible during arid periods.

Another possible explanation is that the erosion of the H1 terrace and deposition of the Stratum 4 cobble layer is tied to volcanic activity at Craters of the Moon, located ~25 km southwest of Pioneer (Figure 2.1). Craters of the Moon consists of basaltic pahoehoe lava flows that formed from multiple shield volcanos and fissure eruptions during the Pleistocene and Holocene. The Minidoka eruption, in particular, was the largest of the Eruptive Period B eruptions of the middle-late Holocene and formed a ~250 km^2 lava field. This eruption would have consisted of several days of violent expulsion of gas-charged molten lava and tephra followed by a subsequent massive lava flow dated to 4085-3701 cal yr B.P. (W-4447) (Kuntz et al. 1986), overlapping at 2σ the pooled mean age of the five dates acquired from the Stratum 4 cobble layer at Pioneer (3889-3725 cal yr B.P.). A similar eruption at nearby Devil's Cauldron was similarly dated to 4149-3839 cal yr B.P. (W-4339), also potentially overlapping the pooled mean age from Pioneer Stratum 4.

This period of increased volcanism generated intense ashfall, heat, and even brushfires from the associated initial blasts and cinder cone formations; potentially enough to create local super-storms in the nearby Lost River Range and Pioneer Mountains and a sudden increase in precipitation that could have affected Pioneer and potentially even the Carlson landslide. A similar effect has been documented by Bell and House (2007) as occurring at over 20 sites in western Nevada where large, cobble-filled flash-flood deposits were found to consistently overlay intact fine-grained alluvial deposits and tephra from eruptions at Mono and Inyo crater beds during the late Holocene.

A rapid snowmelt could also have been caused by tephra-fall-induced decreased albedo of nearby snowpack and glaciers in the mountains (e.g., Nield et al. 2013). While the degree of tephra ejection was substantially less than the classic Plinian eruptions of the Mono and Inyo craters, the initial eruption could have been enough to trigger flash flooding on a local scale.

II.7 Conclusions

Like many rivers in the Intermountain West, the Big Lost River during the Holocene has been characterized as a very low energy, seasonally flowing stream running through remnant Pleistocene-aged channels toward the Big Lost River Sinks on the current day Idaho National Laboratory, assuming little to no significant deposition during the Holocene (Nace et al. 1956; Nace et al. 1975). However, recent work by Ostenaa and O’Connell (2005) as well as this study show a much more complex and dynamic history. Besides clear signs of multiple episodes of deposition and erosion during the Pleistocene and through much of the Holocene, there is evidence for flash floods during the middle-late Holocene triggered by intense precipitation and rapid snow melt, possibly linked to volcanic activity. The thick deposits of fine-grained overbank flood alluvium preserved at Pioneer and along the Big Lost River channel provide a valuable opportunity for future studies to find and excavate preserved, stratified sub-surface human occupation surfaces dating to the Holocene and possibly even terminal Pleistocene in an arid environment otherwise dominated by surface palimpsest sites. The Pioneer excavation confirms this assessment, providing evidence of multiple cultural occupations spanning more than 3700 years, making it one of a handful of open-air, stratified multi-component sites known in the arid Intermountain West.

In addition to providing a cultural record, the sedimentary record at Pioneer provides some insight into the paleoclimatic history of southeastern Idaho and the greater Intermountain West from the early-middle Holocene transition ~7200 cal yr B.P. to the historic period. While evidence for early-middle Holocene climate variation is scant with the present sample, radiocarbon data from this paper and Ostenaa and colleagues (Ostenaa 2002; Ostenaa and O'Connell 2005) indicate a period of increased deposition between ~8400-6500 cal yr B.P., potentially correlating with a possible cooling interval between 8100-6700 cal yr B.P. during the middle Holocene based on data from Grey’s Lake (Beiswenger 1991). There were subsequent periods of deposition and soil formation between 6500-3800 cal yr B.P., though the exact age and extent are unknown at this time.

There is minimal deposition during much of the late Holocene between ~3800 cal yr B.P. and ~750 cal yr B.P. at Pioneer, though elsewhere along the Big Lost River, deposition increases around ~2700 cal yr B.P., correlating roughly with wetter climatic conditions generally thought to have occurred coincident with the beginning of the late Holocene (Beiswenger 1991; Bright 1966; Bright and Davis 1982; Henrikson 2003). More recent deposition at Pioneer, corresponding with similar periods of deposition downstream (Ostenaa et al. 2002; Ostenaa and O'Connell 2005), and limited evidence of post-1000 cal yr B.P. re-filling of Lake Terreton (Bright and Davis 1982; Forman 1997) indicate a period of cooler and wetter climate in the region between 750-630 cal yr B.P., potentially coinciding with the early onset of the MCA.

Though currently providing the primary source of paleoclimatic data for the region, much of the existing lake-core pollen records (Beiswenger 1991; Bright 1966; Bright and Davis 1982; Davis et al. 1986) for the upper Snake River Plain are becoming increasingly outmoded, necessitating the need for new well-dated high-resolution proxy records. Moreover, future geoarchaeological testing is required along the Big Lost River, to fully assess the archaeological and paleoclimatic potential of these Holocene-aged terraces as well as to test the hypothesis that an “older flood” event affected the area during the middle-late Holocene, and what may have been its cause. Although alluvial-climate relationships are complex, geomorphological alluvial terrace testing can be used in arid environments across the Intermountain West to identify intact, open-air subsurface archaeological sites and better understand Holocene climate fluctuations.

CHAPTER III

A DIACHRONIC PERSPECTIVE ON GREAT BASIN PROJECTILE POINT MORPHOLOGY FROM VERATIC ROCKSHELTER, IDAHO*

III.1 Introduction

Projectile-point typologies have long been an important tool used by archaeologists to assign chronometric ages to archaeological components without datable geological contexts. Thomas' Monitor Valley/Gatecliff Rockshelter chronology for the central Great Basin (1981), for example, provided a much-needed standardization of projectile-point variability using metric attributes. However, it is becoming increasingly apparent that different regions of the Intermountain West have variations in form and chronology inconsistent with Thomas' key (e.g. Bettinger 1999; Holmer 1986; Schmitt and Madsen 2005). Most recently, Smith et al. (2013b) suggested that, based on benchmark sites with established chronologies, the Great Basin has at least five areas with distinct projectile-point chronologies. These inter-regional differences go beyond merely affecting chronologies; they also have implications for understanding culture change and regional cultural interactions throughout the Holocene in the Great Basin. However, to establish these chronologies for specific regions, it is crucial to have stratified, well-dated benchmark sites with occupations containing diagnostic points

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spanning much of the Holocene. One such site is Veratic Rockshelter, located on the upper Snake River Plain, Idaho.

This paper evaluates the geochronology and projectile-point variability of Veratic Rockshelter, a multi-component, stratified site located on the northeastern edge of Idaho's Snake River Plain (Figure 3.1). Veratic and adjacent Bison Rockshelters were originally excavated by Earl Swanson, Jr. and colleagues in the early 1960s as part of the Birch Creek archaeological survey project (Swanson 1972). Swanson's excavations were cutting-edge for their time, applying stratigraphic and radiocarbon techniques to establish the context of over 400 diagnostic projectile points and 1100 other lithic artifacts from 13 components that ranged from 500 to more than 10,000 radiocarbon years ago (^{14}C B.P.). Not surprisingly, Swanson's study played a key role in developing projectile-point typologies for the Snake River region (Butler 1978; Holmer 1986, 2009).

Despite the significance of the Veratic and Bison records, no attempts have been made to re-examine the shelters since Swanson published his site report in 1972 (but see Hughes 2007; Lohse and Sammons 1994). The early conventional radiocarbon methods used to originally date the site required large bulk samples of organic matter, resulting in substantial standard deviations on combined samples spread across multiple features and even stratigraphic horizons (see Bradley 2013, pp. 62). As a result, some of the original ages likely represent a mix of materials from multiple, non-contemporaneous features. Furthermore, detailed lithic analyses and stratigraphic contexts of specific artifacts were not reported by Swanson (1972) and diagnostic points were divided into numerous sub-groups, many of which do not match typologies in use today.

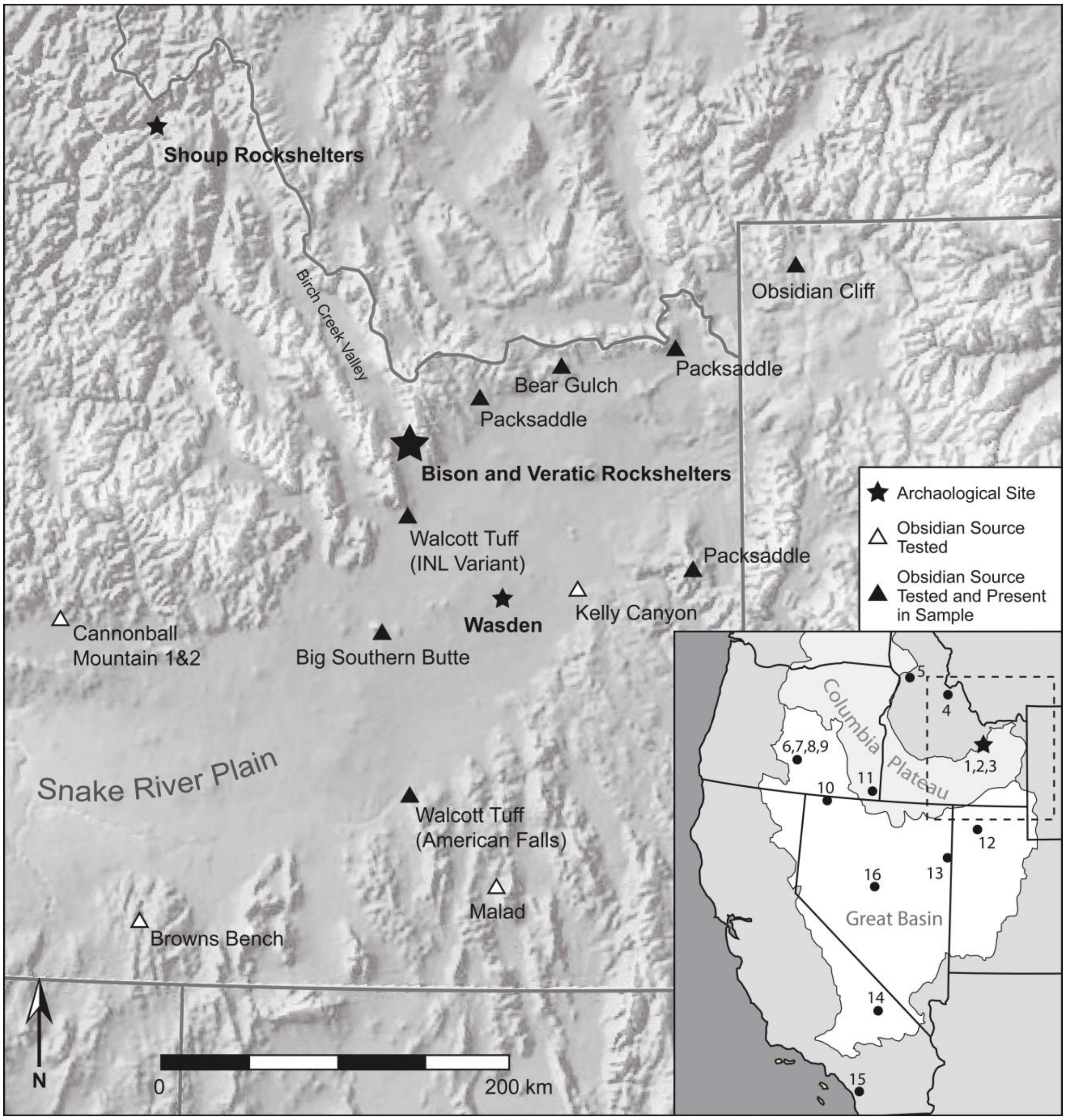

Figure 3.1. Map of the Snake River Plain of southern with archaeological sites and obsidian sources discussed in text. Inset: 1) Veratic Rockshelter, 2) Bison Rockshelter, 3) Jackknife Cave, 4) Shoup Rockshelters, 5) Cooper's Ferry, 6) Fort Rock Cave, 7) Connley Caves, 8) Paulina Lake, 9) Buffalo Flat, 10) Last Supper Cave, 11) Dirty Shame Rockshelter, 12) Hogup Cave, 13) Bonneville Estates Rockshelter, 14) Henwood, 15) C. W Harris, 16) Gatecliff Rockshelter.

Using the curated assemblage at the Idaho Museum of Natural History, I examined diachronic variability in projectile points from Veratic Rockshelter using new accelerator mass spectrometric (AMS) radiocarbon dates and lithic analyses focusing on latest Pleistocene to late Holocene spear, dart, and arrow points. The large assemblage of artifacts as well as the still curated charcoal samples at the museum make the Veratic assemblage ideal for updating the Snake River Plain's regional point typology.

In addition to re-dating cultural components from the site and re-assessing the current lithic assemblage, the analysis focused on three questions: 1) What is the age of the stemmed-point component at Veratic, and how do these point forms correlate with Western Stemmed Tradition (WST) points from elsewhere in western North America? 2) What is the age of early Elko dart points from Veratic, and can they be distinguished from Northern Side Notched points? 3) How else can morphological variability be organized among point forms at Veratic Rockshelter, and how do relative frequencies of these forms change through time? These questions are further explained below.

To address the stemmed-point question, layer 30 at Veratic, previously dated to ~11,500 calendar years ago (cal B.P.) (Swanson 1972), contains a significant number of stemmed points, which, along with adjacent Bison Rockshelter and other Birch Creek Valley sites (Swanson et al. 1964; Swanson and Sneed 1966; Swanson and Dayley 1968; Swanson and Sneed 1971; Swanson 1972), provided the type collection for "Birch Creek" style points. Though Birch Creek points are generally grouped with WST points (Bryan 1980; Justice 2002; Swanson 1972), early reports referred to them as "Agate Basin-style Lanceolate" points (Butler 1978), implying that they may have been brought from the northern Plains ~300 km to the northeast. Swanson's original designations for these points are problematic, with numerous other Archaic forms and preforms grouped within them, and with inconsistently applied sub-groupings. Furthermore, no direct dates were previously acquired for layer 30, and the only correlative date from Bison Rockshelter (10,340 ± 830 ^{14}C B.P.) has an extremely high standard deviation (Table 3.1) (Swanson 1972).

Regarding the chronology of Elko points, the Veratic Rockshelter assemblage has 20 identifiable Elko Corner Notched and Eared points from known stratigraphic contexts potentially dating to before 6000 cal B.P. (Swanson 1972). All of the early Elko points at Veratic, however, are found in the same contexts as Northern Side Notched points, raising the possibility that early "Elko" may indeed be mis-identified Northern Side Notched points. Previous studies in the western/central Great Basin (Bettinger and Taylor 1974; Elston and Budy 1990; Heizer and Hester 1978; Hockett and Murphy 2009; e.g., O'Connell 1967; Thomas 1981) refer to a "short chronology" for Elko points, placing their age between ~3250-1200 ^{14}C B.P. (3450-1120 cal B.P.). Proponents of a "long chronology" (e.g. Aikens 1970; Goebel et al. 2008; Holmer 1986; Holmer 2009; Milliken and Hildebrandt 1997; Rusco and Davis 1987; Smith et al. 2013b), or inter-regionally-variable short and long chronologies (Bettinger 1999; Thomas 1981), have used evidence of corner-notched Elko points from archaeological sites across the Great Basin pre-dating 3450 cal B.P. to support the existence for early Elko (Table 3.2, Figure 3.1). In a recent debate in *American Antiquity*, Hockett et al. (2014) critically evaluated the early Elko points directly dated by Smith and colleagues (2013b), raising the possibility that many of these and other “long-chronology,” early corner-notched points may in fact be mis-identified Northern Side Notched points (also called “Large Side-notched” or “Bitterroot Side Notched” points) (see also Flenniken and Wilke 1989; Heizer et al. 1968). Furthermore, issues of unreliable radiocarbon chronologies, inconsistent terminology (i.e. “Elko Side Notched” versus Northern Side Notched), and the use of qualitative, non-replicable criteria to classify point forms into one of these categories should be considered before accepting a long chronology. Can early Elko at Veratic Rockshelter be differentiated from Northern Side Notched based on quantitative morphometric data, and can it be securely dated to before 3500 cal B.P.?

The previous issue of morphologically distinguishing Northern Side Notched and Elko points can and should be expanded to consider other notched dart points such as Elko Eared versus Elko Corner Notched forms, as well as potential variation within Gatecliff and Humboldt points, comparing known Intermountain West regional typologies to the Veratic assemblage. Additionally, a sample of Stemmed Indented Base dart forms found at Veratic were originally labeled as Pinto (Swanson 1972), though it is unclear whether they are Gatecliff Split Stem points (Thomas 1981), Pinto points (Amsden 1935; Harrington 1957; Heizer and Hester 1978; Vaughan and Warren 1987), or some combination of both, as suggested by Holmer (1986). In other words, how does Archaic dart-point variability at Veratic change through time, and how do these dart points compare morphologically and chronologically to the Monitor Valley typology (Thomas 1981)?

Table 3.1. Radiocarbon dates from Veratic

Lab No.	Catalog no. and taxonomic ID	Modern fraction		$\delta^{13}C$ (‰)		^{14}C age B.P. (1σ)		Calibrated age range (2σ)	p-value	Layer
New AMS dates										
UCIAMS-140280	24173, Artemisia cf. tridentata	0.8528	±0.0018	-147.19	±1.8	1280	±20	1181-1214	0.396	20
								1220-1277	0.604	
UCIAMS-140278**	CS-28, Artemisia cf. tridentata	0.9567	±0.0020	-43.3	±2.0	355	±20	318-395	0.508	21
								424-491	0.491	
UCIAMS-140281	25773, Artemisia cf. tridentata	0.7718	±0.0016	-228.24	±1.6	2080	±20	1995-2115	1	22
UCIAMS-140284	CS-52, Artemisia cf. tridentata	0.6896	±0.0014	-310.4	±1.4	2985	±20	3076-3098	0.128	24
								3102-3218	0.872	
UCIAMS-140276**	CS-30, Hardwood tree or shrub (unid.)	0.9771	±0.0020	-22.93	±2.0	185	±20	modern-21	0.181	25
								143-217	0.616	top
								266-287	0.203	
UCIAMS-140279**	CS-20, Artemisia cf. tridentata	0.9593	±0.0020	-40.68	±2.0	335	±20	313-466	1	25
UCIAMS-140274	CS-45, Pseudotsuga menziesii	0.5968	±0.0014	-403.24	±1.4	4145	±20	4581-4729	0.693	26
								4734-4743	0.017	
								4747-4769	0.091	
								4781-4821	0.198	
UCIAMS-140272	CS-31, Artemisia cf. tridentata	0.6186	±0.0014	-381.36	±1.4	3860	±20	4163-4166	0.006	27
								4181-4198	0.047	
								4230-4407	0.948	
UCIAMS-140275	CS-75, cf. Juniperus sp.	0.5992	±0.0015	-400.85	±1.5	4115	±20	4530-4563	0.09	27
								4565-4651	0.508	
								4670-4702	0.126	
								4758-4808	0.275	
UCIAMS-140282	CS-72, Artemisia cf. tridentata	0.512	±0.0013	-487.96	±1.3	5375	±20	6027-6041	0.022	28
								6069-6075	0.006	
								6117-6150	0.142	
								6176-6223	0.494	
								6230-6277	0.337	
UCIAMS-140277	CS-56, Artemisia cf. tridentata	0.4858	±0.0011	-514.22	±1.1	5800	±20	6537-6666	1	28
UCIAMS-140273	CS-39, Pseudotsuga menziesii	0.5173	±0.0012	-482.74	±1.2	5295	±20	5994-6125	0.783	29
								6143-6179	0.217	
UCIAMS-140283**	CS-34, Artemisia cf. tridentata	0.9597	±0.0020	-40.31	±2.0	330	±20	310-341	0.207	29
								347-462	0.793	
UCIAMS-140271	CS-61, Pinus sp.	0.4202	±0.0012	-579.8	±1.2	6965	±25	7706-7855	0.98	F6
								7905-7916	0.02	
Beta-331430	CS-60, "soft pine" (Pinus sp.)			-22.9		7300	±40	8020-8180	1	F6
UCIAMS-148190	CS-66, unid.	0.3465	±0.0010	-653.5	±1.0	8515	±25	9485-9537	1	30
UCIAMS-140285**	CS-44, Artemisia cf. tridentata	0.615	±0.0013	-384.98	±1.3	3905	±20	4257-4271	0.032	31
								4286-4418	0.967	
Beta-331431	CS-70, "spruce"			-23		8850	±40	9745-9752	0.008	31
								9762-10158	0.992	

Table 3.1 (cont.)

Lab No.	Catalog no. and taxonomic ID	Modern fraction	$\delta^{13}C$ (‰)	^{14}C age B.P. (1σ)		Calibrated age range (2σ)	p-value	Layer
Previously reported conventional dates (Swanson 1972)								
UCLA-217	F1 bulk charcoal?			370	80	157-165	0.01	19-20
						285-535	0.99	
UCLA-160	bulk charcoal?			1580	80	1310-1622	0.99	22
						1673-1688	0.01	
UCLA-218	F8 bulk charcoal?			2920	120	2793-2833	0.03	26
						2836-3358	0.97	
WSU-502	bulk charcoal from			3995	470	3255-3292	<0.01	27
	base of charcoal pit cut into base of L27					3328-5644	>0.99	
I-452	F11 bulk charcoal?			4500	170	4655-4668	<0.01	29
						4706-4756	0.01	
						4810-5590	0.98	
UCLA-162	F5 bulk charcoal?			5670	120	6218-6235	0.01	29
						6273-6740	0.99	
UCLA-161	bulk charcoal?			5870	120	6407-6980	1	29
WSU-503	bulk charcoal?			6030	190	6446-7313	1	F6
TBN-304.2	bulk charcoal?			6282	229	6653-7589	1	F6
WSU-760*	Bone collagen			10340	830	9598-13787	1	30

*Date estimated by Swanson (1972) based on stratigraphic association with Bison RS.

**New date rejected by author

Table 3.2. Great Basin regions and associated age-ranges for diagnostic point forms (adapted from Smith et al., 2013: Table 1)

Region	Northern Side Notched	Humboldt	Gatecliff	Elko	Rosegate	DSN	Reference
Central Great Basin	pre-650	4950-1250	4950-3250	3250-1250	1250-650	post-650	Thomas 1981
Sierra Cascade Front	7000-4000	3500-1300	5000-2000	4500-1300	1900-200	post-200	Hildebrandt and King (2002)
Bonneville Basin	8300-4500	6300-2900	5100-2850	8800-700	2000-500	post-900	Schmitt and Madsen (2005), Goebel et al. (2008)
Chewaucan Marsh, OR	7000-5000	6000-1300	5000-2000	5000-1000	post-2000	post-1000	Oetting (1994)
North-central Great Basin	-	5700-3700	5700-3700	3700-1300	1300-600	post-600	Hockett and Murphy (2009)
Snake River Plain	8350-4950	5730-3190	5730-3190	8350-1120	1590-140	680-140	Holmer (2009)
Southeast Caifornia	-	5730-1380	7850-3780	3780-1380	1380-670	640-140	Bettinger (1999)

III.2 Materials and Methods

Analyses were performed at the Idaho Museum of Natural History. First, I re-assessed recorded stratigraphic contexts of all lithic artifacts and charcoal samples in the collection using Swanson's notes and publications (Swanson 1972; Swanson et al. 1964) (see Appendix A for a description of the stratigraphic profile). Bison Rockshelter produced noticeably fewer artifacts, and only a few charcoal samples still exist in the collection, preventing its inclusion in the current study. A large collection of faunal material was collected from Veratic by Swanson as well, a full analysis of which is beyond the scope of this project and will be addressed in a future publication.

III.2.1 AMS Radiocarbon Dating

Dates were acquired on curated samples collected by Swanson and colleagues from secure, stratified deposits, the majority from hearth features. Plant identifications were made by David Rhode at the Desert Research Institute (Reno) to help rule out roots and old wood. Sixteen samples were then submitted to the Human Paleoecology and Isotope Geochemistry Lab at Pennsylvania State University for standard acid/base/acid pre-treatment and then analyzed at the Keck-Carbon Cycle AMS facility at the University of California, Irvine, following Kennett et al. (2014). Prior to this, two charcoal samples were submitted as part of a pilot study to Beta Analytic for AMS dating using standard acid/base/acid pretreatment. All dates referenced in this paper were calibrated using Calib 7.1 (Stuiver and Reimer 1993) and the IntCal 13 radiocarbon calibration curve (Reimer et al. 2013).

III.2.2 Artifact Analyses

All point fragments from known stratigraphic contexts at Veratic were subjected to metric analysis. In addition to recording material type, Munsell color, obsidian source, and weight, this included basic linear dimensions following Andrefsky (2005: 186) and Thomas (1981) and including maximum thickness, haft length (HL), neck width (NW), shoulder-to-base length (SBC), proximal- and distal-shoulder angle (PSA and DSA respectively), tang width (TW), maximum-base width below notches (MBW), basal-indentation/basal-width ratio (BIW), and stem angle for shoulder-less points (SA) (Figure 3.2), measured with digital calipers to 0.1-mm accuracy, and an Adobe Acrobat angle-measuring tool (averaging left and right angles, when possible). Additional metrics were recorded (Figure 3.2) to provide morphometric data and descriptive characteristics useful in differentiating projectile-point forms. Except where otherwise stated, point names and metric attributes were based on Thomas' (1981) typology for the central Great Basin, as these provided the closest corresponding forms to those present in the eastern Snake River Plain. Additions to the Thomas typology include WST/Haskett (Bryan 1980; Butler 1965; Swanson 1972 (Birch Creek sub-variety)), Salmon River dart points (Swanson and Sneed 1966), Pinto points (Vaughan and Warren 1987), and Avonlea arrow points (Morlan 1988).

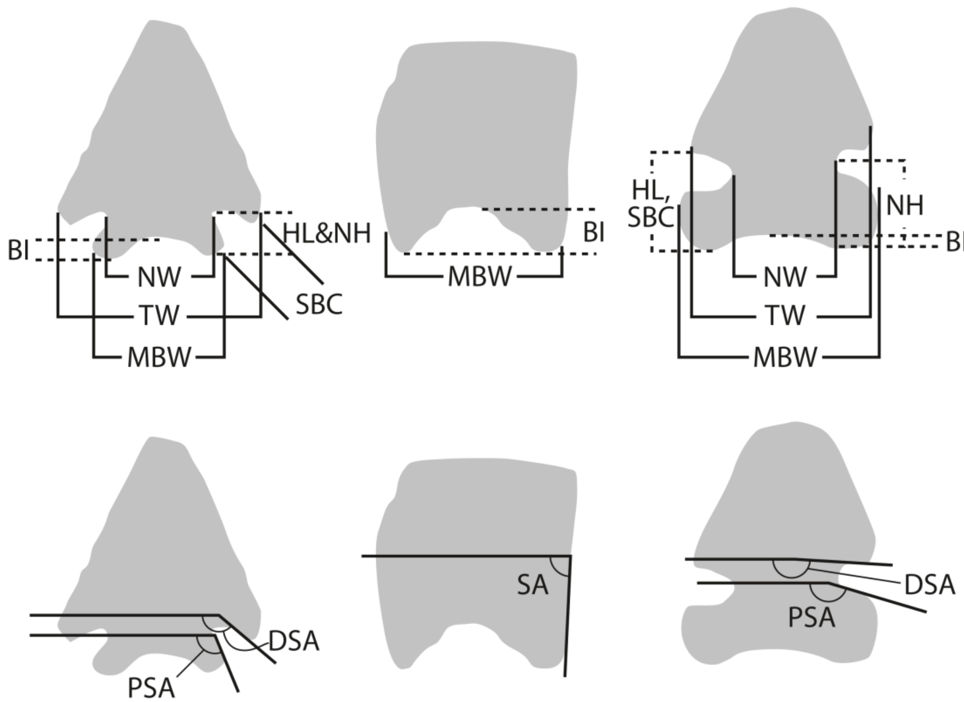

Figure 3.2. Projectile-point attributes measured/referred to in text (adapted from Andrefsky 2005, Thomas 1981).

III.2.3 X-Ray Fluorescence Analysis

X-ray fluorescence (XRF) analysis was used to correlate a sample of 106 obsidian points (with known provenience and context) to known obsidian sources. Artifacts not meeting basic criteria for size (> 1 cm diameter), thickness (> 4 mm) and surface geometry (clean and smooth non-cortical surfaces) were excluded (see Ferguson 2012; Shackley 2011).

To define the geochemistries of the upper Snake River Plain's obsidian sources (mapped by Skinner 2014), I analyzed a minimum of ten samples from each, following the criteria above for surface topography and minimum size. These included Browns

Bench, Bear Gulch, Big Southern Butte, Cannonball I and II, Cedar Butte, Kelly Canyon, Malad, Obsidian Cliff, Packsaddle, Topaz Mountain, Teton Pass I, Walcott Tuff (American Falls/Deep Creek), and an outcrop of obsidian from the northwestern border of the Idaho National Laboratory previously identified as Walcott Tuff, but with a distinct elemental signature from American Falls (Fig.1).Walcott (American Falls) and Walcott (Deep Creek) are considered to be geochemically identical (Bailey 1992). Idaho State University provided a Bruker Tracer pXRF equipped with a Rhodium target and a 170 eV resolution Si PIN detector with a 13μ Be detector window, a 45 kV x-ray generator, and 12-mil Al, 1-mil Ti, and 6-mil Cu filters. Raw data were calibrated using the GL1 calibration developed by the University of Missouri Research Reactor (MURR) and Bruker for the detection of optimal elements in obsidian (Ferguson 2012) (see Appendix B).

III.2.4 Data Analysis

Basic scatterplots and point-density histograms were generated using Mystat 12. In addition, the statistical significance of modes visible on histograms of morphometric variables was evaluated using Silverman's Test (Silverman 1981). This test is ideal for use with low-dimensional archaeological data to test the null hypothesis that there is no more than "k" modes in the total population of point forms for a given variable, versus an alternate hypothesis that there are more than k modes (Baxter and Cool 2010). This test can be repeated (k = 1, k = 2, k = 3, etc.) to identify the specific number of statistically significant modes in a given sample. In cases testing the null hypothesis that k = 1, Hall and York's (2001) method of providing a more precise p-value is used. This p-value varies slightly upon repetition, as each run is based on R = 999 bootstrap resamples (following Baxter and Cool 2010). Analyses were performed using the "Silvermantest" statistical package for R (Schwaiger and Holzmann 2013), which was also used to generate density histograms.

III.3 Results

III.3.1 Geochronology

Veratic Rockshelter is located at the base of a steep limestone cliff where a small alluvial fan flows out of the mountains from the eastern edge of Birch Creek valley. Sediments consist of a combination of fine-to-coarse alluvial fan sediments and gravels, streambed deposits, fine-grained eolian deposits, and rockfall deposits from the cliff-overhang. Strata are numbered 9 to 32 from the top down, with strata 1-8 intentionally left out by the original excavators to make the sequence better match deposits from neighboring Bison Rockshelter. Strata 9-18 consist of historic dung deposits, while strata 19-30 (and possibly 31) contain prehistoric cultural materials and are the focus of this study (Figure 3.3). Culturally sterile stratum 32 overlies limestone bedrock approximately 3-4 m below the surface (Appendix A presents detailed descriptions of relevant strata).

Eighteen new AMS radiocarbon ages were acquired from charcoal samples collected by the original excavators and compared to the existing conventional ^{14}C chronology provided by Swanson (1972) for the shelters (Table 3.1). Thirteen follow a chronologically ordered sequence, leaving five that are anomalously young by thousands of years and are considered to be the result of contamination or improper collection (Table 3.1) (UCIAMS-140278, -140276, -140279, -140283 and -140285). These were not included in chronological interpretations. Calibrated age ranges for each layer are depicted in Figure 3.4 (and Table 3.3). While some of the new dates roughly match those acquired by Swanson (i.e., layers 29, 27, and 24), many are significantly different. New dates for the oldest confirmed stemmed-point occupation, layer 30, place it between ~10,000 and 9500 cal B.P., making it as much as 2000 years younger than previously estimated based on a single conventional date of 13787-9598 cal B.P. (WSU-760) from the lower layers of Bison Rockshelter. Conversely, layers 26-19 (~3950-725 cal B.P.), may be older than earlier thought, as most of Swanson's ages for these layers appear anomalously young, even in the conventional radiocarbon chronology. Other layers, such as 31, 30, 28, and 24, were never directly dated by Swanson but now have age estimates. Conversely, the precise ages of layers 25 and 21 are still unknown, as no reliable dates have yet been acquired. It should also be noted that layer F6 consists largely of a matrix of Mazama tephra; its new AMS dates closely match the age estimate provided by Zdanowicz et al. (1999) (7627 ± 150 cal B.P.) for the eruption.

III.3.2 Projectile-Point Typology of Veratic Rockshelter

The attribute analysis included 390 projectile points and point fragments, including 283 identifiable to specific diagnostic types. While most were considered to be *in situ*, a small percentage may have been redeposited. For example, the small, isolated arrow points in the early and middle Archaic horizons may be a result of rodent disturbance, while the presence of early and middle Archaic dart points in later horizons also could be due to such a natural process or cultural recycling of older points by later occupants. As a result, point forms with samples of two or fewer in a given layer were considered suspect when determining age estimates for the types.

Table 3.3. Point form by layer at Veratic Rockshelter

		WST Forms						*Elko Forms*			*Gate-cliff*										
Layer	**Age (cal B.P.)**	**1**	**2**	**3**	**4**	**Unknown Stem**	**Northern Side Notched**	**Eared**	**Corner**	**Ind.**	**Split**	**Contracting**	**Pinto-like**	**Humboldt**	**Salmon River**	**Rosegate**	**Desert Side Notched**	**Avonlea**	**Cottonwood**	**Unknown**	**TOTAL**
19+	~1150-300								1	2						2	1	2		2	**10**
20	~1150								4	1						3				3	**11**
21	2000-1200						1		3							6			1	3	**14**
22	2000-1500							1	6							1				5	**13**
23	3200-2000					1		2	6	1						2		1		5	**18**
24	3200-3100						1		4		2	1				1				4	**13**
25	4800-3100					2	1	4	2		7		2				1	2	1	8	**30**
26	4800-3100		1	1	1		1	2		1	1			1		1					**10**
27	4800-4200		1		2		6	15	5		4			2	1		1			11	**48**
28	6700-6000						24	5	5		1		2		1					26	**64**
29	6700-6000					3	25	1	3		2			1	1		2	1		35	**74**
F6	8200-7400			1			11		1	1								1	1	9	**25**
30	10,200-9500	12	7	7	2	7	4	3	2		1			1	1					8	**55**
TOTAL:		**12**	**9**	**9**	**5**	**13**	**74**	**33**	**42**	**6**	**18**	**1**	**4**	**5**	**4**	**16**	**5**	**7**	**3**	**119**	**##**

III.3.2.1 Stemmed points at Veratic. New dates for layer 30 at Veratic place it at the end of the Paleoindian period, ~9500 cal B.P. (Table 3.1, Figure 3.4). This is the only layer with a significant assemblage (n = 34) of stemmed/lanceolate points and point fragments (Figure 3.5). Despite all being originally grouped as “Birch Creek Stemmed Points” based on their long, edge-ground stems without shoulders (Swanson 1972), there is noticeable variation between forms, suggesting the occurrence of distinct sub-forms, or even unique forms.

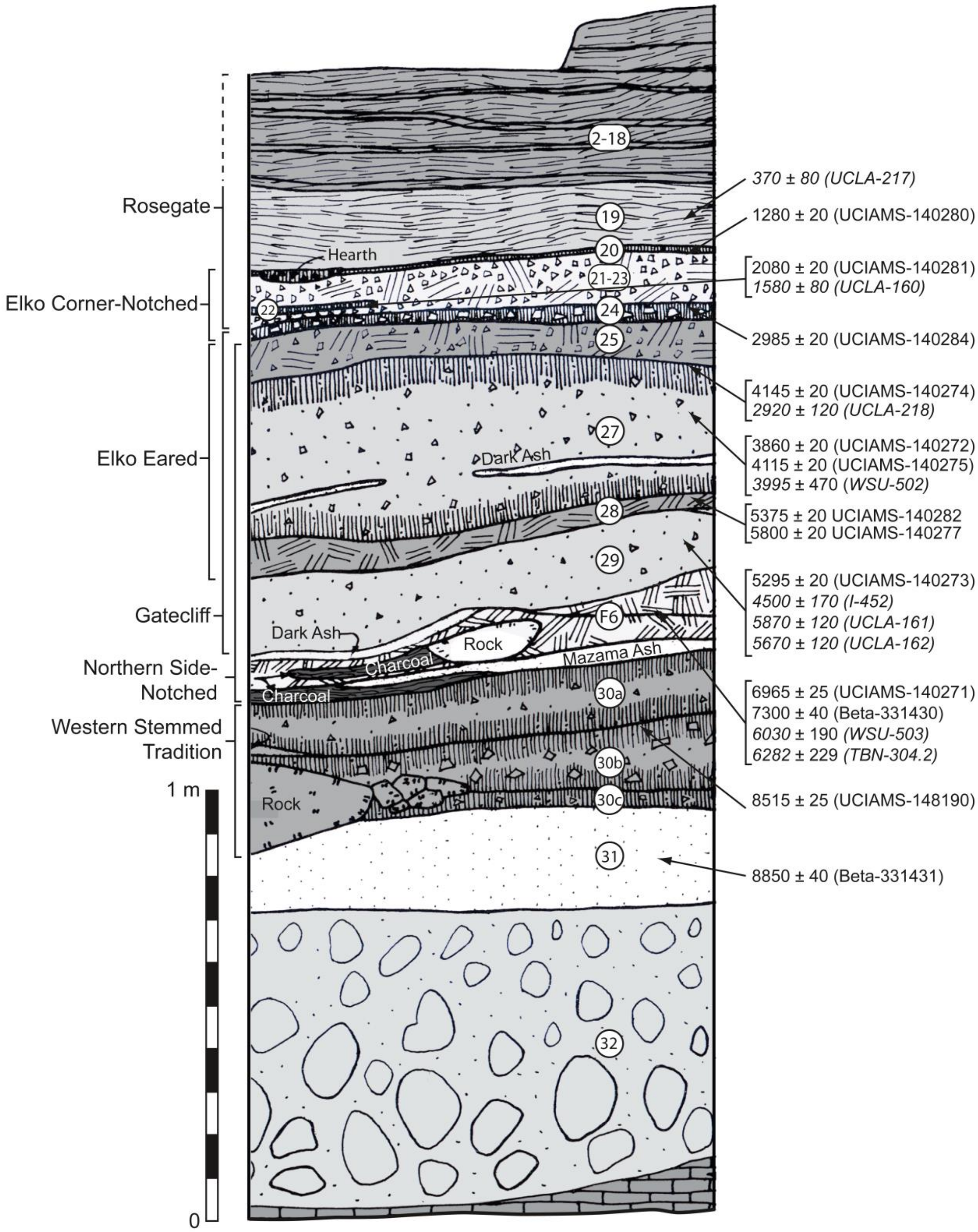

Figure 3.3. Representative stratigraphic profile from Veratic Rockshelter with accepted radiocarbon ages and stratigraphic ranges for certain projectile-point forms. Adapted from Swanson (1972): figure 18, south wall of block 10AN.

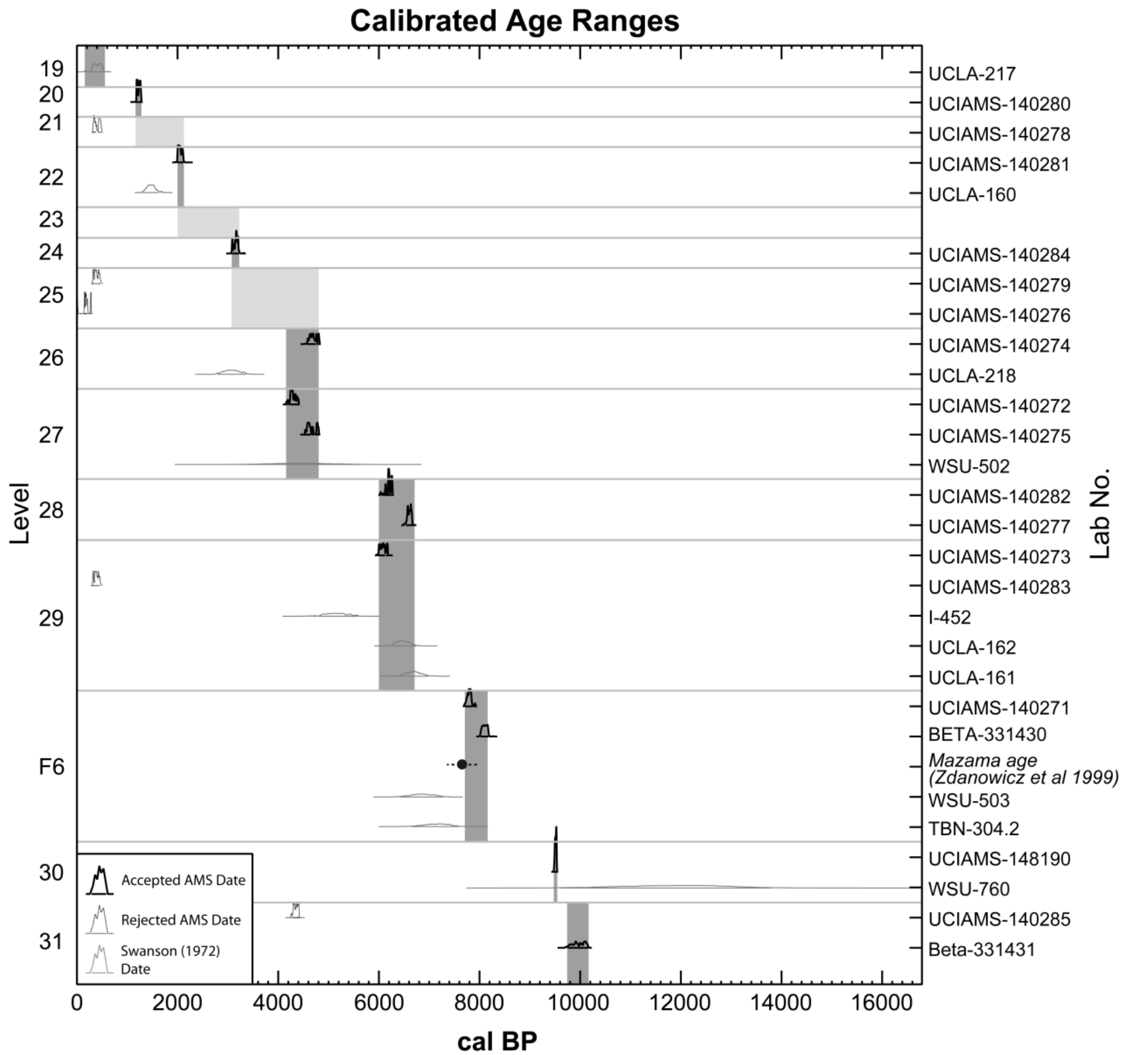

Figure 3.4. Calibrated age ranges for dates from Table 3.1.

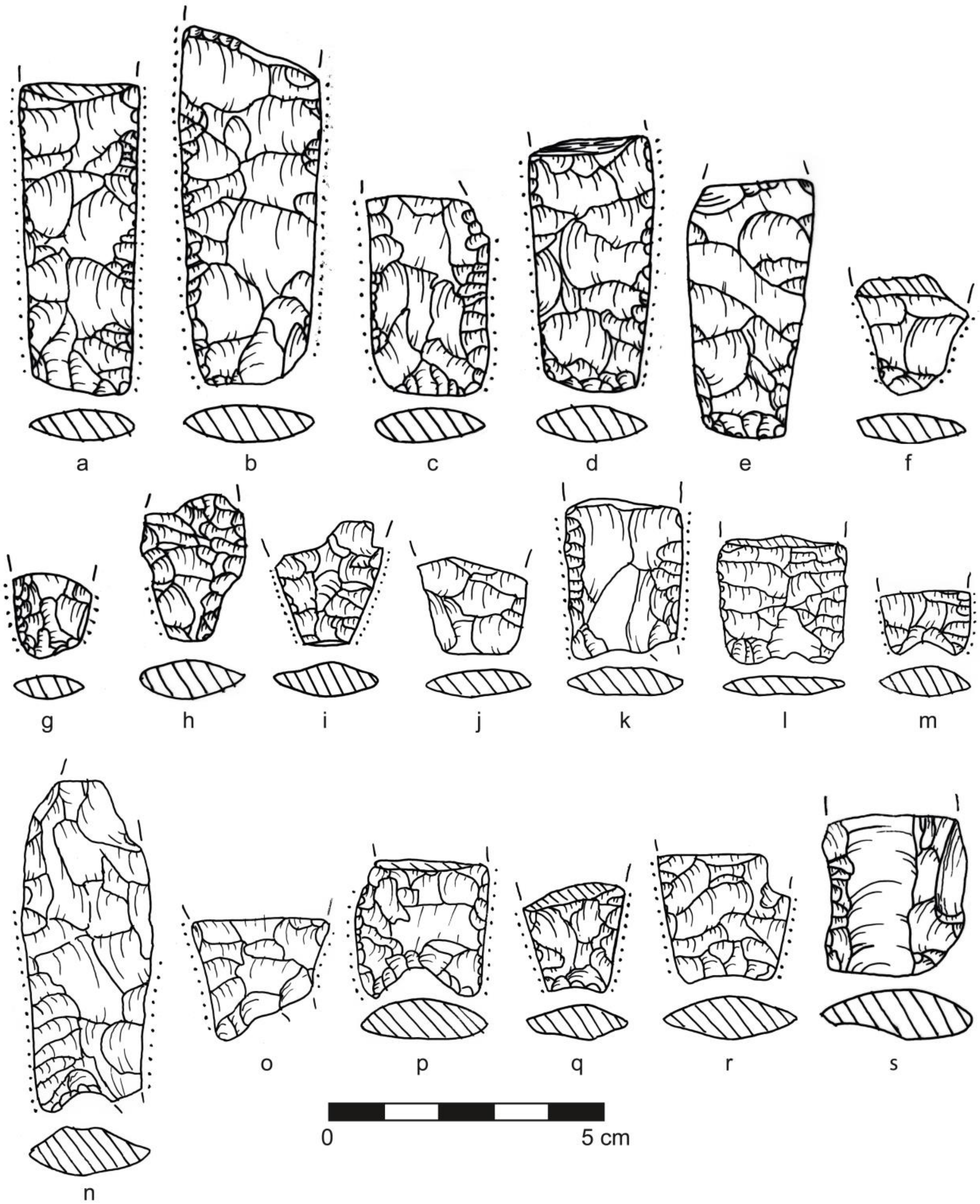

Figure 3.5. Early points from layer 30 (dotted lines indicate edge-grinding). Western Stemmed Tradition (Birch Creek) points: Form 1 (parallel sides, flat/convex base): a-e, Form 2 (contracting sides, flat/convex base): f-j, Form 3 (parallel sides, concave base): k-p, and Form 4 (contracting sides, concave base): q-r; Possible fluted-lanceolate point fragment: s.

In the attribute analysis, no statistically significant attribute modes were identified, though BIW came closest, with two weakly expressed modes (Silverman's test $k = 1$, $p = 0.259$). Among metric variables, SA and BIW best distinguish variability in the stemmed points (Figure 3.6). Most have SA values clustering around 70-75° or 80-85°, indicating contracting to straight stems, and most have no basal indentation, though 12 (35%) have concave bases with BIW ratios of 0.02-0.27. Considering all of the data, four basic stemmed-point forms can be distinguished. Form 1 corresponds to Swanson's Birch Creek Varieties A and B, including points with SA ≥ 80° and BIW < 0.02. They tend to have nearly parallel sides at the haft, have convex or straight/angled bases, and tend to be more than 7 mm thick. Form 2 corresponds to Birch Creek Variety C2, including seven points with SA < 80°, BIW < 0.02 mm, contracting stems, and straight or convex bases. They also tend to be less than 7 mm thick. Form 3 corresponds to Swanson's "Plainview/McKean" category – seven parallel-sided, concave-based points with SA ≥ 80°, BIW > 0.02, and concave bases more than 3 mm deep. Form 4 corresponds to Birch Creek Variety C1 and includes two points with SA < 80° (i.e., contracting stems), BIW > 0.02, and concave bases. Also worth mentioning is a small crypto-crystalline silicate (CCS) lanceolate point fragment from layer 30 (Figure 3.5s) with a flat base and a large flute scar on one face, which resembles a Folsom point fragment recovered from nearby Owl Cave (Miller 1982).

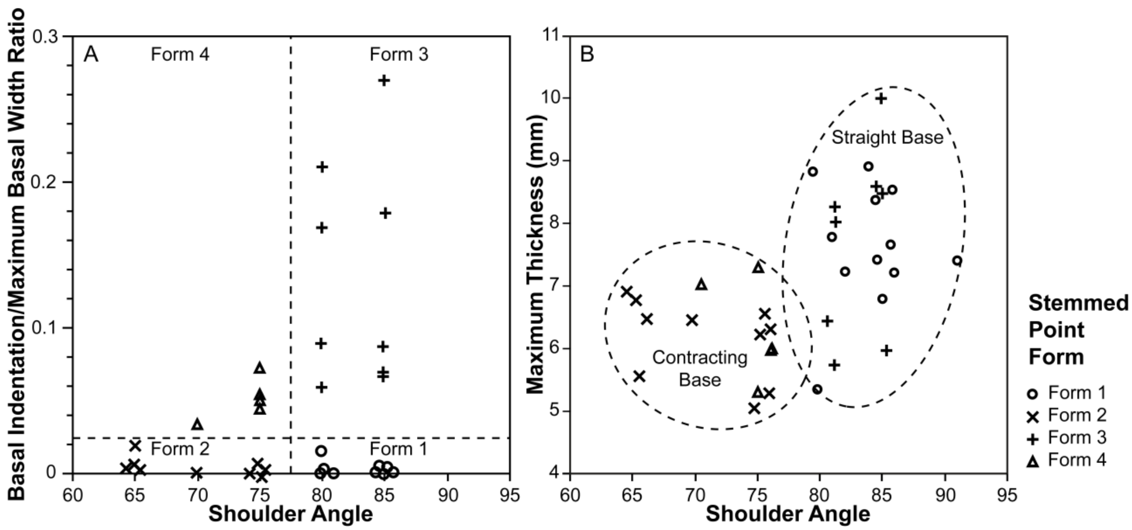

Figure 3.6. Scatterplots grouped by new point-form categories (1-4). A) Shoulder angle vs. basal indentation/maximum basal width for layer 30 Western Stemmed Tradition points; B) Shoulder angle versus maximum thickness.

The four stemmed-point forms are based primarily on SA and thickness (Figure 3.6b); however, raw material also varies according to form (Figure 3.7A), with Form 1 points on the greatest variety of materials, including obsidian, CCS, fine-grained volcanics (FGV), and quartzite; Form 2 exclusively on obsidian; Form 3 on obsidian and quartzite; and Form 4 exclusively on CCS. As for chemical characterization of obsidian, the sample size is too small to make definitive conclusions, but it is interesting to note that Form 1 includes two points made on Obsidian Cliff obsidian, a distant source (~190 km NE, Figure 3.1). Conversely, the nearby Walcott (Deep Creek) source (~28 km NE) does not occur at all (Figure 3.7B).

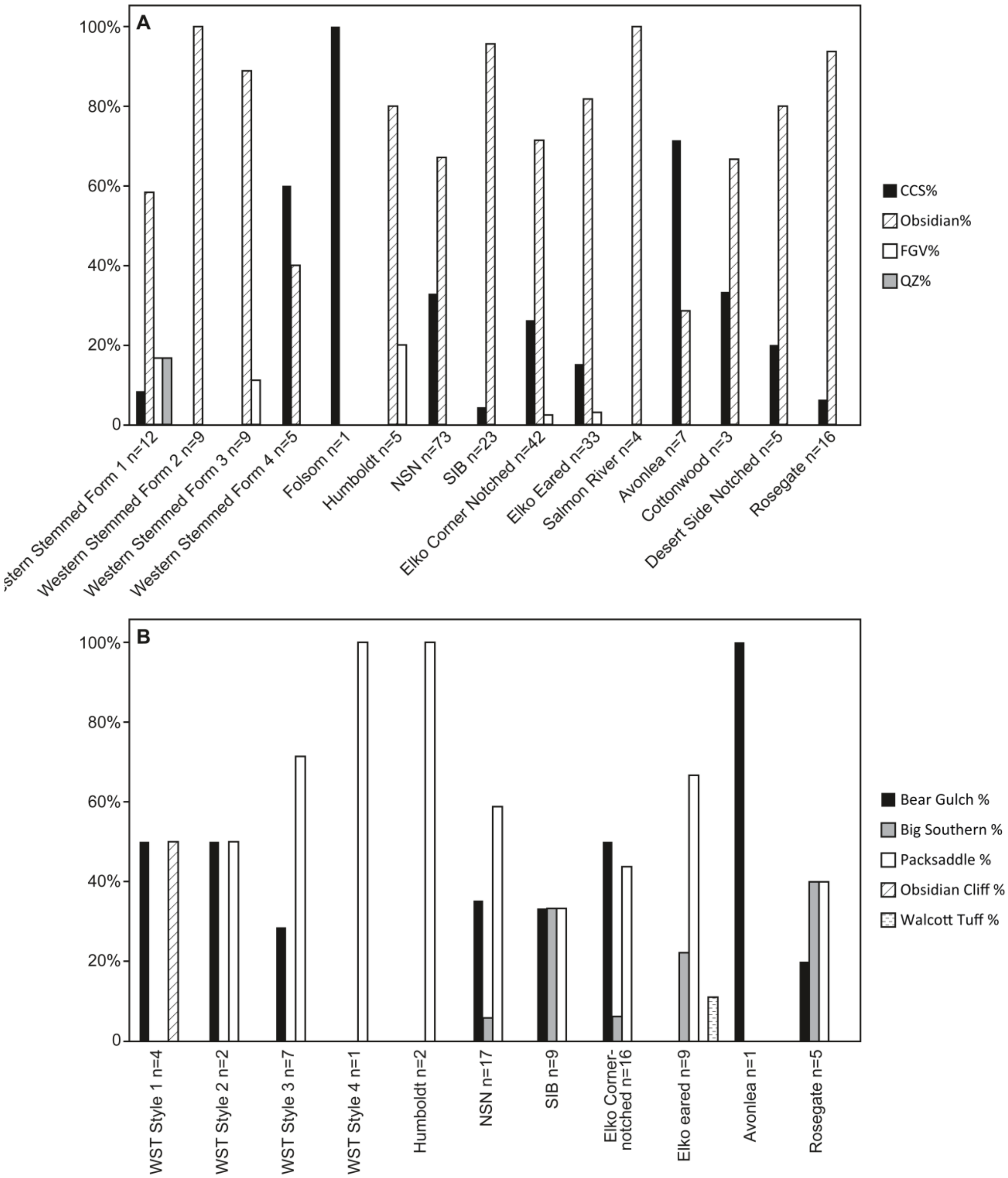

Figure 3.7. A) Raw material type and B) obsidian preference by point type.

III.3.2.2 Elko and Northern Side Notched point variation. Layer 28 at Veratic, dated to 6700-6000 cal B.P., contains 64 identifiable projectile-point fragments (Table 3.3) (Figure 3.8). Among them are 24 Northern Side Notched points, 3 Stemmed Indented Base points, 1 Salmon River point, 4 Beaverhead preforms, 15 unknown notched-point fragments, and 10 Elko points. To test the hypothesis suggested by Hockett et al. (2014) that early Elko points may be mis-identified or re-worked side-notched points, a Mann-Whitney U test was used to see whether any variables helped separate them into two statistically meaningful groups, i.e., Elko or Northern Side Notched. Of the variables tested, PSA ($U = 2.500$, $p = 0.000$) and TW/MBW ($U = 97.00$, $p = 0.000$) were significantly different, with an average PSA for Elko points of 122° and an average TW/MBW of 1.266, while Northern Side Notched points have an average PSA of 156° and an average TW/MBW of 1.006 (Figure 3.9A, see also Figure 3.10). Raw material and obsidian source were also considered, though neither indicated a statistically significant correlation to point form (Figure 3.7B).

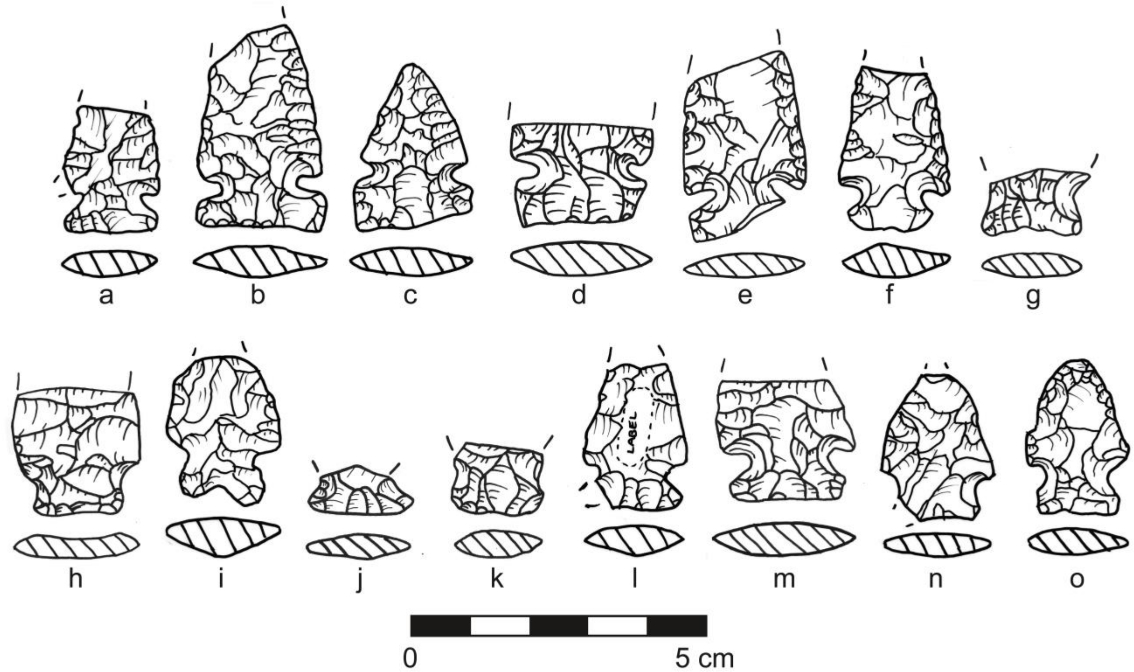

Figure 3.8. Northern Side Notched (a-f) and Elko points (g-o) from layer 28.

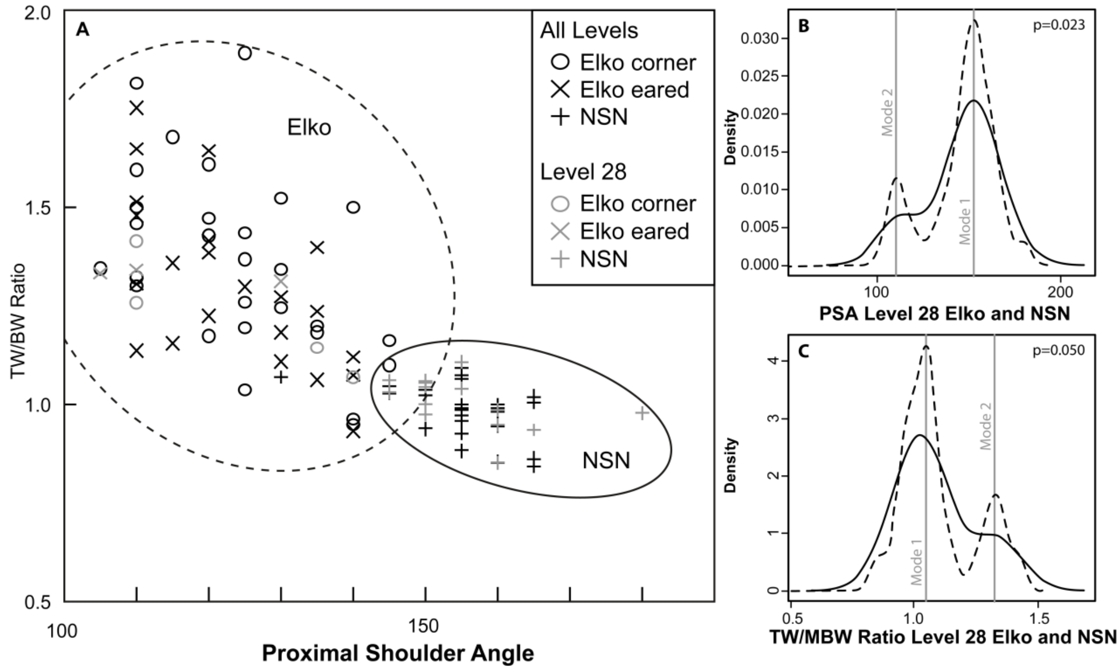

Figure 3.9. A) Scatter plot of proximal shoulder angle (PSA) vs. tang width/maximum basal width (TW/MBW) ratio for Elko and Northern Side Notched (NSN) points, with histograms showing modes for: B) PSA, layer 28; and C) TW/MBW, layer 28. Histograms show two curves, with the solid line indicating a single mode distribution, and the dotted showing a 2-mode distribution, with a p value showing the likelihood of the 2-mode distribution.

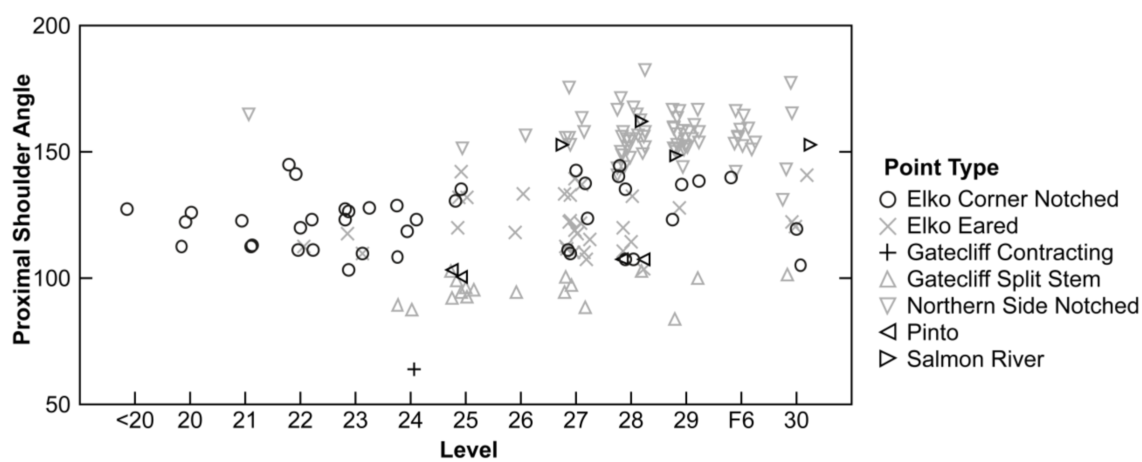

Figure 3.10. Scatterplot of PSA by layer, grouped by point style, with slight random jitter.

While a Mann-Whitney test shows the two groups have significantly different PSA values, it does not confirm whether the two represent two significant modes, as opposed to an arbitrary separation of a single mode. To further determine whether the two perceived point forms were discrete and non-arbitrary, a Silverman's test was performed on the combined sample of layer 28's Elko and Northern Side Notched points. PSA (n = 35) had two statistically significant modes (p = 0.023), correlating with characteristics of Northern Side Notched versus Elko, indicating two distinct populations separated at ~145°, positively identifying points with an ~88% success rate (Figure 3.9B). Additionally, TW/MBW (n = 21) provided two statistically significant modes (p = 0.050), again correlating to Elko and Northern Side Notched point forms, positively predicting point form with a ~90% success rate (Figure 3.9C). Thus, Elko and Northern Side Notched points from layer 28 at Veratic cluster into two distinct, non-continuous populations (Figure 3.9A), and these correlate with established point forms, suggesting that at Veratic Rockshelter, Elko and Northern Side Notched points were purposefully made between 6700 and 6000 cal B.P. This pre-dates the "short chronology" for Elko points in the Great Basin by as much as 2500 years.

III.3.2.3 Differentiating Elko Corner Notched and Elko Eared points. The most useful attribute differentiating Elko Corner Notched and Eared forms (Figure 3.8) is BIW; however, Silverman's test did not identify multiple modes for this variable (Figure 3.11). Nonetheless, BIW did change through time with Elko Eared points dominating the early assemblage (6700-3100 cal B.P.) (BIW = 0.016, n = 23) and Elko Corner Notched points dominating the later assemblage (post-3100 cal B.P.) (BIW = 0.067, n = 47), based on the pooled variance of a two-sample T test of BIW for early versus late assemblages (T = 3.586, p = 0.001). Obsidian also varied between forms, with Elko Eared points being most commonly made on Walcott (Deep Creek) Big Southern Butte, and Walcott Tuff obsidian, and Elko Corner Notched points being dominated by Bear Gulch obsidian (50%) as well as Walcott (Deep Creek) and Big Southern Butte obsidian (Fig. 7B).

III.3.2.4 Differentiating Stemmed Indented Base forms: Gatecliff and Pinto. Stemmed Indented Base points (Figure 3.12b-j) were arbitrarily differentiated from Elko forms based on a minimum PSA of 110° for Elko points, as per Thomas (1981). Two PSA modes seem evident, separated at about 105°, but a Silverman's test failed to distinguish them (k = 1, p = 0.267), suggesting continuous variability between Elkos and Stemmed Indented Base points (Figure 3.13). However, PSA values for these two forms are more continuous in layers 28 and 27 (6700-4200 cal B.P.), but become more discrete in younger layers (Figure 3.10). Silverman's test of PSA values on 26 points from layers 26-24 (4800-3100 cal B.P.) demonstrates two well-distinguished modes (h_0: $k \leq 1$, p = 0.0027), but not for 37 points from layers 28-27 (6700-4200 cal B.P.) (h_0: $k \leq 1$, p = 0.3327). In terms of raw materials, Elko points are largely obsidian, with some CCS and FGV, while Stemmed Indented Base points are exclusively obsidian, but no difference in obsidian is apparent between the two forms (Figure 3.7).

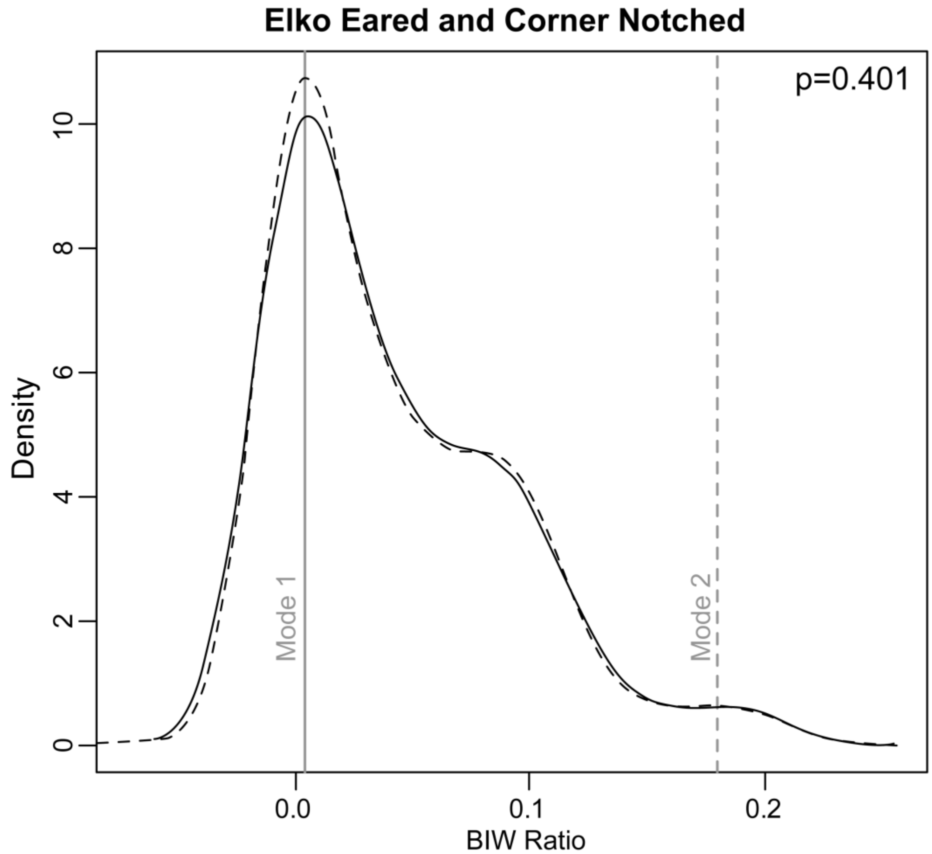

Figure 3.11. Histogram of BIW ratio for all Elko points.

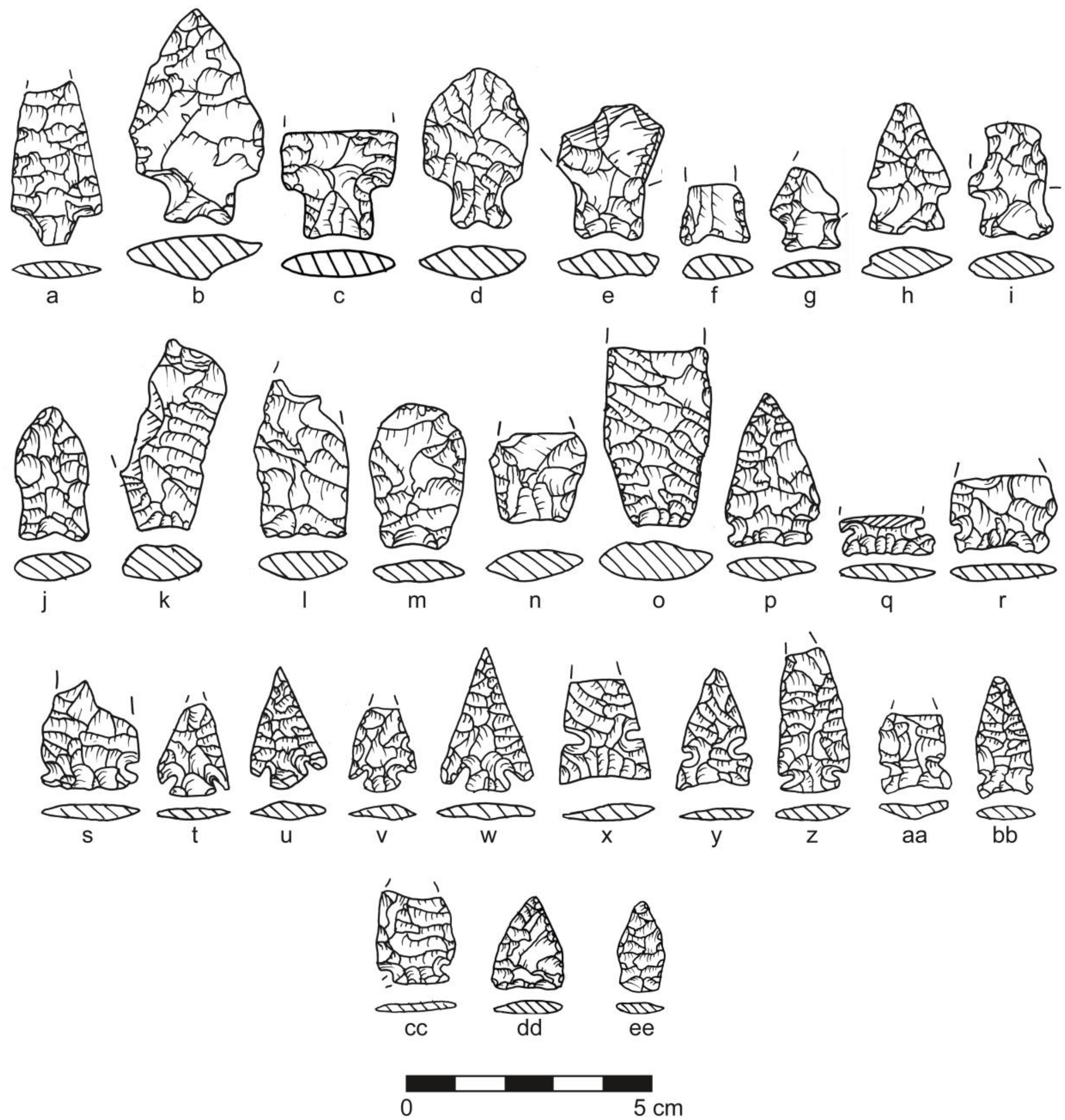

Figure 3.12. Other Archaic point styles: Gatecliff contracting-stem: a, Gatecliff split-stem: b-e, Pinto: f-j, Humboldt: k-o, Salmon: p-s, Rosegate: t-w, Desert Side Notched: x-y, Avonlea: z-cc, Cottonwood: dd-ee.

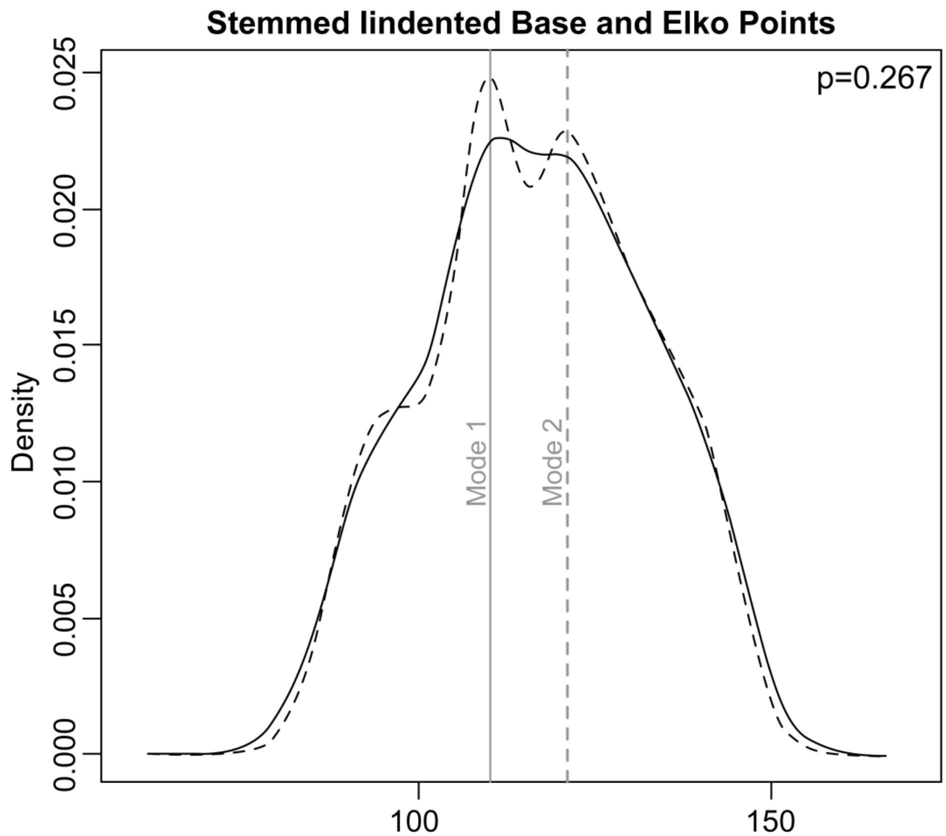

Figure 3.13. Histogram of proximal shoulder angle for Elko and Stemmed Indented Base points.

To address the original claim (Swanson 1972) that the assemblage contains some Pinto points (specifically, Figure 3.12f-j), an attempt was made to further sub-divide Stemmed Indented Base points based on metric variables. Though a Silverman's test of TW/MBW came closest (h_0: $k \leq 1$, $p = 0.082$) (Figure 3.14), none of the metric variables measured indicate a significant separation into two sub-groups - Gatecliff and Pinto - potentially due to small sample size.

All Stemmed Indented Base points, including potential Pinto forms, are on obsidians from Bear Gulch, Walcott (Deep Creek) and Walcott Tuff. Only one "Pinto" point was sampled for XRF, and it was sourced to Bear Gulch (Fig. 7). A single point made on CCS resembles a Gatecliff contracting stem point and was found in layer 24 (3200-3100 cal B.P.) (Fig. 12a).

III.3.2.5 Other dart and arrow point forms. Five Humboldt points from Veratic are lanceolate forms with parallel to slightly contracting lateral margins (SA: 70-85°), no shoulders, parallel-oblique transverse flaking, and basal thinning with a slightly concave base (BIW = 0.02-0.09) (Figure 3.12k-o). These were dispersed across layers 30-26, providing a broad age range of 9700-3100 cal B.P. (Table 3.2). Four are made on obsidian and one from FGV; two of the obsidian points were assigned to the Walcott (Deep Creek) source.

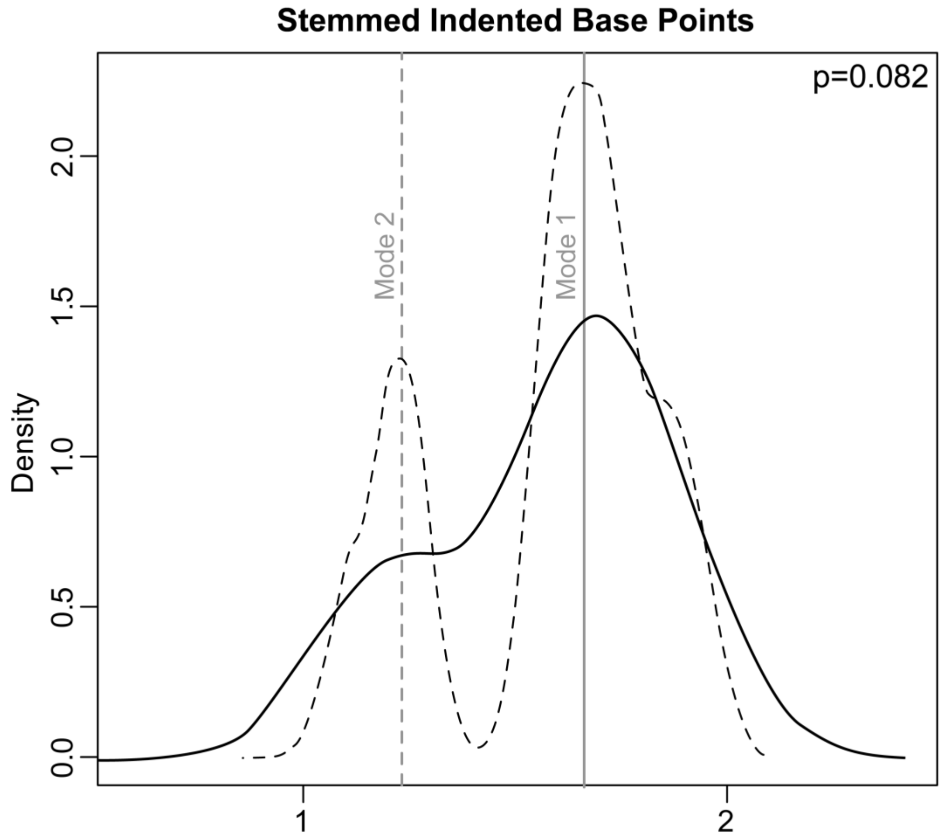

Figure 3.14. Histogram of tang width/maximum basal width ratio for Stemmed Indented Base Points (including Gatecliff Split Stem and potential "Pinto" points).

Salmon River points (Swanson and Sneed 1966) are not a formally recognized point form for the eastern Snake River Plain, though they have been identified at a few sites and called by a variety of names. They are very shallowly side-notched dart points (basal width + max thickness > 21 mm, NW/MBW > 0.75) resembling Besant points of the late Archaic northern Plains (2100-1500 cal B.P.) (Peck 2011, pp. 283), although their recovery from layers 30-27 (~10,000-4500 cal B.P.) suggests that at Veratic they are much earlier in age (Figure 3.12p-s). Mann-Whitney tests show that PSA values of the four Salmon River points at Veratic overlap the PSAs of all 74 Northern Side

Notched points (U = 186.00, p = 0.233) (Figure 3.10), but NH (U = 255.00, p = 0.001) and NW/MBW (U = 3.000, p = 0.001) do not, allowing for the differentiation of Salmon River points from Northern Side Notched points based on shallower side-notches located closer to the base of the point. Using a Silverman's test, they also significantly separate from a limited sample (level 27 only, n = 6) of Northern Side Notched points in NW/MBW (h_0: $k \leq 1$, $p = 0.044$), with average Salmon River point measurements of NH = 4.345 mm and NW/MBW = 0.831, compared with Northern Side Notched average measurements of NH = 7.878 mm and NW/MBW = 0.600.

Rosegate points include both Eastgate and Rose Spring forms of corner/basal-notched triangular arrow points (PSA < 150˚, neck width + maximum thickness ≤ 11.8 mm) (Hildebrandt and King 2012; Thomas 1981) and are the most common arrow-point form at Veratic. While one appears in layer 26 and two in layer 23, the majority (11) are concentrated between layers 21-19, placing them between 2000-1150 cal B.P., and possibly as recent as ~300 cal B.P.

Desert Side-notched points are small, triangular arrow points with side notches far from a squared base (PSA > 150˚, neck width + maximum thickness ≤ 11.8 mm) (Hildebrandt and King 2012; Thomas 1981). There are only five from Veratic, and their distribution is scattered between layers 29-19, preventing any reliable age estimate.

Avonlea points are similar to Desert Side Notched points in that they are small, side-notched arrow points, although their notches are closer to the base and are much shallower (PSA > 150˚, neck width + maximum thickness ≤ 11.8 mm, neck width/base width > 0.75) (Hildebrandt and King 2012; Morlan 1988; Thomas 1981). Also like

Desert Side Notched points, they are uncommon and scattered throughout the profile at Veratic, making it difficult to assign an age.

Cottonwood points are small (basal width + max thickness < 21 mm) triangular points with flat or slightly convex/concave bases and no notches. There are only two present at Veratic, and their stratigraphic locations are variable (layers F6 and 25), preventing a clear estimate of an age.

III.4 Discussion

III.4.1 What Is the Age of the Stemmed-Point Component at Veratic, and How Do These Forms Correlate with WST Points from the Northern Plains?

New radiocarbon dates from layers 31 and 30 provide bracketing ages of 9950-9500 cal B.P. for the Paleoindian “Birch Creek” component at Veratic Rockshelter, significantly post-dating the original assessment by Swanson (1972) of 11,700 cal B.P. While early claims of an “Agate Basin” influence from the northern Plains (Butler 1978) are supported by the occurrence of square-based and long, slightly contracting stems of WST forms 1 and 2 (Birch Creek A and C2) (Figure 3.4a-j), the age range for Agate Basin on the northern Plains is much earlier (~12,500-11,500 cal B.P.) (Holliday 2000). For this to be the same form, Agate Basin points would have had to have persisted on the Snake River Plain for more than 1500 years after their disappearance in the Plains, or the age of layers 31-30 is broader than the two new AMS radiocarbon dates suggest.

The Birch Creek complex does seemingly fit within the 12,700-8850 cal B.P. age range for WST points on the Snake River Plain (Holmer 2009), although a recent critical review of radiocarbon dates provides a much narrower range of 12,100-11,200 cal B.P. (Reid 2011) by not including components without two or more corroborating dates within adequate stratigraphic contexts. Though the new, younger age for layer 30 at Veratic is based on a single AMS radiocarbon date (9500 cal B.P.) and needs to be confirmed (Goebel and Keene 2014; following criteria set by Reid 2011), it is corroborated by an underlying date from layer 31 (~9950 cal B.P.). While potentially discordant with the conservative age range espoused by Reid (2011), the new age from layer 30 at Veratic does fit the age range of stemmed-point component LU6 at Cooper's Ferry, recently dated to ~10,200-8900 cal B.P. (Davis et al. 2014), as well as other Birch Creek sites like Jacknife Cave layer 8 (9400-8720 cal B.P.) (Swanson and Sneed 1971) and Shoup Layer 6D (9550-8520 cal B.P.) (Swanson and Sneed 1966) (Figure 3.1 – sites 2-5), though these two early reports did not have two or more overlapping dates for WST bearing strata. There is further evidence in the greater Intermountain West for WST points being associated with archaeological components post-dating 10,000 cal B.P., for example at Fort Rock and Connley Caves (Bedwell and Cressman 1971; Bedwell 1973), Paulina Lake (Connolly and Jenkins 1995), Dirty Shame Rockshelter (Aikens et al. 1977; Hanes 1980; Hanes 1988), Last Supper Cave (Grayson 1988; Layton and Davis 1978; Smith and Kielhofer 2011), Hogup Cave (Aikens 1970), C. W. Harris (Warren 1967), Rogers Ridge (Jenkins 1987), Henwood (Warren 1967), and Buffalo Flat (35LK2076) (Oetting 1994b) (Figure 3.1).

The wide variety of stemmed/lanceolate point forms from layer 30 at Veratic (10,000-9500 cal B.P.) brings into question the appropriateness of lumping them into a single “Birch Creek” category. Morphologically, many of the stemmed/lanceolate points at Veratic are most similar to Haskett points, originally defined by Butler (1965) for their lack of shoulders and long stems that contract towards a flat or rounded base. While this type is most similar to Form 2 (Birch Creek B and C2) and Form 1 (Birch Creek A), the latter appears more distinct from Haskett due to their square or diagonally slanted bases and nearly parallel sides. Differences in raw-material preference also emphasize the possibility that Form 1 may be a distinct point form. Unfortunately, the wide range of morphological attributes prevents the clear separation of one point form from another, and other stemmed/lanceolate points from this component (Forms 3-4: Birch Creek C1 and Plainview) vary significantly in basal concavity and PSA, with some forms possibly even resembling late Paleoindian concave-base lanceolate points. Swanson (1972) indicated that layer 30 could be subdivided into multiple sub-strata (30a-30c), but unfortunately artifact provenience was not recorded to such a degree. Further dating may indicate that layer 30 is a palimpsest, or renewed excavations may indicate that distinct stemmed-point forms occur in different sub-layers, both of which would suggest a longer occupation span than the new dates suggest, though the lower-limiting date of 9950 cal B.P. from layer 31 makes this unlikely. Conversely, further dating may show that stemmed points dominate the lower sub-layers of 30, while Northern Side Notched and early Elko points dominate the upper sub-layers.

III.4.2 Do Elko Corner Notched and Eared Points at Veratic Fit the Elko "Long Chronology," and Can They Be Distinguished from Northern Side Notched Points?

The late WST component in layer 30 (9950-9500 cal B.P.) is followed by Northern Side Notched points in layers F6-27, and may even co-occur with Western Stemmed points in layer 30, but more likely date to 7800-4500 cal B.P., with the earliest significant number of points in layer F6 associated with Mazama ash. To address the potential issue of mis-identification of some Northern Side notched points as early Elko points, as recently suggested by Hockett et al. (2014), this study sought to find a way to use replicable, morphometric data to quantify the basic attributes used to differentiate the two point forms: the slope of the notch (PSA) (e.g., Thomas 1981) and the predilection for corner-notched points, as described by Hockett et al. (2014), to be missing a corner of the base, resulting in a narrower base compared to width across the tangs (i.e., TW/MBW ratio). For side-notched and apparently early corner-notched points from layer 28 at Veratic, Silverman's tests of both of these variables, despite not being separated by pre-conceived assumptions about point form, produced either statistically significant or practically significant separation of the sample into two modes matching independently designated point types. This strongly suggests that both Northern Side Notched and Elko points were separate point forms and not just arbitrary divisions on a continuum, and that they co-occur at Veratic 6700-6000 cal B.P., and possibly earlier.

This provides further support for the Elko "long chronology," argued for recently by Smith et al. (2013), as well as others working in the Snake River Plain (Arkush 1999; Miller 1972; e.g., Swanson and Sneed 1966; Swanson and Sneed 1971), northern Great

Basin (e.g., Aikens et al. 1977; Oetting 1994a; Wilde 1985), western Great Basin (Milliken and Hildebrandt 1997; e.g., Rusco et al. 1987; Smith et al. 2013b), and Bonneville Basin (e.g., Aikens 1970; Goebel 2007; Goebel et al. 2008; Madsen and Rhode 1990; Schmitt and Madsen 2005). Thus, Elko points of both forms (Corner Notched and Eared) appear by 6700 cal B.P. and co-occur with Northern Side Notched points for 2000 years. Elko Eared forms dominate the early-middle Holocene Elko assemblage (6350 to 3950 cal B.P.), while Elko Corner Notched points become more common 4800-3100 cal B.P. Interestingly, this switch from Eared to Corner Notched Elko forms corresponds with the beginning of the Elko "short chronology," suggesting that, in the Snake River Plain, earlier corner-notched dart points may represent a separate point form distinct from later, more conventionally accepted Elko.

III.4.3 How Else Can Morphological Variability Be Organized Among Point Forms at Veratic Rockshelter, and How Do Relative Frequencies of These Forms Change Through Time?

Besides Northern Side Notched and Elko varieties, other point forms occur in Veratic's middle and Late Holocene deposits, albeit in lower numbers. Stemmed Indented Base points (i.e., Gatecliff) appear in low quantities throughout much of the early-middle Holocene (~7800-3150 cal B.P.), with a Pinto-like variety with a flaring base and narrow shoulders co-occurring. Humboldt (9750-3950 cal B.P.) and Salmon River (9750-4500 cal B.P.) points also occur in the early-middle Holocene, but in too low quantities for their age estimates to be reliable, due to minimal but still apparent sediment mixing at Veratic.

In the shelter's latest intact prehistoric deposits, a limited number of arrow-point forms, including Desert side-notched, Cottonwood, Avonlea, and Rosegate, are present, though all but Rosegate (~1600-725 cal B.P.) are too limited in number and/or out of context to estimate a time-span. Though a few isolated Rosegate points are found in deeper levels, the presence of six Rosegate points in layer 21 (2000-1200 cal B.P.) suggests this layer represents the first clear appearance of arrow points, though Elko Corner Notched points continue to also be present in layers 21 and 20.

III.4.4 The View from Veratic Rockshelter

Of the previous point typologies developed for the Snake River Plain, new age estimates for projectile points from Veratic Rockshelter correlate best with the projectile-point typology developed by Holmer (2009). Outside of the Snake River Plain, however, in the context of Table 3.2, the diagnostic-point chronology at Veratic comes closest to resembling those from sites in the Bonneville basin, for example Camel's Back Cave (Schmitt and Madsen 2005) and Bonneville Estates Rockshelter (Goebel et al. 2008) (Table 3.2). Bonneville Estates in particular has roughly similar ages for late WST (stratum 17b', 11,000-10,500 cal B.P.), early Elko (stratum 14, ~7100 cal B.P.; stratum 11, ~5000 cal B.P.), Northern Side Notched (7500-4500 cal B.P.), Rosegate (~1700-300 cal B.P.) and roughly similar ages for Humboldt and Gatecliff, though both Bonneville Estates and Veratic have low frequencies of the last two forms (Goebel et al.

2008). Minor similarities can be seen from the Salmon River/Birch Creek valleys to the north of Veratic, too, with the appearance of Salmon River notched points (Swanson and Sneed 1966) and Avonlea arrow points (Morlan 1988). It should also be noted that Windust points, though found throughout much of the Snake River Plain and Columbia Plateau to the west (Reid 2011), are absent from Veratic, but it is unclear if this is due to regional variation or because of layer 30's presumed young age.

Another interesting feature of the Veratic record is the significant change in point-form diversity during the late middle Holocene, ~4800-3100 cal B.P. Layers 28-27 (6700-4200 cal B.P.) contain a variety of diagnostic point forms, including Northern Side Notched, Elko Corner Notched and Eared, Gatecliff Split Stem, Pinto, Salmon River, and Humboldt points. A variety of food resources were also utilized during this time, as indicated by the presence of bison, sheep, deer, elk, antelope, and rabbit remains, as well as 17 ground-stone artifacts between levels 29-25 (~6350-3950 cal B.P.) indicating the processing of both plant and faunal resources (Swanson 1972). This diversity during the middle Holocene potentially correlates with greater residential mobility and increased usage of the shelter by multiple groups with differing origins during the middle Holocene. This correlates roughly with the generally increased aridity of the Middle Holocene between ~8400-3100 (Bright 1966), though this period was likely characterized by extreme fluctuations in aridity and humidity (Beiswenger 1991).

In layers 24-21 (~3200-1600 cal B.P.), however, the earlier diversity in projectile point forms decreases to include almost exclusively Elko corner notched points and limited large faunal remains (Swanson 1972). Furthermore, the density of cultural materials (both diagnostic and non-diagnostic) drops off significantly above layer 27 (after ~4500 cal B.P.), suggesting less-frequent or less-intensive use of the site after this period. This potentially correlates with the onset of the cooler and wetter late Holocene ~3500-2800 cal B.P. based on dates from nearby Gray’s Lake (Beiswenger 1991) and Rattlesnake Cave (Bright and Davis 1982). A similarly significant transition to cooler/wetter climate, marking the beginning of the Late Holocene or Medithermal period, occurred in the Bonneville basin to the south around the same time, 4400-3400 cal B.P. (Louderback and Rhode 2009). This shift in climate is generally believed to be directly or indirectly tied to an increased intensification of plant and wetland subsistence, resulting in a decrease in residential mobility (Bettinger 1999). On the Snake River Plain, this pattern is reflected in the emergence of the ethnographically modern southern Plateau pattern of low residential mobility focusing on fishing, collecting of starch-rich roots, and hunting, with base camps in riverine settings and seasonal logistical hunting camps in the highlands starting around 4000 cal B.P. (Holmer and Ringe 1986; Holmer 1990; Reed 1985; Reid and Pitkin 2012; Swanson 1972). This decrease in the utilization of long-term highland residential bases like Veratic, combined with more fixed territories potentially explains the decrease in artifact density and diversity by the time layer 24 was deposited (3200-3100 cal B.P.) at the rockshelter. Based on the continued presence of large faunal remains (primarily bison) throughout the middle and late Holocene (though with a decrease between layers 24-22 (~3150-1500 cal B.P.)), and the lack of ground stone above layer 25 (Swanson 1972), during this time Veratic likely served primarily as a short-term hunting camp and was repeatedly utilized by local people with a limited geographic range and base camps in riverine settings such as the Wahmuza site to the south (Holmer and Ringe 1986).

Also during this transitional period (4800-3100 cal B.P.), the shift from a mix of Elko Eared and Corner Notched points to exclusively Elko Corner Notched points coincides with the beginning of the Elko short chronology (~3500 cal B.P.) (Thomas 1981). This suggests that an older corner-notched variant existed prior to this time, sparsely or inconsistently distributed across the northern Great Basin, only to be subsumed or replaced by a generalized "Elko" form around 4000-3500 cal B.P., not just at Veratic in the Snake River Plain, but also across a broader area of the Intermountain West and coinciding with the aforementioned transition to low residential mobility and increased intensification.

III.5 Conclusions

This study emphasizes the importance of metric projectile-point variability in typology building, and the necessity for considering regional variation within the Great Basin when constructing these typologies. For example, the Elko short chronology (Bettinger and Taylor 1974; Elston and Budy 1990; Heizer and Hester 1978; O'Connell 1967; Thomas 1981) may be valid in some regions of the Great Basin, but it does not necessarily apply to the Intermountain West as a whole. It is also useful to apply quantitative morphological attributes to projectile-point differentiation whenever possible to establish whether proposed point forms represent actual, discrete phenomena. Veratic provides the rare opportunity to study a large assemblage of diagnostic points across a long interval of time, so that diachronic variation in projectile-point morphology as well as relative changes in point-form frequencies can be measured. Results of this study of the Veratic assemblage indicate that: 1) Not only do WST points at Veratic date to significantly later than previously thought, but they have a relatively broad spectrum of morphological variability and may represent multiple separate point forms; 2) early (~6000 cal B.P.) corner-notched dart points are distinct from Northern Side Notched points, supporting the concept of an Elko "long chronology," that may include two separate, morphologically distinct corner-notched point forms on the Snake River Plain; and 3) several distinct varieties of dart points coincided during the middle Holocene (~6000-4200), including Elko Corner Notched and Eared, Northern Side Notched, Stemmed Indented Base (including Gatecliff and possibly Pinto forms), Humboldt, and Salmon River points, all of which were replaced with a single variety of Elko Corner Notched point at the beginning of the Medithermal period.

Another critical feature of this study is the fortuity of being able to apply new methods to re-analyze and re-date a museum collection without renewing excavations. Despite being excavated more than 50 years ago, Swanson's use of stratigraphic excavation and site recording techniques made the current study possible. However, several issues can only be addressed through new excavations. Few datable charcoal samples still exist in the collection, especially from the Paleoindian component. More dates are needed to better establish the age range of layer 30, and a new sample of artifacts is needed to determine whether internal ordering of stemmed-point forms occurs in layer 30's sub-strata. Layer 25 is of similar interest, because it represents a decline in

Archaic dart-point variability sometime between 4800-3100 cal B.P. Thus, by applying current methods of chronological hygiene and morphometric projectile-point analysis to the existing assemblage, we can better understand diachronic technological variability of the upper Snake River Plain and greater Intermountain West.

CHAPTER IV

A TALE OF TWO ROCKSHELTERS: A COMPARISON OF HOLOCENE ENVIRONMENTAL AND LITHIC TECHNOLOGICAL VARIATION BETWEEN THE BONNEVILLE BASIN AND THE UPPER SNAKE RIVER PLAIN AT BONNEVILLE ESTATES AND VERATIC ROCKSHELTERS

IV.1 Introduction

Changes in climate have had a major influence on past human societies, with both abrupt and gradual environmental shifts shown to trigger “crises” that directly affect human population size, technology, and subsistence change (Aimers and Hodell 2011; deMenocal 2001; Kelly et al. 2013; Munoz et al. 2010). This is especially apparent amongst agricultural and industrial societies (Aimers and Hodell 2011; deMenocal 2001; Zhang et al. 2011), but it is also an important factor of change in foraging populations where much depends on the frequency and predictability of plant and animal resources (Binford 1980; Kelly 1995; Kelly et al. 2013; Louderback et al. 2010; Surovell 2009). However, proving a causal link between past environmental and prehistoric culture changes is difficult to do, and slight environmental differences, even in the same regions, may have led to variable degrees of cultural adaptation. One such area is the arid Intermountain West of North America, where elevational, hydrographic, and vegetation differences could have led to varying frequencies and magnitudes of cultural change through time. The hydrographic Great Basin in particular, primarily consisting of the Basin and Range provinces of Nevada and adjacent parts of western Utah, southeastern

Oregon and eastern California, has precipitation rates ranging from >100 cm/year in upland areas to as little as 10 cm/year in the dry lowland basins (Grayson 2011; Madsen 2000).

High-resolution Great Basin proxy records provide a detailed record of past climate fluctuation (Adams et al. 2008; Goebel et al. 2007; Louderback and Rhode 2009; Madsen et al. 2001; Mensing et al. 2013), making it possible to compare changes in prehistoric technological organization with fluctuations in temperature, aridity, and ecological-zone change on a millennial scale or better. Recent archaeological studies have focused on the transition from the cool and wet terminal Pleistocene/early Holocene to the hot and dry middle Holocene, correlating changes in climate with the archaeological record of mobility and subsistence (Duke 2011; Elston and Zeanah 2002; Elston et al. 2014; Goebel 2007; Madsen et al. 2015a). Mobility, specifically residential mobility, was the primary adaptive tool prehistoric populations utilized to respond to the changing availability of patchy resources (Kelly 1992), and organization of technology was clearly tied to this subsistence-settlement pattern, providing a means to understand and quantify basic human adaptation (e.g. Andrefsky 1994; Bleed 1986; Cowan 1999; Elston and Zeanah 2002; Kelly and Todd 1988; Parry and Kelly 1987; Smith 2011). As climate change has the potential to affect resource patch size, frequency, and predictability (Kelly 1995; Surovell 2009), it has also potentially affected mobility and subsistence strategies among prehistoric populations. In this study, diachronic changes in lithic technological organization are compared with paleoclimatic history to determine changes in mobility throughout the Holocene in the Intermountain West. Archaeological proxies for analyzing such changes include artifact-assemblage variability (Elston and Zeanah 2002; Goodyear 1993), formal/informal-tool production (e.g. Andrefsky 1994; Bleed 1986; Cowan 1999; Kelly and Todd 1988; Parry and Kelly 1987), and toolstone procurement based on geochemical analysis (e.g. Duke 2011; Hughes 1986; Jones et al. 2003, 2012; Page and Duke 2015; Smith 2011).

Rockshelters and caves in the Intermountain West provide stratified, datable contexts for multi-component archaeological assemblages, making them ideal for studies of diachronic change. Bonneville Estates and Veratic rockshelters in particular are ideal for the study of paleoclimatic effects on Holocene human subsistence activities for a number of reasons. Both are multicomponent sites with large assemblages of lithic tools from dated contexts, providing precise chronological control typically not available with open-air sites in the region. Both sites have roughly similar occupation histories as well as lithic and faunal assemblages, and both contain records relating to every major climatic phase of the Holocene. Moreover, the two sites are from neighboring sub-regions of the Intermountain West – the western Bonneville Basin and the Snake River Plain - allowing for comparison of environmental and technological variability in two closely related areas marked by various degrees of arid conditions.

The Bonneville Basin, which once contained the massive Pleistocene Lake Bonneville, is a large enclosed basin in the eastern Great Basin of eastern Nevada and western Utah (Figure 4.1). The basin and range topography of the area includes wide, flat-floored valleys with smaller north to south trending mountain ranges with a basin-and-range vegetative system consisting of broad lowland shadscale zones between 1200-

1800 masl (10-40 cm annual precipitation), limited upper valley and mountain-foothill sagebrush and grass-steppe zones between 1500-1870 masl (20-58 cm annual precipitation), higher pinyon-juniper zones between 1730-2300 masl (41-51 cm annual precipitation), upper limber-pine and bristlecone aspen/fir zones between 2300-2900 masl (51-64 cm annual precipitation), and subalpine conifers and alpine herbaceous tundra between 2900-3600 masl (64-102 cm annual precipitation) (Billings 1951; Grayson 2011; Louderback 2007; Lull and Ellison 1950; Madsen 2000). Limited wetland vegetation also exists at perennial marshes which contain cattails, bulrushes, and sedges (e.g. Louderback and Rhode 2009). Generally, this “island-like” morphology results in lower species diversity that is more prone to extirpation due to climatic fluctuation (Brown 1971; Grayson 1993; Madsen 2000). Though relatively constant throughout the year, the basin-and-range topography causes annual precipitation rates to vary geographically between ~155 cm in upland areas and ~13 cm on the basin floors, with slightly higher rainfall in the spring (Currey 1991; Madsen 2000). Mean temperatures are also highly variable based on elevation, with average high and low temperatures of ~-26.5 to -2.9° C for the valley floor around Wendover, NV and 14.5 to -7.2° C in the alpine uplands around Brighton, UT (Madsen 2000; National Climatic Data Center 1997).

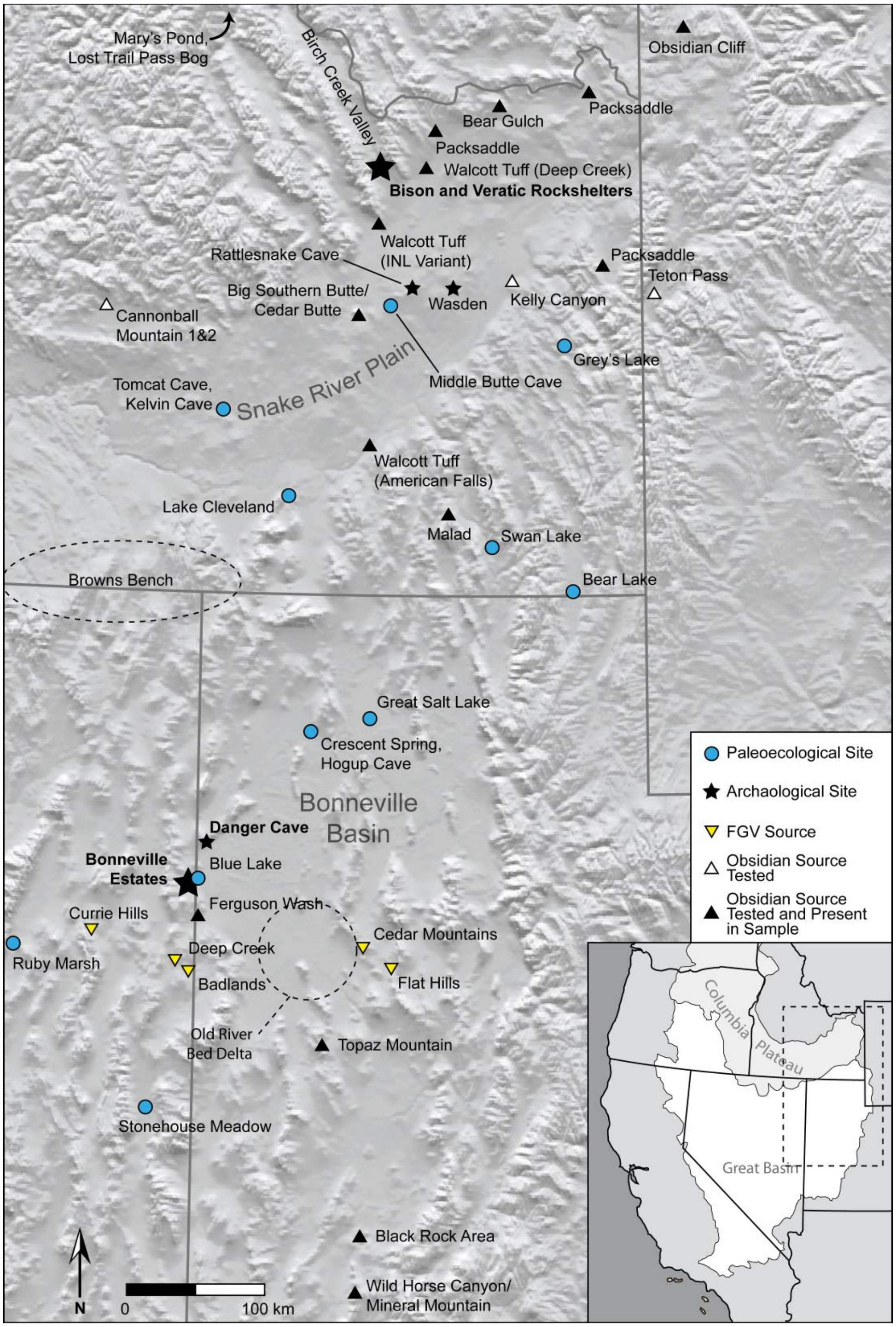

Figure 4.1. Map showing locations of Bonneville Estates and Veratic Rockshelters, important geography, archaeological sites and paleoclimatic sampling locations mentioned in text, and local obsidian sources (with arrows), and FGV sources (from Duke 2011).

The upper Snake River Plain, located ~100 km north of the northern extent of the Bonneville Basin, consists of a long, broad trough following the Snake River in southeastern Idaho ~100 km wide (Figure 4.1) with a gradual increase in slope from west to east ranging between 1300-1700 masl and lacking the basin-and-range topography of the Bonneville Basin. The Snake River Plain is fed by numerous rivers from the surrounding Rocky Mountains, forming the ~26,000 square km Snake River Aquifer. In the area near Veratic Rockshelter, a number of streams flow into the "Pioneer Basin," an enclosed basin that once contained Pleistocene Lake Terreton (Nace et al. 1956). Vegetation is fairly uniform across the plain, consisting primarily of sagebrush steppe with perennial grasses and riparian zones containing predominantly willows, cottonwoods and sedges (Plew 2000). As it is surrounded by mountain ranges, upland vegetation zones comparable in composition and elevation range to the Bonneville Basin exist around the periphery, including pinyon-juniper zones, ponderosa pine, and mountain-mahogany forests (Plew 2000). Rainfall on the plain is consistently low (20-23 cm), with most precipitation occurring in the winter. Seasonal temperatures vary between average summer high temperatures of 38° C and average low winter temperatures of -7° C (Idaho Department of Water Resources 1978; Plew 2000).

These two regions provide a unique laboratory for the investigation of paleoclimatic effects on human populations; while both are arid sagebrush/shadscale step environments in the intermountain West, key differences in lithic raw material availability, topography, and global atmospheric patterns potentially contributed to distinct differences in lithic technological organization. In this paper, we compare the lithic assemblages from two key sites representing these two neighboring regions – Bonneville Estates and Veratic Rockshelters - using models of occupation span and residential mobility recently established by Surovell (2003, 2009) and Smith (2011) to address diachronic differences in obsidian transport, material preference, stage of reduction, and formal-versus informal-tool production, considering these changes in lithic technology in the context of the sites' respective paleoclimates and paleoenvironments. This allows not only for a better understanding of how climatic trends affected prehistoric populations throughout the Holocene, but also provides a means of comparing how related groups in potentially different ecological settings and raw-material landscapes reacted to paleoclimatic changes during the early, middle, and late Holocene.

The paper addresses two major questions:

1) How do paleoclimatic records compare/contrast between the Snake River Plain and western Bonneville Basin? Despite their proximity and general aridity, differences in topography, environment, water availability, elevation, and even atmospheric patterning potentially affected differences in the timing and intensity of climate change throughout the Holocene between the two regions.

2) What is the timing and nature of change in technological organization and residential mobility between Bonneville Estates and Veratic rockshelters, and how do these potentially relate to the paleoclimatic record? Occupation span (i.e. relative length of stay), as determined by relative changes in obsidian source, raw-material use, and stage of reduction, is used to interpret diachronic change in

subsistence and residential mobility, allowing for a comparison of human adaptation between the two regions. Patterns not attributable to raw-material availability have the potential to establish whether groups in both regions reacted similarly to environmental stress through the Holocene, or whether each region experienced variable degrees of environmental change and therefore variable magnitudes of cultural adaptation. Unfortunately, focusing only on these two rockshelters provides a very limited view of the total range of subsistence activities and geographic locations utilized by hunter-gatherers. However, the stratified nature of these sites provides the best means of providing chronometric contexts for assemblages and exploring diachronic change while also ruling out geographic influences on lithic assemblages by holding place constant.

IV.2 Lithic Analyses: Theoretical Background

Mobility, as originally defined by Binford (1980), is commonly used as a basic measure of human adaptation in environments occupied by human foragers, like the Great Basin and Snake River Plain. In this study, occupation span is used as a proxy of residential mobility through analyses of raw material, reduction sequence, formal vs. informal tools, and diversity indices.

IV.2.1 Occupation Span and Raw-material Sourcing

The concept of occupation span, as defined by Surovell (2000, 2003, 2009), and implemented in studies of Intermountain West behavioral ecology (Duke 2011; Duke and Young 2007; Madsen et al. 2015a; Smith 2011, Smith et al. 2013a), relates to the relative length of time humans occupy a residential site before moving. In principle, as resource patches become spaced further apart due to environmental stress, the cost of residential mobility increases while the cost of logistical mobility does not, resulting in longer duration of residential stays and a greater intensification on processing of local resources via short logistical forays before moving to another patch. Though originally applied to highly mobile Paleoindian populations, Smith (2011) applied this concept to a diachronic obsidian sourcing study of diagnostic bifacial points in the northwestern Great Basin, assuming that as residential mobility decreased, occupation span increased, and that a longer occupation span at a site resulted in increased acquisition and working of local toolstone to replace tools and materials brought in from elsewhere. Therefore, an increase in the percentage of "local" (arbitrarily established as < 20 km) obsidian, as determined by XRF analysis, correlates with decreased residential mobility and presumably sparser resource patches.

Applying a similar method to stratified sites instead of surface assemblages allows for greater chronological resolution and the ability to analyze more artifact types than just diagnostic bifacial points. For relatively arid environments like the present study area, when available plant and animal resources declined during drier periods, residential mobility is predicted to have decreased and occupation span to have increased. Though raw material availability strongly influences the raw material preference at a given site, diachronic changes in occupation span is reflected within the lithic assemblage by a relative increase in the percentage of local obsidian over time.

Relative increases through time in other raw materials determined to be “local” may also be indicative of an increased occupation span.

IV.2.2 Reduction Sequence and Occupation Span

Another proxy for residential mobility is stage of bifacial reduction. Bamforth (1991) compared long- and short-term camps, observing that longer-term camps have more evidence of manufacturing, relating to the previous assertion that longer occupation spans result in a greater necessity to re-tool onsite. A proxy for this is a ratio of early-to-late-stage bifaces.

Based on an amalgam of other methods (Callahan 1979; Johnson 1989; Whittaker 1994), Andrefsky’s (2005) five-stage method is used in this paper to determine stage of biface reduction. As explained above, an increase in duration of occupation is expressed by more re-tooling on-site, and a greater percentage of early-stage bifaces. Because proportionally greater degrees of early-stage reduction are also indicative of quarry sites, stage can also be used as a rough gauge of the proximity of raw-material classes which cannot be directly sourced. A relative change in the ratio of early-to-late-stage reduction at a given site through time would then indicate changes in occupation span rather than raw-material constraints, since the availability of raw-material will remain constant through time.

Core/biface ratios are also linked to residential mobility and stage of reduction (Bamforth and Becker 2000; Parry and Kelly 1987), with the assumption that more sedentary communities are more likely to exhaust cores at a single location. It is predicted that as residential mobility decreases, the ratio of cores to bifaces will also increase.

IV.2.3 Occupation Span and Formal/Informal Tools

In the classic view, formal tools are considered to take longer to make, but lead to more efficient use of toolstone and are more easily re-worked and re-used than expedient tools, and thus should be more common at sites occupied by groups with higher residential mobility where individuals are provisioned over places (Bleed 1986; Cowan 1999; Kelly and Todd 1988; Kuhn 1995; Parry and Kelly 1987), with a general trend observed in the Great Basin of increasing presence of expedient tools through time (Smith et al. 2013a). However, raw-material availability potentially has a stronger effect on ratio of formal to informal tools than degree of mobility (e.g. Andrefsky 1994; Eerkens and Lipo 2007; Goodyear 1993; Kelly and Todd 1988). A recent study of Paleoarchaic occupations along the Old River Bed Delta in the western Bonneville basin (Madsen et al. 2015a; Madsen 2016) showed the opposite of the traditional model: that increased recycling of flake tools into points in a resource-poor environment resulted in an increase in formal-tool/expedient-tool ratio during the drier middle Holocene as populations became less residentially mobile and non-local obsidian became more common (Beck and Jones 1997; Beck et al. 2002; Beck and Jones 2015; Madsen et al. 2015b). Again, an understanding of raw-material availability is crucial to understanding provisioning, as the conflicting pattern at the Old River Bed Delta is potentially caused by the low availability of local raw materials.

A comparison of ratios of formal (points, bifaces, formal scrapers) to informal (modified flakes) tools between Bonneville Estates and Veratic rockshelters' assemblages potentially provides a gauge of the raw-material availability at each site, with a predicted lower ratio at Bonneville Estates where high-quality raw materials are scarce. Additionally, based on the trend at the Old River Bed Delta, if raw materials are not readily available at either site, an increase in the percentage of formal artifacts should correspond with a decrease in the use of non-local raw material and decreasing residential mobility.

IV.2.4 Occupation Span Diversity Indices

Diversity provides a measure of richness and evenness of an assemblage of artifacts, with richness indicating the number of classes within an assembage, and evenness the equitability of the distribution within these categories (Kintigh 1984; Odell 2004). Simpson (1949) and Shannon (1948) present indices that can be used to calculate ratios useful in determining relative differences in the richness and evenness of assemblages, often in regards to raw-material and obsidian-source preferences. As mobility increases and occupation spans shorten, foragers will have access to a larger range of raw-material sources through embedded procurement and the diversity should increase, while periods of lower residential mobility and longer occupation span should be reflected by a lower diversity of raw materials (i.e. Eerkens et al. 2007; Smith 2010). Even when the exact source is unknown, this method can provide a measure of relative occupation span for raw materials, where distinct classes are identifiable but the exact source is not known. Diversity of artifact types can also be used to measure relative changes in residential mobility based on the “Clarke Effect”: that the longer a site is occupied, the discard rate will increase, resulting in an increased number of tool types relative to assemblage size (Schiffer and Skibo 1987; Waguespack and Surovell 2003). Similarly, an increase in the diversity of bifacial-point forms, which are potentially stylistically linked to specific populations, could reflect an increase in inter-group interaction and therefore increased mobility and range.

IV.3 Paleoclimatic Context of Bonneville Estates and Veratic Rockshelters

To address diachronic changes in lithic technological organization and their relation to paleoclimatic trends, it is necessary to characterize the paleoclimatic trends for the Bonneville basin and the upper Snake River Plain. Fortunately, the former has recently been well established using high-resolution, well-dated proxy records such as pollen, packrat middens, lake levels, and micro/macrofaunal concentrations from deposits in lake beds, marshes, caves, and archaeological sites (e.g. Benson et al. 2011; Broughton et al. 2000; Goebel et al. 2011; Louderback and Rhode 2009; Madsen and Currey 1979; Madsen et al. 2001; Mensing et al. 2013; Oviatt 1997; Oviatt 2016; Rhode 2000; Rhode et al. 2005) with the Blue Lakes pollen core (Louderback and Rhode 2009), located <10 km from Bonneville Estates, providing a detailed and well-dated proxy record directly comparable to the assemblage at the shelter. Multiple paleoclimatic proxy records are also available for the upper Snake River Plain and its immediate surroundings (Beiswenger 1991; Breslawski and Byers 2014; Bright 1966; Bright and

Davis 1982; Butler 1972; Cummings and Puseman 2005; Davis et al. 1986; Davis 1981; Henrikson 2002; Henrikson 2003; Henrikson and Montana 2007; Moser and Kimball 2009) though they have much less chronological resolution and are not all continuous throughout the Holocene, especially in the immediate vicinity of Veratic Rockshelter.

IV.3.1 Paleoclimatic History of the Bonneville Basin

The Younger Dryas period, marked by globally cooler temperatures, is generally dated to ~12.9-11.6k calibrated years before present (cal B.P.) (Rasmussen et al. 2006), during which time lake levels in the Bonneville Basin remained constant at the Gilbert shoreline (Benson et al. 2011; Goebel et al. 2011; Oviatt et al. 2005). The Blue Lakes cores indicate that high levels of pine and *Artemisia* sp. pollen were present prior to 12k cal B.P. (Louderback and Rhode 2009). This was followed by a gradual decrease in woodland and steppe plants, and the beginning of the drop in lake levels from the Gilbert shoreline ~11.6 k cal B.P. (Benson et al. 2011), indicating an increase in aridity coinciding with the end of the Younger Dryas and the beginning of the early Holocene (Louderback and Rhode 2009; Oviatt et al. 2015; Oviatt et al. 2005; Rhode et al. 2005). Decreases in lake levels opened up new areas for wetlands to form, indicated by increases in marsh plants such as sedges and cattail and the formation of peat deposits by ~10.8k cal B.P. (Louderback and Rhode 2009; Oviatt et al. 2005; Rhode et al. 2005). A recent study by Oviatt et al. (2015) further corroborates that there was likely no lake highstands following the Younger Dryas, with lake levels not rising above modern levels between 11.5-10.2 cal B.P., or any time after the early Holocene.

Increasing warming and drying continued, with an early Holocene drought from ~10.8 to 9.5-9.2k cal B.P. (Grayson 2000; Louderback and Rhode 2009; Schmitt and Madsen 2005; Thompson 1992) as indicated by a decrease in pine and *Artemisia* sp. and increase in arid-adapted Chenopodiaceae-Amaranthaceae (Cheno-Ams) and xerophytic shrubs (Hunt et al. 2000; Louderback and Rhode 2009; Rhode 2000), and a decrease in cool/wet adapted fauna (Grayson 2000; Hockett 2007; Schmitt and Lupo 2012). Further desiccation between ~8.2-6.6 k cal B.P. is indicated by the period with the lowest recorded pollen count at Blue Lakes, as well as a marked increase in Cheno-ams compared to *Artemisia* sp. and wetland plants (Louderback and Rhode 2009). This second drought marks the beginning of the early-middle Holocene and the period of maximum heat and aridity during the Holocene, with similar patterns noted roughly between 8.8-7.8k cal B.P. elsewhere in the Bonneville Basin floral records (Hunt et al. 2000; Madsen and Currey 1979; Mehringer 1985; Mensing et al. 2013; Thompson et al. 2016). Similarly, faunal records suggest an increase in xeric-adapted mammals at this time (Grayson 2000; Madsen et al. 2001). This drought ameliorated somewhat in the late-middle Holocene at ~6.6-7.1k cal B.P. (Louderback and Rhode 2009; Madsen and Currey 1979; Thompson et al. 2016), with further possible amelioration after 6.1 cal B.P. based n Great Salt Lake proxy records (Thompson et al. 2016) as indicated by increasing pollen counts and a higher *Artemisia*/Cheno-am ratio.

The beginning of the late Holocene is characterized by a return to cool and wet conditions, though with several fluctuations between wet and dry, as seen by mesic intervals in the Blue Lakes pollen record between 4.4-3.4k cal B.P. and 2.7-1.5k cal

B.P., based on increases in pine and conifer pollen and a higher *Artemesia/*Cheno-am ratio (Louderback and Rhode 2009). Greater moisture is documented starting at ~4.8k cal B.P. at the Ruby Marsh (Thompson 1992), at ~4.0 cal B.P. at the Great Salt Lake (Thompson et al. 2016), and ~3.8k cal B.P. at Crescent Spring (Mehringer 1985). The arid period between 3.4-2.7k cal B.P. at Blue Lakes (Louderback and Rhode 2009) and between 3.4-2.9 cal B.P. at the Great Salt Lake (Thompson et al. 2016) conflicts with the late Holocene dry period, a drought that affected much of the Great Basin between ~2.8-1.85k cal B.P. (Mensing et al. 2013), but may not have reached parts of the eastern and northern Great Basin (Louderback and Rhode 2009; Mensing et al. 2013). A second dry period starting 1.5k cal B.P. may correspond with the Medieval Climate Anomaly, dated in the western Great Basin to ~1.15-0.7k cal B.P. (Jones et al. 1999; Kleppe et al. 2011; Stine 1994).

IV.3.2 Paleoclimatic History of the Upper Snake River Plain

While the Bonneville Basin has seen concentrated paleoclimatic research, the upper Snake River Plain's record is less well established, especially in the vicinity of Veratic Rockshelter. Additionally, many of the available records are based on outmoded methodologies, or are chronologically incomplete. Moreover, the most complete records commonly used for the Snake River Plain are from the mountains to the south (opposite the position of Veratic Rockshelter) and are just as commonly used as proxy records for the Bonneville Basin (Beiswenger 1991; Bright 1966; Davis et al. 1986; Rosenbaum and Kaufman 2009). Decreasing pine and encroaching sagebrush/Cheno-am steppe pollen frequencies reflect the warming period following the Younger Dryas and indicate the beginning of the early Holocene by ~11.9k cal B.P. at Swan Lake (Bright 1966), by ~11.7k cal B.P. at Grey's Lake (Beiswenger 1991), and sometime between 10-12k cal B.P. at Bear Lake (Doner 2009), matching records from the western Bonneville Basin. An early Holocene drought is indicated between 10.8-9.2k cal B.P. by changes in fossil diatoms indicating decreased river input at Bear Lake (Moser and Kimball 2009), also matching records from the Bonneville Basin. Pollen core records at Greys Lake indicate increased sagebrush and decreased pine between roughly 11.5-7.9k cal B.P., with a xeric peak at ~9.2k cal B.P. (Beiswenger 1991), though low-resolution chronometric data for the Holocene may mean both early and middle Holocene droughts are combined.

The early-middle Holocene drought on the Snake River Plain is indicated by a number of proxy records. At Bear Lake, diatoms indicate a switch from river input to lake evaporation as the major factor affecting lake levels at ~7.6k cal B.P., with a drought between 7.6-5.8k cal B.P. (Moser and Kimball 2009). Similar pollen, plant macrofossil, and charcoal proxy records from the Bear River Range of southeastern Idaho showed the most xeric conditions between 7.1-6k cal B.P. (Lundeen and Brunelle 2016). Pollen records similarly indicate a drop in mesic marsh plants at this time, though chronological control is lacking for this part of the pollen record (Doner 2009). Grays Lake estimates put this transition at ~8.2k cal B.P. (Beiswenger 1991), similar to that of the Bonneville Basin, though records from Lake Cleveland indicate a much later thermal maximum post-dating the Mazama eruption (7.6k cal BP Zdanowicz et al. 1999) by as much as 1000 years, due potentially to differences in high-altitude summer insolation at

Lake Cleveland compared to lower-elevation locales nearer the middle of the Snake River Plain.

Pollen and seed records from Rattlesnake and Middle Butte Caves northwest located in the center of the upper Snake River Plain (Bright and Davis 1982; Davis 1981, Davis et al. 1986; Henry 1984) as well as from lake records in the Bitterroot Mountain Range just north of the Snake River Plain (Karsian 1995; Mehringer et al. 1977) also show increases in the ratio of Cheno-ams to *Artemisia* at or shortly prior to the Mazama eruption, though precise chronological control is not available for either site. Pollen records from Kelvin's Cave and Tomcat Cave (Cummings 2002; Cummings and Puseman 2005; Henrikson 2003; Henrikson and Montana 2007) indicate relatively little change throughout the Holocene following a large increase in *Artemisia* sp. pollen ~10.2k cal B.P., though prehistoric mixing of strata, limited radiocarbon dating, and the use of sagebrush branches and leaves as insulation in storing bison meat hinder further paleoclimatic inferences.

Faunal records also indicate a period of middle Holocene maximum aridity some time just prior to the Mt. Mazama eruption, as indicated by a shift from more mesic-adapted pocket gophers to more xeric-adapted pygmy rabbits at the Wasden Site (Butler 1969; Guilday 1969), recently corroborated by stable carbon and nitrogen isotopes from small mammals at Wasden (Commendador and Finney in press). Rates of loess deposition and rockfall at the Birch Creek sites (Swanson 1972) and at Wasden (Butler 1972) are used as coarse proxies for climate on the open Snake River Plain, estimating the age of the middle Holocene drought to ~8.8-5.8k cal B.P., though they are based on limited conventional radiocarbon dates.

Sometime between 6.7-6.4k cal B.P., both Bright and Davis (1982) and Beiswenger (1991) note a middle Holocene fluctuation towards more mesic conditions based on *Artemisia*/Cheno-am ratios and *Pinus* sp. pollen. Packrat and pollen data from Rattlesnake Cave indicate that at ~6.5k cal B.P., Cheno-am/*Artemisia* ratios were higher than today, potentially supporting an arid period lasting until this time (Bright and Davis 1982) and correlating roughly with the beginning of the late-middle Holocene transition period in the Bonneville Basin. Conditions were still drier than today, and records of the timing of dune activation still indicate aridity higher than today between ~6-4.4k cal B.P. (Pearce and Rittenour 2009; Rich et al. 2015).

The timing for the beginning of the late Holocene occurred sometime between 3.5-2.3k cal B.P. (Bright and Davis 1982) and 4-3.6k cal B.P. (Beiswenger 1991). This broad range may be the result of defining the beginning of the neoglacial period (~3.1-2.45k cal B.P. [Madsen et al. 2001]) as the beginning of the late Holocene proper, with the actual start of the late Holocene probably occurring at a similar time as in the eastern Great Basin (~4k cal B.P. (Louderback and Rhode 2009; Mensing et al. 2013)). Estimates from the Bitterroot Range to the north also show an increase in conifer pollen at ~4-3.5k cal B.P. indicating increased moisture (Karsian 1995; Mehringer et al. 1977). This potentially correlates with a sudden erosional event triggered by flooding at the Pioneer Site ~3.8 cal B.P. (Keene 2016a), though this is a local episode that may relate to local volcanic activity rather than increased regional precipitation.

The Great Basin drought does not appear in the limited proxy records for the late Holocene, which Mensing et al. (2013) attribute to differences in weather patterns between the Snake River Plain/northern Great Basin and the Bonneville Basin, causing late Holocene conditions in the Snake River Plain to be more uniformly cool and wet. However, periods of activation of the St. Anthony dune field in southeastern Idaho indicate a dry period after the late Holocene drought ~1-2k cal B.P. (Rich et al. 2015). Periods of deposition and rockfall at the Birch Creek sites (Swanson 1972) indicate possible wet periods between 4.3-3.5k cal B.P. and 2.9k-present, further corroborating periods of wet and dry documented for the Bonneville Basin, with the exception of a missing late Holocene drought between 2.8-1.85k cal B.P.

Finally, conditions in the Snake River Plain became cooler and wetter ~0.6-0.75k cal B.P. based on increased alluvial deposition along the Big Lost River and resurgence of Lake Tereton in the Pioneer Basin of the Idaho National Laboratory (Bright and Davis 1982; Keene 2016a; Ostenaa and O'Connell 2005), corresponding with the Little Ice Age.

These patterns show that the timing and general nature of climate fluctuation on the Snake River Plain generally reflects that of the Bonneville Basin, with the possible exception of a late Holocene dry period between 2.8-1.85k cal B.P. in the Snake River Plain (Mensing et al. 2013). These climatic periods, with associated dates, are shown in Table 4.1 with associated strata from both Veratic and Bonneville Estates rockshelters grouped into broad “components” based on paleoclimatic period, allowing for the comparison of assemblages with roughly similar chronologies and paleoclimatic settings between the two sites.

Table 4.1. Ages of paleoclimatic periods in the Bonneville Basin and Snake River Plain with associated strata and components from Bonneville Estates and Veratic Rockshelters

~Age (k cal B.P.)	Epoch	Period/Conditions	BER strata	Veratic strata	Comp.
12.9-11.6	late Pleistocene	Younger dryas cooling period	18a, 18b		6
11.6-10.8	early Holocene	gradual increase in aridity from YD	17b', 18a		
10.8-9.2		period of increased aridity/drought	17b,17b'	30	
9.2-8.2		gradual increase in aridity from YD	17a		
8.2-6.6	early-middle Holocene	drought: peak aridity	14, 16	F6	5
6.6-4.2	late-middle Holocene	amelioration from previous peak aridity	11, 13	27, 28, 29	4
4.2-3.4	late Holocene	return to mesic conditions	9, 10		3
3.4-2.7		increased aridity (less than middle Holocene)	9	24	
2.7-1.5		return to mesic conditions on SRP and at Blue Lakes, late Holocene dry period in southern GB	4, 5, 7	22	
1.5-0.7		change in winter/summer precipitation, somewhat drier, relating to Medieval Climate Anomaly	3	20	2
0.7+		more mesic conditions - Little Ice Age	0, 1, 2	19+	1

IV.3.3 Bonneville Basin vs. Snake River Plain Climatic Intensity

Though the timing for paleoclimatic events is similar between the Bonneville Basin and Snake River Plain, basic differences in geography, altitude, and latitude have variably influenced past and present climate and ecology in the two regions, potentially affecting forager subsistence and mobility. The modern Bonneville Basin and surrounding area consists of north-south trending basins and ranges with a series of ecological zones ranging from upland subalpine forests to mid-elevation pinyon/juniper woodlands and sagebrush steppe, and lowland salt flats with sparse, shadscale/greasewood plant communities (Billings 1951; Grayson 2011; Madsen 2005). Resources available in this “patchy” environment would have been variable and relatively unpredictable, with changes in climate resulting in significant changes in resource patch size and availability. The record from Blue Lakes (Louderback and Rhode 2009) in particular indicates that while sagebrush steppe was dominant during the late Pleistocene, during the early-middle Holocene period of peak aridity, wetlands largely desiccated and the surrounding basin was dominated by Cheno-ams with very little sagebrush (Figure 4.2).

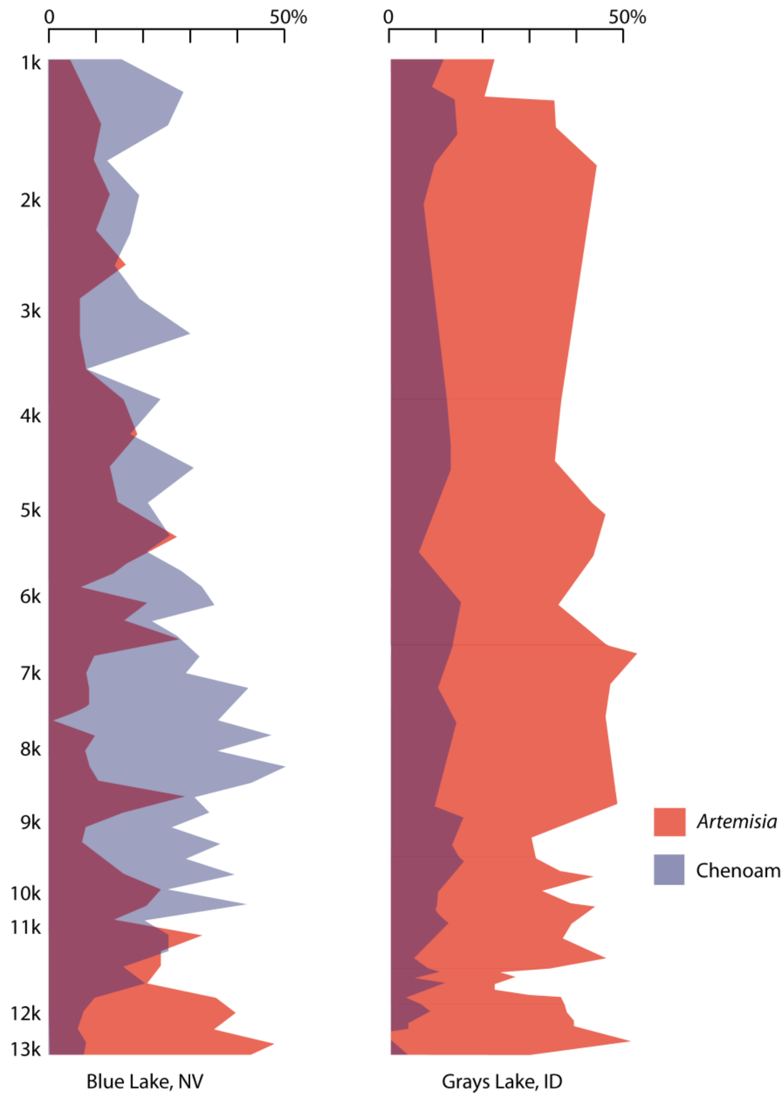

Figure 4.2. Comparison of Blue Lakes (adapted from Louderback and Rhode 2009) and Grays Lake (adapted from Beiswenger 1991) *Artemisia* and Cheno-am percentages throughout the Holocene.

The upper Snake River Plain, however, is a broad, flat, ~100 km wide plain arching across southeastern Idaho and bordered on all sides by mountains. The vast majority of the plain is dominated by a uniform sagebrush steppe intermixed with a variety of grasses and sporadic riparian zones containing willow, cottonwood, sedges, and chokecherries surrounding perennial flowing streams (Plew 2000). On the periphery of the plain (as is the case at Veratic) where it intersects with the surrounding mountain ranges, as elevation increases, vegetation trends follow similar patterns as the Great Basin, with transition to juniper at mid-slopes and *Pinus* and Spruce species at higher elevations. Furthermore, throughout the Holocene, despite paleoclimatic fluctuations, the ecology of the upper Snake River Plain remained essentially the same, with sagebrush steppe dominant (Figure 4.2) throughout the Holocene, though with pollen records from Rattlesnake Cave and Swan Lake indicating an *Artemisia*/Cheno-am mix (though with *Artemisia* sp. still dominant) during the period of peak aridity of the middle Holocene (Beiswenger 1991; Davis 1981; Davis et al. 1986; Swanson and Sneed 1966).

Studies of prehistoric bison populations indicate that because of the unique Great Plains-like conditions on the Snake River Plain, and despite variations in paleoclimate, bison ranged the area continuously throughout the Holocene (Breslawski and Byers 2014; 2015; Henrikson 2003; Henrikson and Montana 2007; Plew and Sundell 2000), while in most other regions of the Intermountain West, including the Bonneville Basin, bison were sparse and only occasionally available, undergoing periodic local extirpations and re-colonizations (Breslawski and Byers 2014; Grayson 2006; Grayson and Woolfenden 2016; Van Vuren 1987). The record of bison kills at early and middle

Holocene occupations in the Great Basin is extremely limited, with a brief fluorescence during the late Holocene during Fremont times (1.65k-0.65 cal B.P.) when summer precipitation increased (Hockett 2015), with the greatest numbers coming from the northern Great Basin (Grayson 2011).

Paleoclimatic records also indicate less extreme variation in mesic vs. xeric conditions in the Snake River Plain than the Bonneville Basin throughout the Holocene. Mensing et al. (2013) indicates that in the north, there was either no change in climate, or an actual increase in moisture during the "Great Basin drought" ~1.85-2.8k cal B.P. This is combined with known global patterns of seasonal atmospheric variation (Grayson 2011; Mitchell 1976), suggesting a persistent boundary between 40-42° where global atmospheric and oceanic patterns resulted in a dipolar pattern of a wet northwest and dry southwest.

Though conditions were arid and resources sparse on the Snake River Plain, with extreme winter/summer conditions and very low rainfall, paleoecological proxies indicate that plant and animal resources available in sagebrush steppe environments may have been consistently present and similarly distributed through time and space, with minor fluctuations in resource patch availability. Conversely, Bonneville basin resources were highly variable both geographically and throughout time, with more extreme changes expressed by significant fluctuations in sagebrush vs. Cheno-ams and saltbush in the basin floor. These differences in variation of resource availability and structure may be reflected in differences in degree of technology/subsistence change between sites in both regions.

IV.4 The Sites

Bonneville Estates and Veratic rockshelters are ideal for a comparison of inter-regional subsistence and technological change for multiple reasons. Both sites were occupied during all major periods of climate change during the terminal Pleistocene and Holocene up to the proto-historic period, with major components dating to the Paleoarchaic (component 6), middle Holocene (components 4 and 5), early-late Holocene (component 3), Fremont period (component 2), and Numic-spread/protohistoric period (component 1). Both have good stratigraphic provenience recorded for most collected materials, both are located in an ecotone with nearby access to lowland and upland resources, and both have broadly similar lithic assemblages reflecting a variety of site activities (Table 4.2). Traditionally, both areas were home to Numic-speaking foragers, and a similar prehistoric cultural tradition between the two sites can be established by the appearance of similar projectile-point forms during roughly the same time periods throughout the Holocene (Table 4.3), as well as exploitation of both large and small game (Table 4.4) and the adoption of ground-stone technology in the middle Holocene (Table 4.2), indicating incorporation of seeds into the diet by that time. Ethnographic accounts for the upper Snake River Plain of Shoshone and Bannock tribes indicate these groups historically practiced a relatively mobile subsistence strategy based on a seasonal round with travel between highland and lowland locales, utilizing a variety of plant and animal resources (Steward 1938). Ethnographic accounts of Shoshone populations of the western Bonneville basin showed similar patterns of increased mobility with seasonally mobile groups banding together at winter base camps and to perform communal hunts (Hockett and Murphy 2009; Steward 1938), though Snake River Plains groups relied more heavily on root foods such as camas that were not available in the Bonneville Basin (Murphy and Murphy 1986).

Table 4.2. Bonneville Estates and Veratic artifact types by component

		Counts by Component							Percentages by Component					
		1	**2**	**3**	**4**	**5**	**6**	**total**	**1**	**2**	**3**	**4**	**5**	**6**
Bonneville Estates	biface	9	27	42	30	62	9	179	14.75%	24.32%	22.95%	26.55%	31.63%	25.00%
	core	11	14	10	5	7	3	50	18.03%	12.61%	5.46%	4.42%	3.57%	8.33%
	expedient	2	5	22	11	29	11	80	3.28%	4.50%	12.02%	9.73%	14.80%	30.56%
	formal scraper	2	6	5	2	7	5	27	3.28%	5.41%	2.73%	1.77%	3.57%	13.89%
	point	28	51	66	50	63	7	265	45.90%	45.95%	36.07%	44.25%	32.14%	19.44%
	ground stone	9	8	38	15	28	1	99	14.75%	7.21%	20.77%	13.27%	14.29%	2.78%
	TOTAL	61	111	183	113	196	36	700						
Veratic	biface	12	24	47	27	75	21	206	36.36%	33.80%	23.15%	21.95%	18.43%	11.35%
	core	0	0	1	1	7	2	11	0.00%	0.00%	0.49%	0.81%	1.72%	1.08%
	expedient	11	13	64	25	112	93	318	33.33%	18.31%	31.53%	20.33%	27.52%	50.27%
	formal scraper	9	24	73	54	146	56	362	27.27%	33.80%	35.96%	43.90%	35.87%	30.27%
	point	1	6	16	12	59	12	106	3.03%	8.45%	7.88%	9.76%	14.50%	6.49%
	ground stone	0	4	2	4	8	1	19	0.00%	5.63%	0.99%	3.25%	1.97%	0.54%
	TOTAL	33	71	203	123	407	185	1022						

Table 4.3. Bonneville and Veratic point types by component

	Component - Bonneville Estates						Component - Veratic					
	1	2	3	4	5	6	1	2	3	4	5	6
Avonlea							2	3	3		2	0
Rosegate	8	16	2	7	1		2	9	4	1		
Cottonwood	3							1	1		1	
DSN	2	3		3	3				1	1	2	
									1			
Gatecliff split stem	1	2	3			1			9	5	3	1
Pinto									2		2	
Humboldt	1		1	1						3	1	1
Elko	4	2	21	5	5	1	3	8	26	22	17	5
Salmon River										1	2	1
NSN	1	2	5	17	20			1	2	7	60	4
WST			1			5			3	6	4	32
Plainview												3
Folsom (?)												1
lanceolate (preform?)				1	2							
Clovis	1											
unknown notched	2	3	4	2	4	5	2	5	17	2	23	2
unknown	5	20	26	13	22	1			3	5	29	5
TOTAL	28	48	63	49	57	13	9	27	72	53	146	55

Table 4.4. Bonneville faunal NISP and MNI by component (from Hockett 2015: table 3)

	Component - NISP						Component - MNI					
	1	2	3	4	5	6	1	2	3	4	5	6
Pronghorn	10	30	382	16	22	7	2	1	9	3	2	1
Mtn. Sheep	2	9	11	1	8	3	1	1	5	1	2	1
Deer	0	0	2	1	1	1	0	0	2	1	1	1
Bison	3	13	7	2	1	1	2	1	2	1	1	1
Hare	4	9	158	30	9	218	1	1	17	4	1	13
Rabbit	0	0	1	10	55	622	0	0	1	2	6	59
Sage Grouse	0	0	0	7	22	619	0	0	0	2	2	18
Black Bear	0	0	0	0	0	1	0	0	0	0	0	1
Bobcat	0	0	2	0	12	1	0	0	1	0	1	1
Coyote	1	0	0	0	0	0	1	0	0	0	0	0
Badger	0	0	0	0	1	0	0	0	0	0	1	0
Weasel	0	0	0	0	1	9	0	0	0	0	1	3
Katydids	0	0	0	0	0	21	0	0	0	0	0	21

IV.4.1 Bonneville Estates Rockshelter

Bonneville Estates Rockshelter (Figure 4.3A) is a large, south-facing rockshelter located on the western edge of the Bonneville Basin in the Lead Mine Hills, at the Bonneville paleoshoreline (1600 m asl) (Figure 4.1). Excavations undertaken by Ted Goebel, Kelly Graf, Bryan Hockett, and David Rhode between 2000-2009 revealed a well-stratified site almost continuously occupied from 12,900 cal B.P. until the historic period. Though a full report of the site is not yet published, the shelter's geochronology has been well established with over 130 AMS dates on hearth charcoal, bone, coprolites, perishable artifacts, and plant material from 20 identifiable strata (Albush 2010; Goebel et al. 2007; Graf 2007; Hockett 2015; Smith et al. 2013b).

Bonneville Estates Rockshelter is near upland plant and animal resources in the Goshute Mountains to the west and lowland wetland resources from the Blue Lakes Marsh to the east. High-quality obsidian is absent from the vicinity of the shelter, with the exception of Ferguson Wash ~18 km to the southeast, which is the only obsidian that falls within the conventional 20-km “local” distance (i.e. reachable in one day) (Surovell 2009; Waguespack and Surovell 2003), though it is only available in very small package sizes (<5 cm) making it difficult to knap (Page and Duke 2015). In addition, chert and siltstone is locally available, and sources of fine-grained volcanics (FGV) are both locally and non-locally available. The faunal assemblage consists of artiodactyls such as pronghorn, deer, mountain sheep, and bison, as well as small game such as cottontails, hares, and sage grouse (Table 4.4), especially in the Paleoarchaic (component 6) and late Holocene (component 3) horizons. The artiodactyl index, as reported by Hockett (2015), increases throughout the Holocene, though sample sizes are relatively small for the late Holocene components.

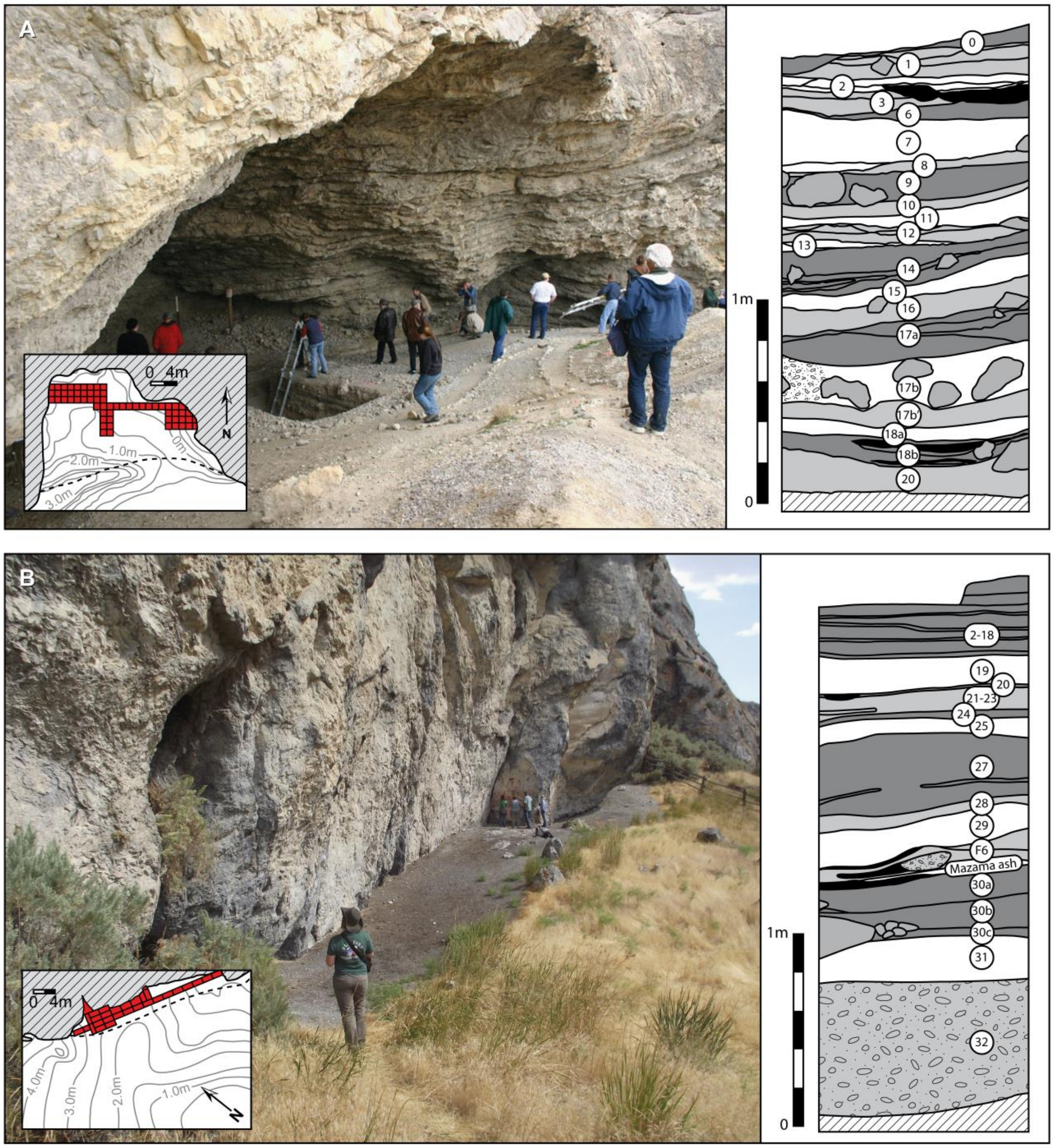

Figure 4.3. A) Bonneville Estates, and B) Veratic Rockshelters, with representative stratigraphic profiles and site maps (after Goebel et al, in press and Swanson 1972, respectively).

IV.4.2 Veratic Rockshelter

Veratic Rockshelter (Figure 4.3B) is a broad, shallow, west-facing overhang located on the northern boundary of the upper Snake River Plain, in lower Birch Creek Valley between the Beaverhead and Lemhi mountain ranges (1850 m asl) (Figure 4.1). Major excavations by Earl H. Swanson Jr. as well as Ruth Gruhn, Alan Bryan, Robert Butler, and Donald Tuohy took place between 1960-1961, uncovering a large, stratified, multi-component site (Swanson 1972) containing extensive lithic artifacts and faunal remains within at least 13 strata dating throughout the Holocene. Though the original chronology is incomplete and used outdated methods, Keene (2016b) recently reanalyzed the assemblage and acquired new AMS dates on existing charcoal samples, producing an updated geochronological context for many of the lithic artifacts in the assemblage.

Veratic has access to the open steppe environment of the Snake River Plain to the south and the upland Salmon River country to the north. Multiple obsidian sources are available in the immediate region, though the closest source is greater than 20 km away. Furthermore, crypto-crystalline silicate (CCS) is locally available in the Birch Creek cobbles and in nearby outcrops. Overall, mountain sheep, as well as bison, pronghorn, deer, and rabbits were utilized throughout the Holocene (Table 4.5), with an increase in sage grouse during the early-middle Holocene (Component 5), and an increase in bison and decrease in small fauna during the late Holocene (Components 1-3) (Swanson 1972).

Table 4.5. Veratic faunal NISP and MNI by component (from Swanson 1972)

	Component - NISP						Component - MNI					
	1	2	3	4	5	6	1	2	3	4	5	6
Antelope		3	6	10	11	1		3	4	3	6	1
Bison	202	135	154	1	2	3	23	14	30	1	1	2
Black Hills Cottontail	2	3	1	1	1		1	3	1	1	1	
Canis	5	3	8	6	4		4	3	6	3	3	
Crow					5						NA	
Deer	3	4	1	3	5		2	3	1	2	4	
Elk		2						1				
Ground Squirrel	1		1				1		1			
Lynx	1	1		1	2		1	1		1	2	
Magpie			1			1						
Mouse			1						1			
Packrat	2	1	8		1	4	1	1	3		1	4
Passerine			1		1							
Pika	1						1					
Pocket Gopher		1	1	2	3	2		1	1	1	2	2
Pygmy Rabbit	1		6		1	1	1		3		1	1
Mountain Sheep	4	24	16	39	93	12	4	6	7	5	16	2
Sparrow Hawk	1						1					
White Tail Jackrabbit	2	4	3	1	5		2	3	1	1	3	
Grouse	2	2	0	1	53	2	1	1	0	1	2	1

IV.5 Materials and Methods

Analyses were performed on an assemblage of 601 lithic tools from Bonneville Estates Rockshelter and an assemblage of 1043 tools from Veratic Rockshelter, currently housed at the Texas A&M University Department of Anthropology and the Idaho Museum of Natural History, respectively. To answer questions about site occupation span and residential mobility, raw-material and tool categories were recorded for all available lithic artifacts from each site, focusing on finished projectile points, bifaces, scrapers/unifaces, cores, and expedient tools (as defined by Andrefsky (2005)). Debitage was not included in the present analysis, as the debitage from the Veratic assemblage was discarded by the original excavators.

IV.5.1 Geochronology

Geochronological context for individual strata was established using previously reported dates for Veratic (Keene 2016b; Swanson 1972) and Bonneville Estates (Albush 2010; Goebel et al. 2007; Graf 2007; Smith et al. 2013b). Strata from both sites were grouped into six broad "components" (Figure 4.4, Table 4.1) to compare similarly aged strata from both sites within a broader paleoclimatic framework. All radiocarbon dates throughout were calibrated using Calib 7.1 (Stuiver and Reimer 1993) and the IntCal13 radiocarbon calibration curve (Reimer et al. 2013).

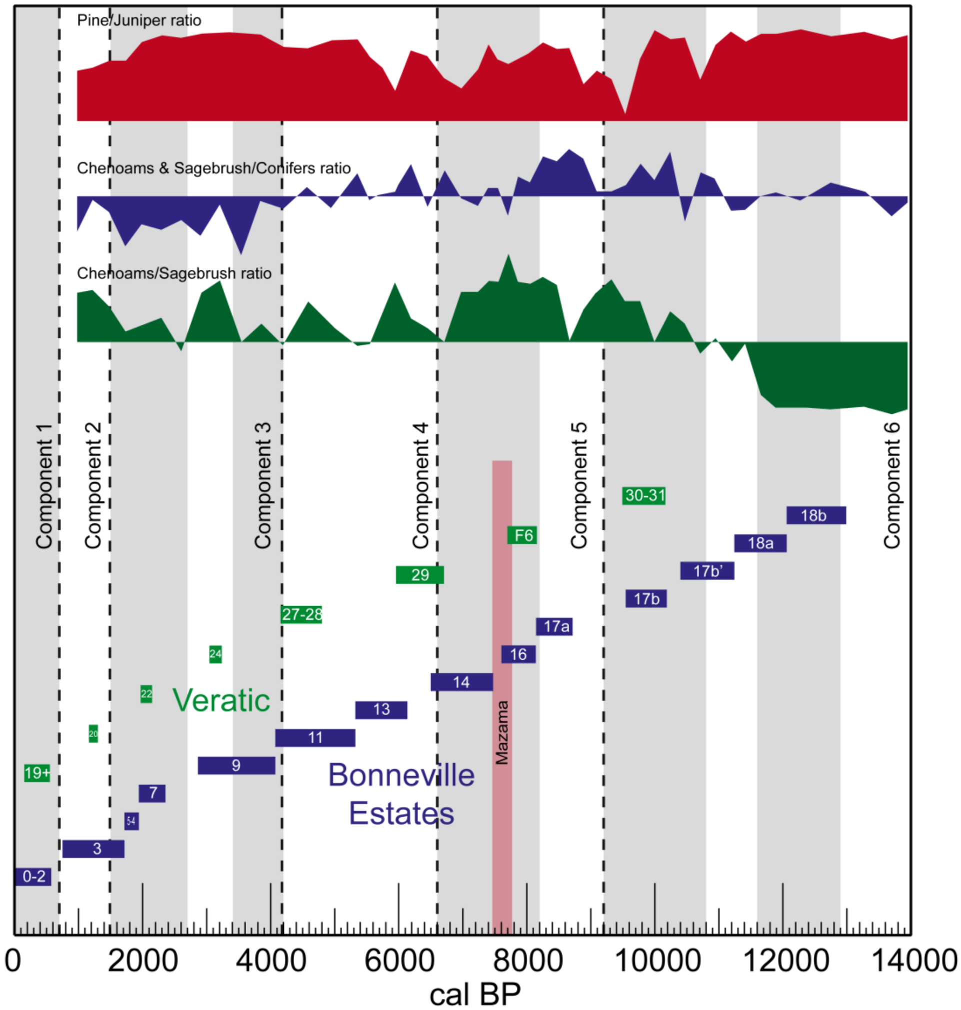

Figure 4.4. Components from Veratic and Bonneville and associated strata, in relation to pollen records from Blue Lake (Louderback and Rhode 2009).

IV.5.2 Lithic Analyses

Biface stage was determined using the following criteria established by Andrefsky (2005): Stage 1 is an unmodified blank, stage 2 bifaces are minimally bifacially worked along an edge, stage 3 bifaces show the first indication of thinning, stage 4 bifaces are more thinned and straightened into point preforms, and stage 5 represents a completed point with hafting elements.

Diversity ratios were generated using Simpson's index (1-D) (1949) and Shannon's Equitability index (Shannon index divided by the logarithm of the number of taxa) (Shannon 1948), both of which account for richness and evenness to differing degrees, and which generally correct for sample size. To establish statistical significance, 95% confidence intervals were generated for each ratio using a bootstrap procedure with 9999 random samples and the same number of individuals as the original sample (after Hammer et al. 2001). While both tests combine richness and evenness into a single ratio, Shannon's Equitability test places a stronger emphasis on evenness. Simpson and Shannon (Equitability) indices of diversity and 95% confidence intervals were generated using PAST statistical software v. 3.12 (Hammer et al. 2001).

IV.5.3 X-ray Fluorescence Analysis

XRF analysis was performed on samples of obsidian artifacts from both Bonneville Estates and Veratic rockshelters. For the Veratic analysis, a Tracer III-V provided by the Idaho State University Anthropology Department was used, with a Si-Pin detector capable of 190 eV at 10,000 cps, scanning for 180 deadtime-corrected seconds at 40 kV and 30 µA with a 12-mil Al, 1-mil Ti, and 6-mil Cu filter, and calibrated to ppm values using an earlier version of the GL1 calibration developed by Bruker in concert with the University of Missouri Research Reactor (MURR) (see Ferguson 2012). Bonneville Estates obsidian was analyzed using a Tracer-III-SD at

Texas A&M University, equipped with a 10 mm 2X Flash SDD peltier cooled detector capable of 145 eV at 100,000 cps, scanning for 60 deadtime corrected seconds with a 12-mil Al, 1-mil Ti, and 6-mil Cu filter and calibrated using the current GL1 calibration. The increased precision of the SDD detector allowed for shorter scan times, re-scanning artifacts with unclear designations at 180 seconds. Due to the potential error caused by comparing results from different XRF devices (Ferguson 2012), the same obsidian reference collection was analyzed by each device separately, and data from the different devices were analyzed and interpreted separately.

XRF analysis was used to correlate samples of obsidian artifacts to known obsidian sources. Artifacts not meeting basic criteria for size (as defined by Shackley [2011] and Ferguson [2012]), and surface geometry were excluded. Geochemical source characterizations were based on reference collections ($n \geq 10$) that were personally collected or provided by the Archaeometry Laboratory at MURR. These included Black Rock (UT), Browns Bench (ID/NV), Bear Gulch (ID), Big Southern Butte (ID), Cannonball I and II (ID), Cedar Butte (ID), Kelly Canyon (ID), Malad (ID), Obsidian Cliff (WY), Packsaddle (ID), Topaz Mountain (UT), Teton Pass (WY), Timber Butte (ID), Walcott Tuff (ID), and Wild Horse Canyon/Mineral Mountain (UT) (Figure 4.1). Obsidian source locations were taken from Skinner (2014), with the exception of the Walcott sources and the Packsaddle source, which have multiple recorded locations across the upper Snake River Plain (provided by R. Holmer, personal communication 2014) (Keene 2016b). For the sake of calculating average distances to obsidian sources with multiple outcrops (e.g. Walcott American Falls/Deep Creek, Packsaddle) or with broad geographic distributions (e.g. Browns Bench), distance was measured from each site to the closest known source, though some may have originated from more distant locations. Due to the non-normal distribution of raw-material distances based on XRF source identification, average obsidian distances between assemblages were compared using a non-parametric Monte Carlo permutation t-test with 9999 random permutations (Hope 1968).

IV.6 Results

IV.6.1 Raw material

Obsidian sourcing alone is not sufficient to fully understand raw-material availability and mobility at both sites, because a significant percentage of both assemblages is made from other materials (especially at Bonneville Estates). At Bonneville Estates, of a sample of 601 artifacts, CCS was most commonly used (61%), followed by obsidian (25%) and FGV (13%). CCS is further divided, as 23% of tools were made from a uniformly gray, low-quality silicified material resembling siltstone, though a more in-depth raw-material identification is necessary. Goebel's surveys indicate it originated from ~5 km to the west in the foothills of the Goshute Mountains, and thus is considered locally acquired (T. Goebel, personal communication 2016). Other forms of CCS are also potentially local, with known sources located within 10 km in the foothills of the Goshute Mountains to the west and in the form of small cobbles along the Gilbert shoreline to the southeast (Goebel et al. in press), though the exact sources are unknown. A similar number of archaeologically relevant FGV sources have been identified in the area ranging from ~50-150 km away (Page 2008; Rogers and Duke 2011) (Figure 4.1), though FGV analyses of Bonneville Estates artifacts is incomplete.

Of the 1058 analyzed artifacts from Veratic, obsidian is most common (55%), followed by CCS (35%), FGV (6%) and quartzite (4%). While the exact source location of the CCS in the Veratic assemblage is unknown, CCS is present in the vicinity as cobbles in nearby Birch Creek and adjacent valleys stemming from the Salmon River system. It is also found in chert-bearing Mississippian carbonate deposits in the mountains directly east of the site, and in an Ordovician limestone formation located ~27 km upstream (Lewis et al. 2012) (Figure 4.1).

IV.6.1.1 Raw Material by Artifact Form. We used raw-material type by artifact form to establish whether certain materials were chosen based on occupation span or based on functional characteristics. In addition, the preference for certain raw materials to be used for early-stage bifaces, cores, and expedient tools can corroborate the proximity of certain raw-material classes. Both sites have some similarities in raw-material preference by artifact form (Table 4.6), the most notable being a preference for CCS (excluding low grade silicified silt/clay stone) for scrapers/unifaces, most likely due to its improved durability over obsidian (Goodyear 1979; Jones and Beck 1999; Smith 2006). Cores at both sites were also made from similar percentages of obsidian (55% at Bonneville, 64% at Veratic) and CCS (34% at Bonneville, 36% at Veratic), though the paucity of cores in the Veratic assemblage was too low to measure this similarity statistically. Nearly all cores at Bonneville Estates are from components 1 and 2. At Bonneville Estates, a variety of materials was used for bifacial points, with CCS being most common (42%), followed by obsidian (31%), siltstone (13%), and FGV (12%), while the majority of points at Veratic were made from obsidian (75%), with ~20% made from CCS. Although obsidian was more commonly used for bifacial points than for other artifact classes, it was significantly less preferred at Bonneville Estates than at Veratic, likely because of the decreased availability of easily usable local obsidian. Bifaces at Bonneville, CCS (34%) and siltstone (32%), presumably more local materials, were most commonly used, with a lower percentage of obsidian (17%) and FGV (15%), while at Veratic, bifaces were made primarily from obsidian (59%), followed by CCS (37%). Raw-material percentages for expedient tools were roughly similar to bifaces within each assemblage, primarily silicified siltstone at Bonneville Estates (49%) and CCS (24%) in addition to FGV (15%) and obsidian (12%), while at Veratic, obsidian (47%) was dominant followed by CCS (42%).

Table 4.6. Tool type by raw material

	Bonneville Estates					Veratic				
	Biface	Core	Expedient	Scraper	Point	Biface	Core	Expedient	Scraper	Point
Siltstone	60	4	41	4	35	0	0	0	0	0
CCS	63	18	20	23	115	77	4	132	79	70
FGV	28	2	13	2	39	5	0	17	7	5
Obsidian	32	29	10	1	83	121	7	150	274	23
Quartzite						3	0	18	2	7
Other	4	0	0	2	0	0	0	1	0	1
TOTAL	187	53	84	32	272	206	11	318	362	106
Siltstone %	32.09%	7.55%	48.81%	12.50%	12.87%	0.00%	0.00%	0.00%	0.00%	0.00%
CCS %	33.69%	33.96%	23.81%	71.88%	42.28%	37.38%	36.36%	41.51%	21.82%	66.04%
FGV %	14.97%	3.77%	15.48%	6.25%	14.34%	2.43%	0.00%	5.35%	1.93%	4.72%
Obsidian %	17.11%	54.72%	11.90%	3.13%	30.51%	58.74%	63.64%	47.17%	75.69%	21.70%
Quartzite %	0.00%	0.00%	0.00%	0.00%	0.00%	1.46%	0.00%	5.66%	0.55%	6.60%
Other %	2.14%	0.00%	0.00%	6.25%	0.00%	0.00%	0.00%	0.31%	0.00%	0.94%

IV.6.1.2 Diachronic Patterns. Based on the local availability of CCS at both sites, changes in the percentage of CCS use over time may indicate changes in occupation span. Further differences in ratios of raw-material types (i.e. silicified siltstone vs. CCS or FGV), though precise source locations are unknown, may also be indicative of changes in assemblage diversity and potentially changes in raw-material procurement and average occupation span over time. All differences in average percentages between components or between artifact classes at each site were tested for significance using a two-tailed Fisher's exact test, unless otherwise stated.

Unlike at Veratic, raw-material preference at Bonneville Estates fluctuated drastically between all components (Figure 4.5a, Table 4.7). Early Holocene component

6 (9500-13,000 cal B.P.) is dominated by CCS and FGV with very little obsidian or siltstone, though this changed with the transition to component 5, where there was a statistically significant increase in silicified siltstone ($p = 0.0024$) and decrease in FGV ($p = 0.0433$). In components 4 and 5 CCS dropped in frequency, with a statistically significant difference between components 6 and 4 ($p = 0.0438$), while obsidian increased (comp. 5 vs. 4 $p = 0.0159$), much of which is potentially attributable to an increase in the use of local Ferguson Wash.

Following the increase in proportion of local raw materials during the middle Holocene, there was a significant drop in FGV ($p = 0.0001$) and rise in CCS ($p = 0.0032$) in Bonneville Estates component 3 (1700-4100 cal B.P.). Component 2 (800-1700 cal B.P.) shows a significant increase in CCS ($p = 0.0008$) and decrease in silicified siltstone ($p = 0.0001$). Finally, in component 1 (0-600 cal B.P.), obsidian again increased significantly ($p = 0.0318$), which may correlate with an increase in local Ferguson Wash obsidian (Figure 4.6).

Table 4.7. Raw-material by component

Bonneville Estates

Comp.	Obs.	CCS	Siltstone	FGV	Quartz-ite	other	total	Obs %	CCS %	Siltstone %	FGV %	Quartz-ite %	Other %
1	24	24	3	1	0	0	52	46.15	46.15	5.77	1.92	0.00	0.00
2	29	64	7	2	1	0	103	28.16	62.14	6.80	1.94	0.97	0.00
3	43	58	35	8	1	0	145	29.66	40.00	24.14	5.52	0.69	0.00
4	27	21	26	24	0	0	98	27.55	21.43	26.53	24.49	0.00	0.00
5	25	46	63	31	2	1	168	14.88	27.38	37.50	18.45	1.19	0.60
6	3	14	5	12	1	0	35	8.57	40.00	14.29	34.29	2.86	0.00
Total	151	227	139	78	5	1	601						

Veratic

Comp.	Obs.	CCS	Siltstone	FGV	Quartz-ite	other	total	Obs %	CCS %	Siltstone %	FGV %	Quartz-ite %	Other %
1	24	10	0	0	0	0	34	70.59	29.41	0.00	0.00	0.00	0.00
2	40	27	0	0	1	0	68	58.82	39.71	0.00	0.00	1.47	0.00
3	129	59	0	9	11	0	208	62.02	28.37	0.00	4.33	5.29	0.00
4	73	43	0	6	2	1	125	58.40	34.40	0.00	4.80	1.60	0.80
5	202	179	0	31	15	2	429	47.09	41.72	0.00	7.23	3.50	0.47
6	113	52	0	16	10	3	194	58.25	26.80	0.00	8.25	5.15	1.55
Total	151	227	139	78	5	1	601						

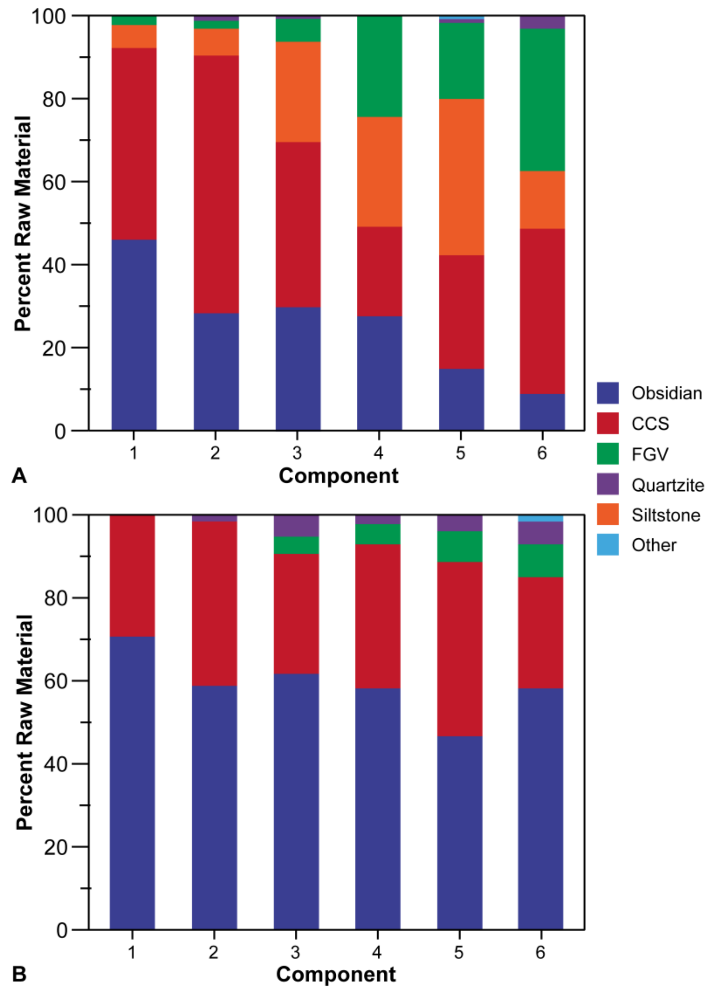

Figure 4.5. Raw-material by component at A) Bonneville Estates and B) Veratic.

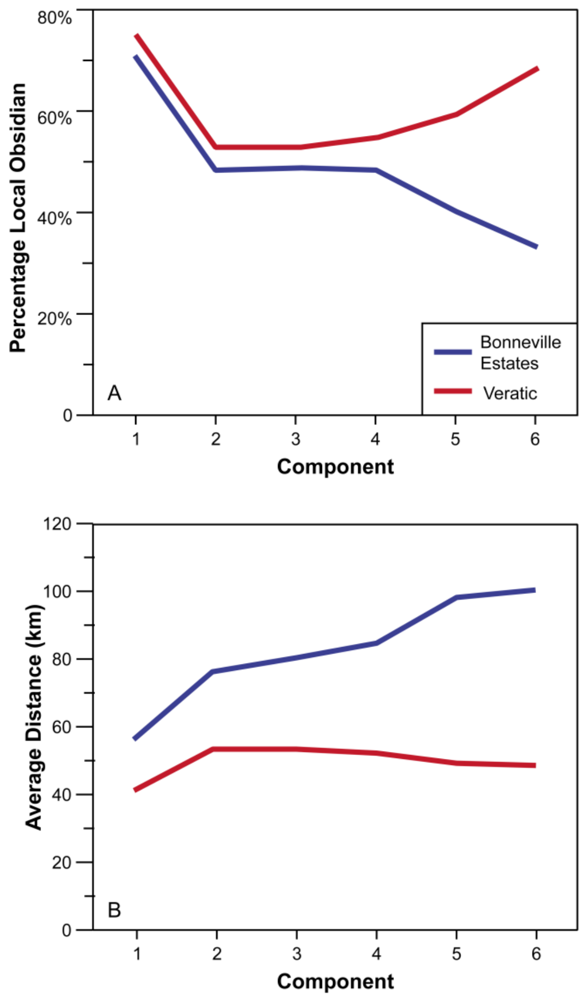

Figure 4.6. A) Percentage local obsidian and B) average distance by site.

Unlike at Bonneville Estates, the raw-material preference at Veratic stayed relatively stable throughout the Holocene (Figure 4.5b, Table 4.7), with the exception of a minor but statistically significant increase in CCS/obsidian ratio in component 5 compared to component 6 ($p = 0.0009$), and subsequent decrease back to early Holocene layers by component 3 (comp. 5 vs. 4, $p = 0.0659$; comp. 5 vs. 4 and 3, $p = 0.0004$). Further late Holocene trends are statistically insignificant.

IV.6.2 Obsidian Source Analysis

In addition to understanding basic raw-material constraints at each site, a comparison of changes in average distance to obsidian source and local versus non-local obsidian usage was used to determine diachronic changes in occupation span for each assemblage. XRF analysis was able to positively attribute >95% of obsidian artifacts to a known obsidian source. At Bonneville Estates, with a sample of 151 obsidian tools, sources identified included Ferguson Wash, Topaz Mountain, Browns Bench, Black Rock, Wildhorse Canyon/Mineral Mountain, and Malad. At Veratic, with a sample of 249 obsidian tools, it was possible to identify Walcott Tuff, the Walcott INL variant (see Keene 2016b), Bear Gulch, Big Southern Butte, and Obsidian Cliff (Figure 4.1). At Bonneville Estates, the nearest source (Ferguson's Wash) comprises ~50% of the obsidian assemblage and is located only 18 km away. However, the remaining sources are significantly further away, with distances ranging from 118 km (Topaz Mountain to the south) to 260 km (Malad to the north). In fact, the second-most common obsidian source is Browns Bench despite being 142 km away. Veratic has no obsidian sources within 20 km, with most obsidian coming from Walcott Tuff, presumably from the source located at Deep Creek 27 km to the east. The other obsidian sources, with the exception of two artifacts from Obsidian Cliff (188 km to the northeast), are considerably closer than most of those available at Bonneville Estates, with Bear Gulch and Big Southern Butte about equidistant at ~83 km to the east and south, respectively. While the percentage of each obsidian assemblage made from "local" obsidian (50% at Bonneville, 59% at Veratic) is comparable ($p = 0.1186$), Bonneville Estates has a statistically higher average distance to obsidian source (Table 4.8) (t = 5.8392, p = 0.0001, Monte Carlo permutation t-test). This difference likely reflects the small package size and poor knappability of Ferguson Wash obsidian, which may also explain the significantly lower fraction of obsidian used as a raw material at Bonneville Estates when compared to Veratic.

Table 4.8. Bonneville Estates obsidian sources, local vs. nonlocal, and average distance (km). BBID – Browns Bench, BRUT – Black Rock, FWUT – Ferguson's Wash, MAID – Malad, TMUT – Topaz Mtn., WHCUT/MMUT – Wildhorse Canyon/Mineral Mountain.

Comp..	BBID	BRUT	FWUT	MAID	TMUT	unknown	WHCUT/MMUT	# local	# nonlocal	% local	% nonlocal	avg dist.
1	4	0	17	0	2	0	1	17	7	70.83%	29.17%	56.5
2	10	0	14	0	4	1	0	14	14	48.28%	51.72%	76.57
3	13	1	21	0	6	1	1	21	21	48.84%	51.16%	80.67
4	11	0	13	1	2	0	0	13	14	48.15%	51.85%	84.89
5	10	0	10	2	3	0	0	10	15	40.00%	60.00%	98.96
6	2	0	1	0	0	0	0	1	2	33.33%	66.67%	100.7
TOTAL	**50**	**1**	**76**	**3**	**17**	**2**	**2**	**76**	**73**			

A diachronic analysis of "local" versus "non-local" obsidian at both sites by component revealed some trends, though the sample sizes were too small to be statistically significant. At Bonneville Estates, local obsidian preference was low during the terminal Pleistocene/early Holocene (TP/EH), increased during the middle Holocene (components 4 and 5), remained constant through much of the late Holocene, then increased again in latest Holocene component 1. Average distance to source at

Bonneville Estates shows a similar trend, with a statistically significant decrease in average distance over time (t = -2.1015, p = 0.0443, Monte Carlo permutation t-test). At Veratic, local obsidian preference started high in the early Holocene, decreased during the middle Holocene, remained constant during the late Holocene, before increasing in component 1 (Figure 4.6, Table 4.9). Average distance at Veratic, however, shows no significant change in average distance throughout the Holocene (t = 0.4875, p = 0.5982, Monte Carlo permutation t-test) (Figure 4.6).

Table 4.9. Veratic obsidian sources, local vs. nonlocal, and average distance (km). BG – Bear Gulch, BSB – Big Southern Butte, OC – Obsidian Cliff, WT – Walcott Tuff, WTINL – Walcott Tuff INL variant.

Comp.	BG	BSB	OC	WT	WTINL	unkn.	# local	# nonlocal	%local	%nonlocal	avg dist.
1	1	0	0	3	0	0	3	1	75%	25%	41
2	5	4	0	10	0	0	10	9	53%	47%	53.74
3	23	5	0	31	0	0	31	28	53%	47%	53.66
4	5	9	0	17	0	0	17	14	55%	45%	52.58
5	25	10	0	53	0	1	53	35	60%	40%	49.39
6	9	3	2	31	1	1	32	14	68%	32%	48.91
TOTAL	68	31	2	145	1	2	146	101			

Comparing local and non-local obsidian at both sites by artifact form showed that local obsidian makes up the majority of obsidian bifaces and cores at both sites, though this pattern is more extreme at Bonneville Estates, where 97% of obsidian cores and 68% of obsidian bifaces were local, compared to 75% and 52% at Veratic (though note the extremely small sample size of cores at Veratic). Conversely, at Bonneville Estates the majority of bifacial points is made from non-local obsidian, while this is not the case at Veratic (Table 4.10). Very few expedient tools were found at either site, and those made of obsidian were 50% local at Bonneville Estates and 64% local at Veratic, again potentially reflecting the inherent lack of availability of nearby, quality obsidian at both sites, but especially at Bonneville Estates. Overall, similarities in preferences for local versus nonlocal obsidian throughout the Veratic record likely reflect the lower distances to "nonlocal" sources (~82-83 km) compared to Bonneville (118-142 km).

Table 4.10. Local vs. nonlocal obsidian by artifact class

	Veratic				Bonneville Estates			
	Local	Nonlocal	Local%	Nonlocal%	Local	Nonlocal	Local%	Nonlocal%
Biface	28	26	51.85%	48.15%	21	10	67.74%	32.26%
Core	3	1	75.00%	25.00%	28	1	96.55%	3.45%
Expedient	48	27	64.00%	36.00%	5	5	50.00%	50.00%
Point	56	42	57.14%	42.86%	0	1	0.00%	100.00%
Scraper	7	6	53.85%	46.15%	25	57	30.49%	69.51%

IV.6.3 Biface Stage

The stage of bifacial reduction, as indicated by relative differences in early- versus late-stage bifaces, is indicative of differences in degree of residential mobility, as shorter occupations will ultimately have a lower percentage of early-stage bifacial reduction, and raw materials from local sources are more likely to be used for early-stage manufacture. Like above, variability between components was measured using a two-tailed Fisher's exact test.

Of 261 analyzed bifaces from Bonneville Estates and 381 bifaces from Veratic, an analysis of biface stage revealed a predominance in final stage, hafted projectile points at both sites, 60% at Bonneville Estates (p = 0.0134) and 68% at Veratic (Table 4.11). A comparison of local vs. non-local obsidian based on early (stages 2 and 3) vs. late (stages 4 and 5) biface stage from both sites showed a significant preference for local obsidian for earlier-stage reduction at Bonneville Estates (p = 0.0027), but not at Veratic (p = 0.30), corresponding with the previous observation of local obsidian preference for cores and greater occurrence of local acquisition and early-stage processing of lithic material at Bonneville Estates. Also indicative of this trend, when taking into account raw-material preference, a greater proportion of late-stage bifaces at both sites was made from obsidian, with early-stage points made from greater percentages of CCS at Veratic and silicified siltstone at Bonneville Estates (Figure 4.7), both of which are presumed to have come from relatively local sources. Interestingly, CCS at Bonneville Estates did not follow this trend, despite its presumed local availability; nor does FGV.

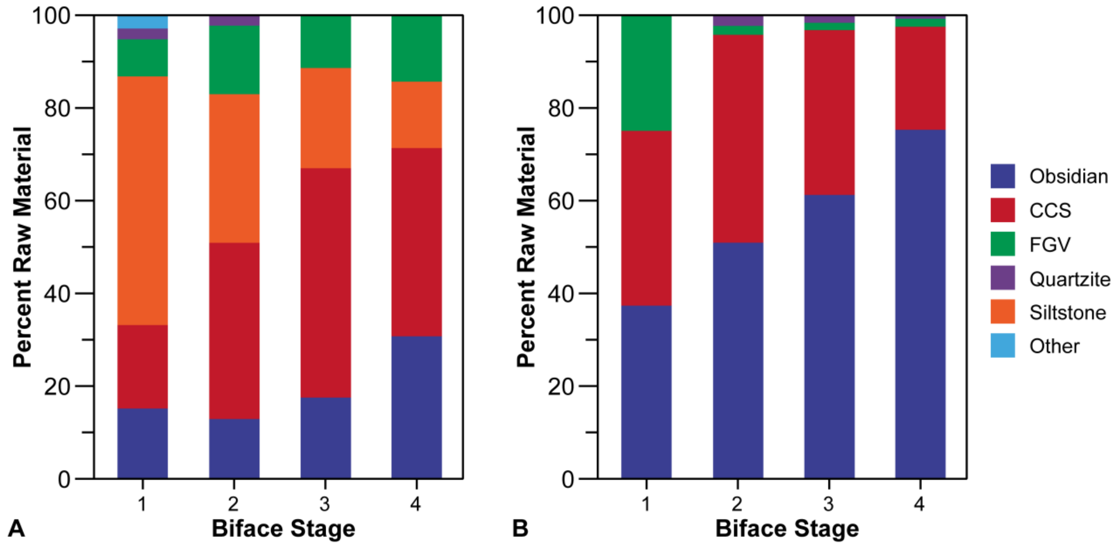

Figure 4.7. Raw-material preference by biface stage at A) Bonneville Estates and B) Veratic.

Table 4.11. Biface stage by component

Comp.	stage 2	stage 3	stage 4	stage 5	stage 2 %	stage 3 %	stage 4 %	stage 5 %
	Bonneville Estates							
1	0	2	5	14	0.00%	9.52%	23.81%	66.67%
2	2	7	11	28	4.17%	14.58%	22.92%	58.33%
3	2	9	29	78	1.69%	7.63%	24.58%	66.10%
4	0	8	16	57	0.00%	9.88%	19.75%	70.37%
5	5	16	44	152	2.30%	7.37%	20.28%	70.05%
6	0	5	19	52	0.00%	6.58%	25.00%	68.42%
total	9	47	124	381				
	Veratic							
	stage 2	stage 3	stage 4	stage 5	stage 2 %	stage 3 %	stage 4 %	stage 5 %
1	0	0	0	3	0.00%	0.00%	0.00%	100.00%
2	0	1	1	2	0.00%	25.00%	25.00%	50.00%
3	3	5	2	9	15.79%	26.32%	10.53%	47.37%
4	5	5	3	9	22.73%	22.73%	13.64%	40.91%
5	10	10	9	11	25.00%	25.00%	22.50%	27.50%
6	2	0	0	0	100.00%	0.00%	0.00%	0.00%
total	20	21	15	34				

At Bonneville Estates, there was significant variation in the percentage of final-stage bifaces over time compared to other stages (components 5-6 vs. 3-4, p = 0.05). At Veratic, however, the ratio between early- and later-stage biface reduction remained constant throughout the Holocene, with a perceptible increase in early-stage manufacture in component 2, but not statistically significant (p = 0.1146) (Figure 4.8, Table 4.11).

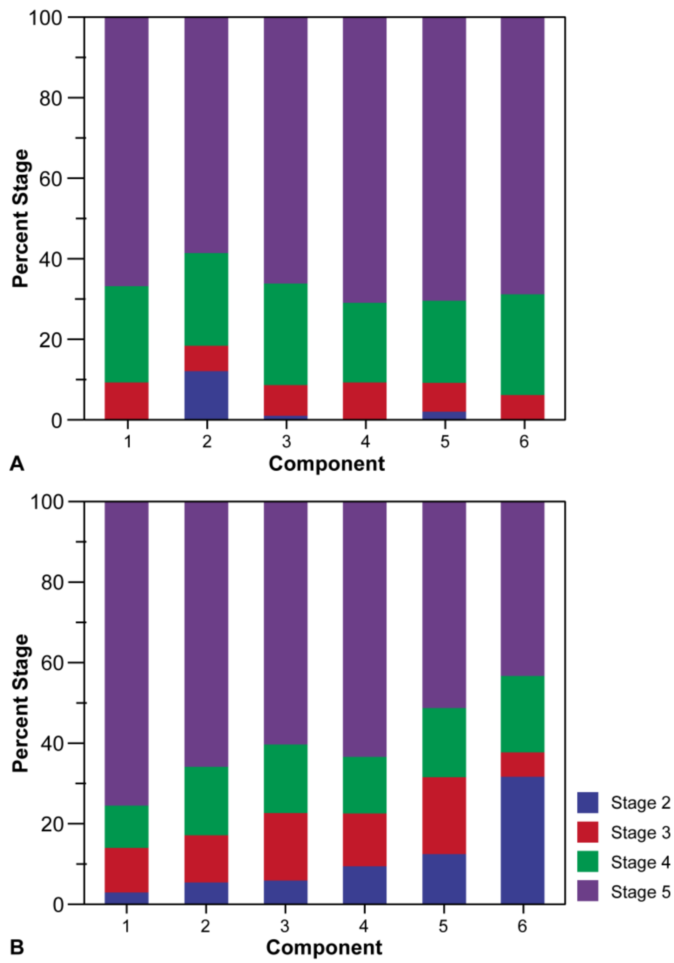

Figure 4.8. Andrefksy biface stage by component at A) Bonneville Estates and B) Veratic.

IV.6.4 Diversity

Diversity can be used as a measure of occupation span and range, with increased diversity of tool types reflecting decreased residential mobility due to an increase in the number of different site activities over the course of a longer occupation. Additionally, increased diversity in raw material, obsidian, and bifacial-point forms potentially reflects increased residential mobility, as a broader-ranging group would interact with a broader variety of raw materials and have more exchange with other groups. Confidence intervals for each component from each site are compared in Figure 4.9, with non-overlapping intervals considered to have a statistically significant difference in variability.

No significant differences were noted in diagnostic bifacial-point diversity between components at Bonneville. At Veratic, however, a significant increase in point form was noted at Veratic between components 5 and 4, indicating a greater variety of bifacial-point forms following the middle Holocene drought. A further nearly-significant increase in point diversity in component 1 at Veratic is most likely the result of surface and looter mixing of artifacts from multiple components. Differences in obsidian source diversity at Bonneville Estates also remained statistically insignificant over time, while at Veratic, a nearly significant increase in evenness of obsidian source preference occurred from component 6 compared to component 5, likely reflecting the increased percentages of the somewhat more distant Big Southern Butte and Bear Gulch obsidians compared to relatively nearby Walcott Tuff (Table 4.9). With both obsidian and bifacial-point diversity, it is not possible to identify a statistically significant difference between Bonneville Estates and Veratic Rockshelters.

Significant differences in raw-material diversity, however, are present between the two shelters. Raw material diversity at Bonneville Estates increases significantly between components 5 and 4, followed by significant decreases in components 3 and 2 (Figure 4.9). Furthermore, during middle Holocene components 5, 4, and possibly 3, raw-material diversity is significantly higher at Bonneville Estates than before. Veratic shows no significant change over time. Finally, there is no significant difference in diversity of basic tool forms (Table 4.2) through time or between sites, with the exception being component 6, within which Bonneville Estates had a significantly higher diversity of tool forms than at Veratic (Figure 4.9). This difference reflects greater numbers of expedient tools, cores, and scrapers at Bonneville, while at Veratic, component 6 has nearly double the percentage of expedient tools, decreasing tool-form evenness.

IV.6.5 Other Proxies

Increased percentages of core to bifaces are expected to correlate with longer occupation spans. Core/biface ratios generally increased through time at Bonneville Estates, especially during the late Holocene (components 1 and 2 combined vs. 3 and 4 combined, $p = 0.0024$) (Figure 4.10A), suggesting increasing occupation span during the late Holocene. A similar test on the Veratic assemblage was not conducted due to the extremely low number of cores at Veratic, the absence of which potentially indicates little change in this activity throughout Veratic's record.

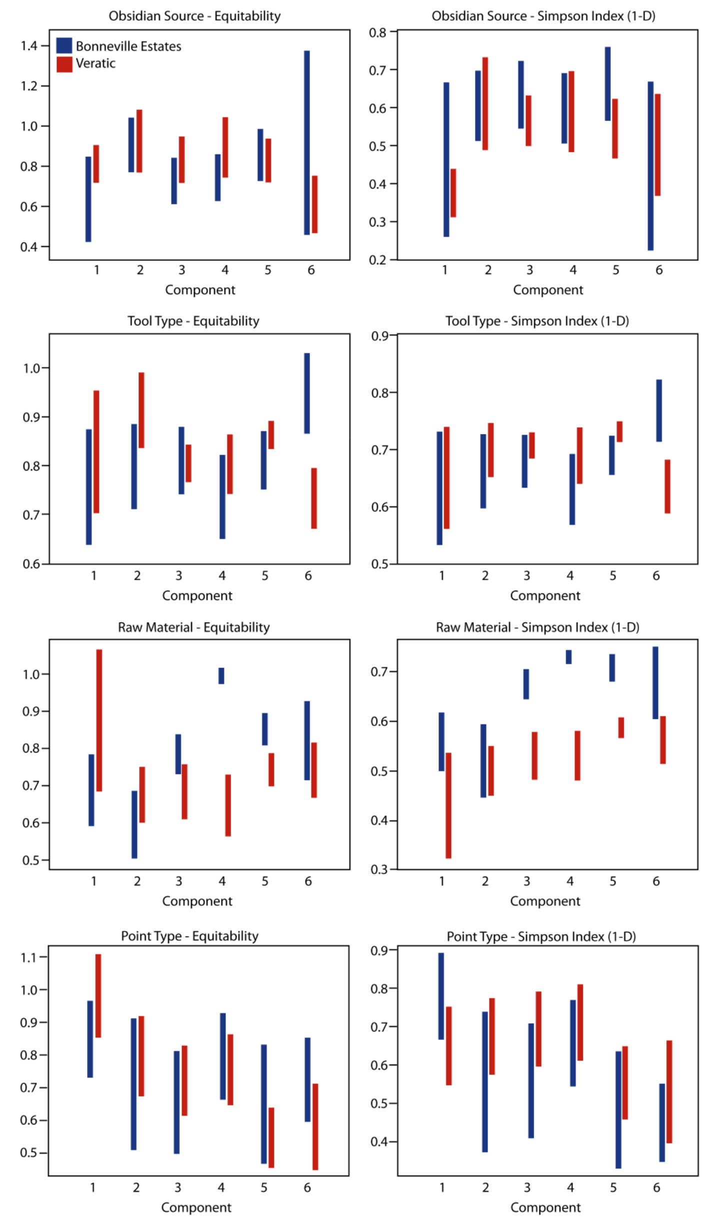

Figure 4.9. Diversity of obsidian source, tool type, raw material, and point type by site, based on Simpson and Equitability indices with 95% confidence intervals shown.

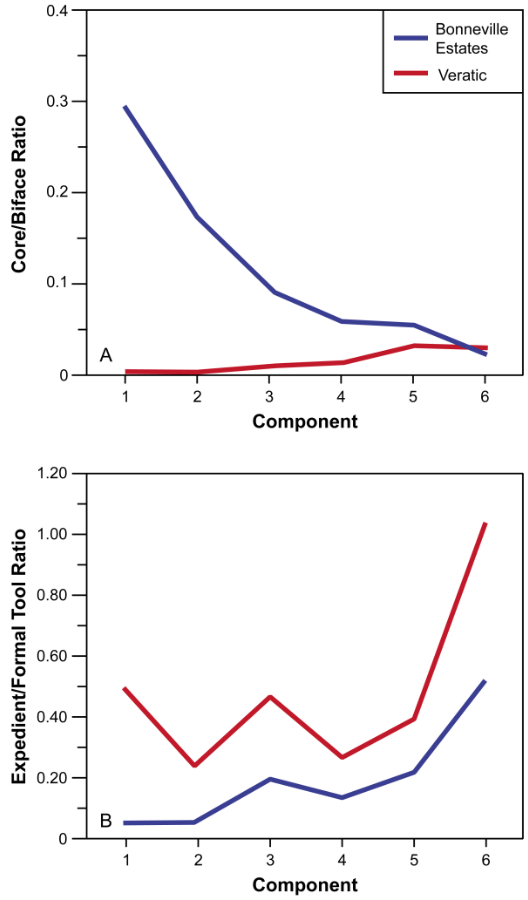

Figure 4.10. Ratios of A) core/biface (incudes points) and B) expedient/formal tools.

Expedient tools are normally expected to increase during periods of longer occupation span and reduced residential mobility. However, the ratio of expedient to formal tools (Figure 4.10B) at both sites actually runs counter to this prediction based on patterns of mobility shown in previous analyses. Both sites show very similar trends, though the trend at Veratic is more dramatic (possibly related to lower raw-material availability). Both sites show a high ratio of expedient to formal tools during the early Holocene, followed by a drop in the middle Holocene (components 4 and 5) (BER, $p = 0.05$; Veratic, $p = 0.0001$), a smaller increase at the beginning of the late Holocene (component 3) (BER, p = 0.442; Veratic, p = 0.0395), and then a continued decline in component 2 (BER, p = 0.0201; Veratic, p = 0.0611).

IV.7 Discussion

A comparison of the paleoclimatic records of the Bonneville Basin and Snake River Plain showed a similar timing of transitions to the early-middle Holocene drought, the late-middle Holocene period of amelioration, and the late Holocene period of cooling, though the intensity of said trends and their effects on local environments varied between the two regions. While the Snake River Plain was covered in sagebrush steppe continuously throughout the Holocene, with largely consistent populations of bison and other artiodactyls, the Bonneville Basin fluctuated between sagebrush steppe and more barren Cheno-am ecological zones over time, with increased extirpation of plant and animal species in isolated cooler/wetter "islands" as a result of its basin-range topography. Furthermore, differences in climate based on latitude may have also brought consistently high precipitation and cool temperatures to areas north of ~40° latitude. To see if and how these climatic trends related to variable degrees of settlement and change in technological organization, lithic assemblages from similar time periods at Bonneville Estates and Veratic Rockshelters were compared to analyze changes in duration of occupation though time, and how these changes related to paleoclimatic trends. The focus of these analyses was on changes through time in raw-material preference (including obsidian preference), biface stage, formal vs. expedient tool production, core vs. biface production, and obsidian-source and bifacial point richness.

IV.7.1 Raw-material Availability and Effect on the Archaeological Record

Raw material availability for each region had a direct effect on lithic procurement strategies at each site, explaining absolute differences in raw material preferences between the two sites. *Differences* in available lithic material are apparent between Bonneville Estates and Veratic rockshelters, with a greater availability of useable obsidian at Veratic when compared to Bonneville Estates. This is most easily demonstrated by differences in the ratio of expedient to formal tools at both sites, which shows a distinctly lower ratio at Bonneville Estates, despite showing very similar diachronic trends (Figure 4.10B). Additionally, the lithic assemblage at Veratic indicates a high proportion of points from local obsidian sources (57%), compared to 30% local at Bonneville Estates. This is potentially related to the consideration that the ~83 km needed to travel to the other obsidian sources in the area around Veratic may have fallen within the range of a logistic foray and therefore may not have produced the same results as at Bonneville Estates, where alternative sources were much more distant (at least 118 km away). Due to the small package size of local Ferguson Wash obsidian, Topaz Mountain and Browns Bench were nearly as frequently used as Ferguson Wash at Bonneville Estates, despite being 118 and 142 km away, respectively. As a result, occupants of Bonneville Estates seem to have relied more heavily on local non-obsidian sources than at Veratic, including CCS (especially those materials resembling siltstone) and FGV, though their precise sources remain undetermined. While a higher proportion of points was made from obsidian compared to bifaces and other tools at Bonneville, suggesting a preference for obsidian when making points, CCS was the most commonly used toolstone, most likely due to the constraints posed by the obsidian source distance and distribution. However, 75% of obsidian points were made from non-local obsidian, confirming the prediction that points would have been made predominantly on non-local materials (Brantingham 2003).

IV.7.2 Diachronic Change

IV.7.2.1 Component 6 (13-9.5k cal B.P.). It is difficult to fully understand the extent of change during this period with the current assemblages, despite its lasting over 3000 years, because lithic materials from component 6 at Bonneville Estates are so sparse, and Component 6 at Veratic likely dates to the very end of this period. This makes it impossible to track any significant changes during the terminal Pleistocene/early Holocene transition, despite significant paleoclimatic change following the onset of the Younger Dryas. There is a lower percentage of bifaces and points than later components at both sites, but a higher percentage of expedient tools and scrapers (much higher at Veratic), suggesting a possible decreased degree of re-use and recycling during this period, as suggested for this period by Madsen et al. (2015a). The relative ratios of obsidian to CCS at Veratic are roughly similar to most other time periods, with the exception of component 5. Component 6 at Bonneville Estates, however, is dominated by FGV and CCS, with relatively little obsidian (65% non-local) and argillite.

IV.7.2.2 Component 5 (6.5-8.2k cal B.P.). The timing of this component corresponds to the maximum aridity of the Middle Holocene, and both sites show an apparent reaction to this episode with a decrease in expedient/formal tool ratio and an increase in the use of lower quality, non-obsidian raw materials, indicating a significant increase in occupation span over the Paleoindian period (see also Goebel 2007 for Bonneville Estates). Both adopt groundstone technology during this time, also indicative of an increased processing of lower-ranked resources such as seeds or underground storage organs. In addition, there is a sudden increase in sage grouse remains at Veratic, but a much lower percentage of grouse and rabbits at Bonneville compared to component 6, though this may reflect a potentially older habitation of Bonneville Estates during component 6 compared to Veratic. The change in raw material preference at Bonneville is more complex than at Veratic, with an increase in argillite, and a decrease in FGV and CCS. This is reflected by an increase in raw material diversity at Bonneville during this time that continues through the subsequent component 4, potentially reflecting a greater reaction to increased middle Holocene patchiness in the Bonneville Basin. Though the exact distance to FGV and CCS sources is not presently known, Argillite is presumed to be local based on raw material surveys of the area coupled with the significantly larger percentage of early stage bifaces and expedient tools compared with other raw materials. Finally, the percentage of later stage bifaces at Bonneville Estates may begin to increase at this time, with a more significant increase in later components, while biface stage at Veratic shows no apparent change,

IV.7.2.3 Component 4 (6.1k-4.1k cal B.P.). During this time, Holocene climate alleviates from the extreme aridity and temperatures of the early Middle Holocene, and is considered a transitionary period to the Late Holocene. This transitionary period corresponds with an increase in the use of obsidian at Bonneville Estates and a return to Early Holocene values of obsidian to CCS ratio at Veratic, suggesting, to some extent, an increase in the use of non-local materials and an increase in residential mobility. However, seemingly counter to this, there is a continued increase in the ratio of late- to early-stage bifaces at Bonneville Estates and a continued decrease in the percentage of expedient tools at both sites. Bonneville Estates also continues to have a greater diversity of raw-material types during this time compared to Veratic. Further, though the percentage of obsidian increases at Bonneville Estates, the amount of local Fergusons Wash obsidian also increases, and the use of argillite, though slightly lower, remains high, suggesting that perhaps residential mobility remained low, especially in the Bonneville Basin, during this period.

IV.7.2.4 Component 3 (4.1-1.7k cal B.P.). Corresponding with the onset of the increased moisture and decreased temperatures of the early Late Holocene, this component also overlaps with the "Late Holocene Drought" between ~2.65-1.65k cal B.P. in the Great Basin (Mensing et al. 2013). At Bonneville Estates, expedient tools increase, though not significantly, and there is a significant increase in CCS, but decrease in FGV. This change in raw material marks the beginning of an extreme change in raw material preference at Bonneville, where CCS becomes dominant in the assemblage, though how this applies to changes in climate or mobility is unknown at this time because its exact source cannot be identified.

While raw material ratios and average distance to obsidian source stays relatively stable at Veratic, the percentage of expedient tools goes up significantly, especially compared to finished points. This suggests a possible decrease in occupation span potentially relating to an apparent increase in bison hunting at Veratic. The percentage of Bear Gulch obsidian to the east also increases while Big Southern Butte obsidian drop out almost completely, suggesting populations at the time were less likely to visit the open plain to the south during this time. It is possible that the late Holocene drought that occurred during this period affected the Bonneville Basin by limiting the overall cooling during this period, while the upper Snake River Plain to the north remained cool and wet (Mensing et al. 2013).

IV.7.2.5 Component 2 (1.7-0.8k cal B.P.). This component corresponds to the Medieval Climatic Anomaly, an episode marked by a switch from winter to summer precipitation. At Bonneville Estates, argillite drops significantly, coupled with a continued increase in CCS, though again it is unclear what is affecting this change. The core/biface ratio at Bonneville Estates increases as well, further indicating a decrease in residential mobility. Both sites show a significant drop in expedient/formal tool ratios, suggesting a possible decrease in mobility, though no other patterns are noticeable at Veratic. It is also interesting to note at Veratic the return of Big Southern Butte obsidian during this period and relative decrease in Bear Gulch obsidian.

IV.7.2.6 Component 1 (post-0.8k cal B.P.). Dates for component 1 assemblages at both sites overlap with the Little Ice Age and the historic period (600+ cal B.P.). Artifacts from the upper-most components at both sites are sparse, and are likely to include out of context surface and near-surface artifacts and potential looter disturbance. Despite this, at Bonneville Estates, core/biface ratio continues to increase, as does percentage of local obsidian, suggesting a continued trend of decreased residential mobility, while at Veratic no significant trends are visible.

IV.8 Conclusions

Both Bonneville Estates and Veratic Rockshelters show trends indicating relatively higher residential mobility during the TP/EH compared to a significant decrease in residential mobility following the transition to the middle Holocene. Populations in both locations adapted to increased aridity and temperatures by increasing occupation span and utilizing lower-ranked resources within a smaller area. Similar trends are seen in the Bonneville Basin at the Old River Bed Delta (Madsen et al. 2015a), as well as in the northwestern Great Basin (Smith 2011). XRF studies from the Snake River Plain also show a similar trend, with conveyance zones shrinking during the middle Holocene (Fowler 2014; Marler 2009) and movement of groups away from quickly drying wetlands to lower-ranked riparian and sagebrush steppe sites (Long 2007). This dry period was followed by a return to mesic conditions at the beginning of the late Holocene, at which time assemblages from Bonneville Estates and Veratic rockshelters indicate a temporary return to somewhat increased residential mobility, followed by a return to increasingly lower residential mobility over time, though this pattern is more apparent in the eastern Bonneville Basin.

Despite these similarities, other results show differences in raw-material availability and possibly environmental productivity between the Bonneville Basin and the upper Snake River Plain. Raw-material is likely a factor affecting some of these differences, as the lack of quality obsidian within 140 km of Bonneville Estates compelled its occupants to use less obsidian from much further away and more, lower-quality but locally available lithic material. This affected stages of manufacture and formal versus informal tool ratios compared with the relative availability of obsidian nearby Veratic.

Other differences, however, cannot be accounted for simply by raw lithic material availability. Faunal records from both sites indicate that at Bonneville Estates, TP/EH populations were utilizing a disproportionately large amount of small game compared to artiodactyls (Hockett 2015), and hunted bison to the same extent as Veratic during the Late Holocene. While timing and direction of mobility change roughly matched in the lithic assemblage between Bonneville Estates and Veratic rockshelters, the intensity of this change appears much more extreme at Bonneville Estates, with drastic changes in raw-material preference for each component (Figure 4.5) throughout the Holocene. These changes are particularly significant with some material classes such as CCS and FGV where exact source location is unknown. Overall, this is reflected by a significantly higher raw-material diversity during this time at Bonneville Estates which is not seen at Veratic. This may reflect a greater degree of adaptation to shifting resource patches in the Bonneville Basin, affecting embedded procurement of lithic resources. Decreases in residential mobility during components 2 and 1 during the late Holocene at Bonneville Estates are less apparent, or not visible at all, at Veratic.

Interestingly, both sites showed similar patterns of change in ratios of formal to expedient tools mirroring the trend observed at the Old River Bed Delta (Madsen et al. 2015a), but conflicting with a basic assumption that expedient tools should decrease with decreased mobility (Andrefsky 1994, 2005) during the arid early-middle Holocene. Decreases in early-stage bifaces and increases in local, lower-quality raw materials at both sites correspond with a significant decrease in the ratio of expedient to formal tools. This may be related to the non-local (>20 km) availability of high quality raw-materials at both sites, resulting in increased recycling and re-use of available materials.

What is the cause of these differences in intensity of technological and subsistence change between these two sites? Munoz (2010) and others (deMenocal 2001; Zhang et al. 2011) argue that climatic changes have drastic effects on human populations, resulting in crises that effect significant changes in population, technology, and subsistence practices. The more diachronically variable lithic record at Bonneville Estates may be a product of the harsher conditions that prehistoric populations living in the Bonneville Basin would have faced. In addition to the Snake River Plain being cooler and wetter during the late Holocene (Mensing et al. 2013), occupants of Veratic Rockshelter throughout the Holocene lived at a higher elevation and had better access to lithic raw-materials, regularly flowing streams and rivers, and increased and potentially continuous bison populations (Breslawski and Byers 2014; Henrikson and Montana

2007). Though changes did occur in the Veratic lithic assemblage, these changes were not as apparently extreme, which potentially indicates that these populations were under less ecological stress, and thus less prone to population crashes and other ecological crises. Agriculture, which was present in the Bonneville Basin during the Fremont period but not the Snake River Plain (Plew 2000), had the potential to affect Bonneville Estate components 1 and 2. However, the lack of a significant change from component 3 to 2 and the lack of significant cultivated remains at the site suggests such influence on the lithic record was minimal.

Despite these trends, this analysis is limited by a focus on only two sites using relatively small components of the total material culture records at each site. These results are also limited by the relatively sparse dating at Veratic, and the as yet unidentified exact sources of non-obsidian raw materials at both sites. To further investigate these diachronic trends in cultural adaptation to paleoclimate in the Snake River Plain also requires more, higher resolution climatic proxy records.

CHAPTER V

CONCLUSIONS*

The previous chapters cover a series of diverse yet related topics relating to: 1) geochronological context and site formation; 2) diachronic variation in lithic technological organization, raw material procurement, and projectile point typology; and 3) the relationship between this variation and paleoecological and geographic variation. Data used to explore these topics are drawn from three buried and stratified multi-layered archaeological sites in Idaho and Nevada – Pioneer, Veratic Rockshelter, and Bonneville Estates Rockshelter. In Chapter II, an analysis of the site formation processes at Pioneer, in addition to providing the ages of archeological and stratigraphic components at the site, refines the terrace formation history of the Big Lost River and potentially links a recorded flood event observed at Pioneer with volcanic activity at the beginning of the Late Holocene. Chapter III provides new dates and an analysis of diagnostic projectile points at Veratic Rockshelter, the results of which redefine the age ranges of certain diagnostic projectile point styles for the Snake River Plain, as well as identify trends in projectile point diversity throughout the Holocene. Finally, in Chapter IV, analytical results show broadly similar trends throughout the Holocene in climate and lithic technology between the Snake River Plain, but with some differences between

*Parts of this chapter are reprinted with permission from: 1) “Geochronology and Geomorphology of the Pioneer Archaeological Site (10BT676), Upper Snake River Plain, Idaho” by Joshua L. Keene, 2016. *Geoarchaeology: An International Journal* 31(4):282-303, Copyright 2016 by John Wiley and Sons, and 2) “A Diachronic Perspective on Projectile Point Morphology from Veratic Rockshelter, Idaho” by Joshua L. Keene, (available online May 2016). *Quaternary International*, Copyright 2016 by Cambridge University Press.

technological organization, paleoecological variation, and the extent of ecological "crises" affecting human populations.

V.1 Pioneer Site Formation

Like many rivers in the Intermountain West, the Big Lost River of eastern Idaho during the Holocene traditionally has been characterized as very low energy (Nace et al. 1956; Nace et al. 1975). It flows seasonally through remnant Pleistocene-aged channels toward the Big Lost River Sinks on the current-day Idaho National Laboratory, assuming little to no significant deposition during the Holocene (Nace et al. 1956; Nace et al. 1975). However, recent work by Ostenaa and O'Connell (2005) as well as the results in Chapter II show a much more complex and dynamic history. Excavation of the Pioneer archaeological site provides evidence of multiple cultural occupations spanning from 3800 cal B.P. to the Protohistoric, making it one of a handful of open-air, stratified multi-component sites known in the arid Intermountain West. Site stratigraphy consisted of multiple episodes of fine-grained alluvial deposition and soil formation beginning ~7200 cal B.P., with at least four periods of stability and soil formation, though more may have been truncated by a flood event ~3800 cal B.P. as indicated by a surface of large rounded cobbles truncating older stratigraphic layers. Archaeological deposits at the site indicate habitation beginning in the mid-late Holocene transition. The earliest component dates to ~3800 cal B.P. and consists of limited lithic scatter and faunal remains associated with "Beaverhead" style dart point preforms. Multiple later components date to ~600-750 cal B.P. and consist of hearth features, faunal remains, and extensive obsidian lithic reduction debris, with associated Desert Side Notched, Cottonwood, Rosegate, Avonlea, and Elko point forms.

In addition to providing a cultural record, the sedimentary record at Pioneer provides some insight into the paleoclimatic history of southeastern Idaho and the greater Intermountain West from the early-middle Holocene transition ~7200 cal yr B.P. to the historic period. While evidence for early-middle Holocene climate variation is scant with the present sample, radiocarbon data presented here and by Ostenaa and colleagues (Ostenaa 2002; Ostenaa and O'Connell 2005) indicate a period of increased deposition between ~8400-6500 cal yr B.P., potentially correlating with a possible cooling interval during the middle Holocene between 8100-6700 cal yr B.P. based on data from Grey's Lake (Beiswenger 1991). There were subsequent periods of deposition and soil formation between 6500-3800 cal yr B.P., though the exact age and extent of these events are unknown at this time. There is minimal deposition during much of the late Holocene between ~3800 cal yr B.P. and ~750 cal yr B.P. at Pioneer, though elsewhere along the Big Lost River, deposition increases around ~2700 cal yr B.P., correlating roughly with wetter climatic conditions generally thought to have occurred coincident with the beginning of the late Holocene (Beiswenger 1991; Bright 1966; Bright and Davis 1982; Henrikson 2003). More recent deposition at Pioneer, corresponding with similar periods of deposition downstream (Ostenaa et al. 2002; Ostenaa and O'Connell 2005), and limited evidence of post-1000 cal yr B.P. re-filling of Lake Terreton (Bright and Davis 1982; Forman 1997) indicate a period of cooler and wetter climate in the region between 750-630 cal yr B.P., potentially coinciding with the early onset of the Medieval Climatic Anomaly.

In addition to providing geochronological context to archaeological components at Pioneer, this study provides clear signs of multiple episodes of terrace formation and erosion during the Pleistocene and through much of the Holocene along the Big Lost River, including evidence for flash floods during the middle-late Holocene triggered by intense precipitation and rapid snow melt, possibly linked to volcanic activity. The thick deposits of fine-grained overbank flood alluvium preserved at Pioneer and along the Big Lost River channel provide a valuable opportunity for future studies to find and excavate preserved, stratified sub-surface human occupation surfaces dating to the Holocene and possibly even terminal Pleistocene in an arid environment otherwise dominated by surface palimpsest sites. This has implications for other river systems in southern Idaho, where similar periods of alluvial deposition during the Holocene could have also preserved archaeological sites.

V.2 Veratic Geochronology and Projectile Point Typology

Veratic Rockshelter, located in the Birch Creek Valley on the northern border of the Snake River Plain, was initially excavated by Earl Swanson in 1961, producing over a thousand stone tools from stratified contexts, including hundreds of diagnostic projectile points ranging from the late Paleoindian to the late prehistoric period from 13 cultural horizons. Chapter III provides a new evaluation of the geochronology of the site using 18 new AMS radiocarbon dates acquired from charcoal features sampled during the original excavation. These new ages are then compared with metric analyses of diagnostic projectile points from the existing assemblage to examine diachronic variability and morphological discreteness in this artifact class to tie them to existing Snake River Plain and Intermountain West projectile-point typologies as well as answer questions about late Paleoindian and Archaic spear- and dart-point variability.

The updated projectile point typology emphasizes the importance of metric projectile-point variability in typology building, and the necessity for considering regional variation within the Great Basin when constructing these typologies. For example, the Elko short chronology (O'Connell, 1967; Bettinger and Taylor, 1974; Heizer and Hester, 1978; Thomas, 1981; Elston and Budy, 1990) may be valid in some regions of the Great Basin, but it does not necessarily apply to the Intermountain West as a whole. It is also useful to apply quantitative morphological attributes to projectile-point differentiation whenever possible to establish whether proposed point forms represent actual, discrete phenomena. Veratic has provided the rare opportunity to study a large assemblage of diagnostic points across a long interval of time, so that diachronic variation in projectile-point morphology as well as relative changes in point-form frequencies could be measured. Results of this study of the Veratic assemblage indicate that: 1) not only do WST points at Veratic date to significantly later than previously thought, but they have a relatively broad spectrum of morphological variability and may represent multiple separate point forms; 2) early (~6000 cal B.P.) corner notched dart points are distinct from Northern Side Notched points, supporting the concept of an Elko "long chronology," which may include two separate, morphologically distinct notched dart point forms on the Snake River Plain; and 3) several distinct varieties of dart points coincided during the middle Holocene (~6000-4200), including Elko Corner Notched and Eared, Northern Side Notched, Stemmed Indented Base (including Gatecliff and possibly Pinto forms), Humboldt, and Salmon River points, all of which were replaced with a single variety of Elko Corner Notched point at the beginning of the Late Holocene.

Another critical feature of this study has been the application of new methods to re-analyze and re-date a museum collection without renewing excavations. Despite being excavated more than 50 years ago, Swanson's use of stratigraphic excavation and site recording techniques made the current study possible. Thus, by applying current methods of chronological hygiene and morphometric projectile-point analysis to the existing assemblage, it was possible to better understand diachronic technological variability of the upper Snake River Plain and greater Intermountain West.

V.3 Comparison of Bonneville Estates and Veratic Rockshelters

The updated geochronology of Veratic Rockshelter (Chapter III), combined with the extensive AMS dating and careful excavation of archaeological components at Bonneville Estates Rockshelter (Albush 2010; Goebel et al. 2007; Graf 2007; Hockett 2015; Smith et al. 2013b) allowed for the in-depth comparison of the two sites in Chapter IV. Both Bonneville Estates and Veratic rockshelters show trends indicating increased residential mobility during the terminal Pleistocene/early Holocene (TP/EH), with a significant decrease in residential mobility following the transition to the middle

Holocene. Populations in both locations adapted to increased aridity and temperatures by increasing occupation span and utilizing lower-ranked resources within a smaller area. Similar trends are seen in the Bonneville Basin at the Old River Bed Delta (Madsen et al. 2015a), as well as in the northwestern Great Basin (Smith 2011). XRF studies from the Snake River Plain also show a similar trend, with conveyance zones shrinking during the middle Holocene (Fowler 2014; Marler 2009) and movement of groups away from quickly drying wetlands to lower ranked riparian and sagebrush steppe sites (Long 2007). This dry period was followed by a return to mesic conditions at the beginning of the late Holocene, at which time assemblages from Bonneville Estates and Veratic rockshelters indicate a temporary return to somewhat increased residential mobility, followed by a return to increasingly lower residential mobility over time, though this pattern is more apparent in the eastern Bonneville Basin.

Despite these similarities, other results show differences in raw-material availability and possibly environmental productivity between the Bonneville Basin and the upper Snake River Plain. Raw material is likely a factor affecting some of these differences, as the lack of quality obsidian within 140 km of Bonneville Estates compelled its occupants to use less obsidian from much further away and more, lower-quality but locally available lithic material. This affected stages of manufacture and formal versus informal tool ratios compared with the relative availability of obsidian nearby Veratic.

Other differences, however, cannot be accounted for simply by raw lithic material availability. Faunal records from both sites indicate that at Bonneville Estates, TP/EH populations utilized a disproportionately large amount of small game compared to artiodactyls (Hockett 2015), and they hunted bison to the same extent as Veratic during the late Holocene. While timing and direction of change in mobility inferred from the lithic assemblages roughly match between Bonneville Estates and Veratic rockshelters, the intensity of this change appears much more extreme at Bonneville Estates, with drastic changes in raw-material preference for each component throughout the Holocene. These changes are particularly extreme with some material classes such as cryptocrystalline silicate and fine-grained volcanics where exact source location is unknown. Overall, this is reflected by significantly higher raw material diversity at Bonneville Estates, a pattern not seen at Veratic. It is not clear what factors are affecting such changes as they do not correlate with changes in local/nonlocal preference for other materials. They may reflect a greater degree of adaptation to shifting resource patches in the Bonneville Basin, affecting embedded procurement of lithic resources. Inferred decreases in residential mobility during the late Holocene at Bonneville Estates are less apparent, or not visible at all at Veratic.

Interestingly, both Bonneville Estates and Veratic showed similar patterns of change in ratios of formal to expedient tools, mirroring the trend observed at the Old River Bed Delta (Madsen et al. 2015a), but conflicting with a basic assumption that expedient tools should increase with decreased mobility (Andrefsky 1994, 2005) during the arid early-middle Holocene. Decreases in early-stage bifaces and increases in use of local, lower-quality raw materials at both sites correspond with a significant decrease in the ratio of expedient to formal tools. This may be related to the non-local (>20 km) availability of high quality raw materials at both sites, resulting in increased recycling and re-use of available materials.

What is the cause of these differences in intensity of technological and subsistence change between these two sites? Munoz (2010) and others (deMenocal 2001; Zhang et al. 2011) argue that climatic changes have drastic effects on human populations, resulting in crises that effect significant changes in population, technology, and subsistence practices. The more diachronically variable lithic record at Bonneville Estates may be a product of the harsher conditions that prehistoric populations living in the Bonneville Basin would have faced. In addition to the Snake River Plain being cooler and wetter during the late Holocene (Mensing et al. 2013), occupants of Veratic Rockshelter throughout the Holocene lived at a higher elevation and had better access to lithic raw materials, regularly flowing streams and rivers, and increased and potentially continuous bison populations (Breslawski and Byers 2014; Henrikson and Montana 2007). Though changes did occur in the Veratic lithic assemblage, these changes appear to have been much less extreme, potentially indicating that these populations were under less ecological stress, and thus less prone to population crashes and other ecological crises.

V.4 Future Studies

Though currently providing the primary source of paleoclimatic data for the upper Snake River region, much of the existing lake-core pollen record for the upper Snake River Plain is becoming increasingly outmoded or is from the neighboring

Bonneville Basin or mountain ranges to the south (Beiswenger 1991; Bright 1966; Bright and Davis 1982; Davis et al. 1986; Doner 2009), necessitating the need for new well-dated high-resolution proxy records for the Plain itself. Locally derived packrat middens and pollen cores would significantly further studies of diachronic and interregional variation of past climate and human subsistence change.

Moreover, future geoarchaeological testing is required along the Big Lost River to fully assess the archaeological and paleoclimatic potential of its Holocene-aged terraces as well as to test the hypothesis that an “older flood” event affected the area during the middle-late Holocene, and what may have been its cause. Although alluvial-climate relationships are complex, geomorphological alluvial terrace testing can be used in arid environments across the Intermountain West to identify intact, open-air subsurface archaeological sites and better understand Holocene climate fluctuations. Comparitave studies are needed to determine whether patterns documented here are local or regional in scale, and represent specifica geological events or climate trends.

Though many rockshelters in the Intermountain West have complex or disturbed stratigraphy, revisiting rockshelter sites to update their geochronology is an important way to better understand paleoecology, typology, and technological organization of the upper Snake River Plain and Great Basin to the south. Re-examination of Veratic and other rockshelters along Birch Creek are warrented. Though new data were available through existing collections (Chapter III), few datable charcoal samples still exist in the collection, especially from the Paleoindian component, and those that do are now more than 50 years old. More dates and a new sample of artifacts is needed not only accommodate for the numerous debitage and bone pieces discarded by the original excavators, but also to determine whether internal ordering of stemmed-point forms occurs in layer 30's sub-strata. Layer 25 is of similar interest, because it represents a decline in Archaic dart-point variability sometime between 4800-3100 cal B.P, though this layer has yet to be directly dated. Thus, by applying current methods of chronological hygiene and morphometric projectile-point analysis to the existing Veratic assemblage, we can better understand diachronic technological variability of the upper Snake River Plain and greater Intermountain West; however, with renewed excavations we can do so much more.

Finally, continued studies of large scale, inter-regional diachronic change will provide a better understanding of the scope of prehistoric hunter-gatherer adaptations to raw material and ecological constraints. Despite the differential trends seen between Veratic and Bonneville Estates rockshelters in Chapter IV, this analysis was limited by a focus on only two sites using relatively small components of the total material culture records at each site because debitage was not saved at Veratic. These results are also limited by the relatively sparse dating at Veratic, and the as yet unidentified sources of non-obsidian raw materials at both sites. Further investigation of these diachronic trends in cultural adaptation in the Snake River Plain also will require higher resolution proxy records of paleoclimate.

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APPENDIX A VERATIC ROCKSHELTER STRATIGRAPHY*

The following is a summary of stratigraphic designations for Veratic Rockshelter with brief descriptions of sediments, how they were thought to have formed, their distribution across the site, and ages and cultural affiliations originally provided by Swanson (1972). These are then compared with newly acquired AMS radiocarbon dates to provide an age estimate for each layer. Refer to Figure 3 in the original article for a representative stratigraphic profile.

Layers 32-31 consist of stream-bed deposits left when Birch Creek originally flowed against the cliff face forming the back wall of the shelter. Layer 32 was only exposed in limited sections of the original excavations and contains stream-bed or bar deposits with large rounded cobbles. Layer 31 is part of a fining-upward sequence of gray, massive sandy loam deposited by overbank flood deposits. Though not directly dated, these layers were estimated by Swanson to have formed between ~13,000-12,000 ^{14}C B.P. based on similar deposits at Bison located below a deposit of tephra (Bison levels 32c-32d) identified by Powers and Wilcox as Glacier Peak B ash (Powers and Wilcox, 1964). This age estimate is also supported by a single shell-date from the Shoup site of 12,410 ± 115 ^{14}C B.P. (15,046-14,103 cal B.P.) (WSU-416 (Swanson and Sneed 1966)) from deposits presumed to have formed under similar climatic conditions, though this date is unreliable. While these layers at Veratic are largely devoid of artifacts, two

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bifacial preforms and one modified flake were recovered, though they may have drifted down from higher layers or were recovered from the contact between layers 31 and 30. One new accepted date on charcoal from near the top of layer 31 provides an age of 8850 ± 40 (10,160-9760 cal B.P.).

Based on these data, layer 32 potentially began forming prior to 13,710-13,410 cal B.P. based on current ages for "Glacier Peak B" ash (Kuehn et al. 2009) which was presumably present between levels 31 and 32 (Swanson 1972). However, the tephra at Veratic was never tested, and its Glacier Peak B designation is based on stratigraphic correlation with tephra analyzed from Bison (Powers 1964) that has not been recently confirmed. A single new AMS radiocarbon date of 10160-9760 cal B.P. provides an upper limiting date for the surface of layer 31.

Layer 30 is a light brownish-grey, massive gravelly loam. It was further subdivided into layers 30a-30c by Swanson based on differing gravel size, though artifacts were not consistently attributed to these sub-horizons. These angular gravels ("Fan Gravel I") and sediments likely were deposited by gradual alluvial-fan deposition and are topped by very large boulders as part of the "Rock Fall I" event that impeded excavation of portions of this layer. Layer 30 is the deepest confirmed cultural component at Veratic and contains a large concentration of Paleoarchaic-style western Stemmed spear points and other artifacts. This layer was not directly dated by Swanson, who instead provided a correlative date from Bison Rockshelter of 10,340 ± 830 ^{14}C B.P. (13787-9598 cal B.P.), though this indirect association and the extremely large standard deviation makes this age highly suspect. A single new AMS radiocarbon date was acquired from this layer dated to 8515 ± 25 ^{14}C B.P. (9537-9485 cal B.P.), which most likely reflects the actual age of this occupation, and has a lower bracketing age of 10,160-9760 cal B.P. from the surface of the underlying layer 31, making this layer ~2000 years younger than previously assumed. While the deepest component at Bison may still pre-date this age, no samples from a confirmed stratigraphic context were available to date this horizon.

Layer F6 is a layer originally thought to be a feature that lies between layers 30 and 29 consisting of pale-brown to white fine sand to fine sandy loam intermixed with large amounts of Mazama tephra. Dense cultural deposits containing early-middle Holocene dart-point forms are intermixed with Mazama ash, suggesting the occupation occurred shortly before or shortly after the eruption, and that artifacts were potentially mixed into the ash by trampling. Swanson acquired two dates from this layer of 6030 ± 190 ^{14}C B.P. (7313-6446 cal B.P.) and 6282 ± 229 ^{14}C B.P. (7589-6653 cal B.P.), which post-dates the current date for the Mazama eruption (7777-7477 cal B.P. (Zdanowicz et al.1999)) by hundreds of years. Two new AMS dates from this layer provide ages of 6965 ± 25 ^{14}C B.P. (7855-7706 cal B.P.) and 7300 ± 40 ^{14}C B.P. (8180-8020 cal B.P.) roughly matching or slightly pre-dating the Mazama eruption. This cultural horizon clearly dates to the Mazama eruption, and is intermixed with artifacts and hearth features suggesting humans were occupying the shelter directly after and potentially just before the eruption between ~8200-7400 cal B.P.

Layer 29 is a light greyish-brown, gravelly loam formed from a combination of fan gravel deposition and roof-fall. Both layers 27 and 29 formed as part of a continuous gravel deposition and rockfall (Rock Fall II and Fan Gravel II) events, with layer 29 referred to as "Rock Fall IIa," though the rock fall referred to consists mainly of gravels and not the large boulders found in Rock Fall I. In some places, layers 27 and 29 are separated by a thin eolian silt layer (layer 28, aka F4), though in others they are indistinguishable." All three of these layers contain extensive middle-Archaic assemblages marked by several dart point forms. Swanson acquired three radiocarbon dates from features in this layer: 4500 ± 170 ^{14}C B.P. (5590-4810 cal B.P.), 5670 ± 120 ^{14}C B.P. (6740-6273 cal B.P.), and 5870 ± 120 ^{14}C B.P. (6980-6407 cal B.P.). The single accepted AMS date for this layer dates to 5295 ± 20 ^{14}C B.P. (6179-5994 cal B.P.), and overlaps slightly with the latter two of Swanson's original dates while the other, earlier Swanson date (4500 ± 140 ^{14}C B.P.) appears to be anomalously young, especially when compared with dates from overlying layers. For this reason, the likely age range of this layer is considered to be ~6700-6000 cal B.P.

Layer 28 (aka layer F4) partially tops layer 29 and is a thin, pale brown, slightly gravelly loam considered by Swanson to be largely eolian in origin. Swanson did not acquire radiocarbon ages on this layer, instead assuming an age of 2550-2350 BC (~5300-4800 cal B.P.) based on deposition rate and stratigraphic inference from other locales. Two new AMS radiocarbon ages were acquired for this layer: 5800 ± 20 ^{14}C B.P. (6666-6537 cal B.P.) and 5375 ± 20 ^{14}C B.P. (6277-6027 cal B.P.), completely overlapping ages for the underlying layer 29. This suggests that layer 28 may actually be part of layer 29, or that it rapidly formed on the surface of layer 29 shortly after it was deposited. Either way, layer 28 is also believed to date between ~6700-6000 cal B.P.

Layer 27, referred to as “Rockfall IIb” by Swanson, is a gravelly, greyish-brown sandy loam topping layers 28 and 29 and considered to have formed from a combination of minor colluvial activity and alluvial fan deposition. Swanson acquired a single radiocarbon age from this deposit of 3995 ± 470 ^{14}C B.P. (5644-3328 cal B.P.). Though this age has a very high standard deviation, it overlaps both new AMS radiocarbon dates from this layer: 3860 ± 20 ^{14}C B.P. (4407-4181 cal B.P.) and 4115 ± 20 ^{14}C B.P. (4808-4530 cal B.P.). It would appear, then, that this layer dates to ~4200-4800 cal B.P.

Layer 26 is an extremely gravelly, intermittent, coarse sandy loam layer, though Swanson also confusingly refers to it as part of an “eolian silt” deposit that includes layer 25, potentially due to an erroneous association with deposits at Bison Rockshelter. There are relatively few artifacts associated with this layer, possibly due to its thin and intermittent nature. Swanson acquired a single date of 2920 ± 120 ^{14}C B.P. (3358-2793 cal B.P.) for this layer. One accepted new AMS radiocarbon date for layer 26, however, comes to 4145 ± 20 ^{14}C B.P. (4821-4581 cal B.P.), which overlaps the age of the underlying layer 27. While Swanson’s age seems young when compared with a slightly younger AMS age from layer 24, a lack of acceptable ages from layer 25 and the possibility that the 4145 ± 20 ^{14}C B.P. age may actually be from the contact between layers 26 and 27 does not rule out this date entirely. It is also possible that layer 26 is part of the same depositional episode that formed layer 27. Therefore, a conservative age for this layer is somewhere between ~4800-3100 cal B.P.

Layer 25 is an extremely gravelly sandy loam overlying layer 26 and containing mid-late Archaic style dart points and other artifacts. Swanson did not directly date this layer, though based on dates from Bison and rates of sediment accumulation, he assumes that depositional unit "Va," which includes layers 25-26, dates between 1450-950 BC (~3700-3000 cal B.P.), though this age is unreliable. Unfortunately, both samples submitted for AMS from this layer came back anomalously young, preventing a clear dating of this horizon. However, the age of this horizon is limited by dates in layers 26 and 24, indicating that it deposited some time between ~4800-3100 cal B.P.

Layer 24 is a light brownish-grey very gravelly sandy loam, possibly formed partly by sheet-flood deposits from the alluvial fan along with layers 21-23. Cultural deposits continue to have a mix of dart point styles and other lithic tools. Swanson did not acquire any dates on this layer, instead lumping it with layers 21-24, or component "Vb," which he estimates to last between 950 BC-1250 AD (~3000-650 cal B.P.). A single new AMS radiocarbon date from this layer dates it to 2985 ± 20 ^{14}C B.P. (3218-3076 cal B.P.), partially overlapping of Swanson's age range, providing an estimate of ~3200-3100 cal B.P.

Layer 23 is a gravelly deposit not clearly described by Swanson with a relatively sparse lithic assemblage dominated by Elko style dart points. Swanson did not directly date this layer, and no samples were available for AMS radiocarbon dating, making its age unclear. However, limiting dates for layers 22 and 24 roughly place the age of this layer between ~3200-2000 cal B.P.

Layer 22 is a very gravelly greyish brown loam with a low number of lithic tools. Swanson provided a single age of 1580 ± 80 ^{14}C B.P. (1622-1310 cal B.P.) for this layer, and a single new AMS radiocarbon date gives an age of 2080 ± 20 ^{14}C B.P. (2115-1995 cal B.P.). While the newer date is likely more reliable than the older conventional age, both may be relevant ages for this layer, placing its age around ~2000-1500 cal B.P.

Layer 21 is a very gravelly, very dark greyish brown loam with a relatively sparse cultural component containing both Elko dart points and various arrow points. Swanson did not date this layer, but provides an age of ~650 cal B.P. as a terminal date for this depositional episode based on stratigraphic association and rate of deposition. While this age is based on inference and is highly suspect, the new AMS radiocarbon date for this horizon was unfortunately anomalously young. Dates from layers 20 and 22, however, provide a bracketing age range of ~2000-1200 cal B.P.

Layers 19-20 are gravelly, dark greyish brown sandy loams containing small amounts of rockfall (Rockfall III) and associated with the youngest preserved prehistoric component at the site, though the vast majority of artifacts came from layer 20. For dating purposes, Swanson lumped both of these layers together, providing a single age of 370 ± 80 ^{14}C B.P. (535-285 cal B.P.). One new AMS date of 1280± 20 ^{14}C B.P. (1181-1127 cal B.P.) from layer 20 is noticeably older than this age, suggesting that Swanson's sample may have had younger contamination, or that layer 19 is simply ~800 years younger than layer 20. For the purposes of this study, it is assumed that layer 20 dates to ~1150 cal B.P., while layer 19 dates to somewhere between ~1150-300 cal B.P.

APPENDIX B PXRF METHODOLOGY*

Since all artifacts from Veratic rockshelter are currently housed at the Idaho Museum of Anthropology, the Idaho State University Anthropology Department allowed me access to their Bruker TRACER III-V energy dispersive hand-held portable XRF (pXRF) spectrometer for this part of the analysis. The pXRF was equipped with a Rhodium target and a 170 eV resolution Si PIN detector with a 13µ Be detector window, a 45 kV x-ray generator, and a 12 mil Al, a 1 mil Ti, and a 6 mil Cu filter. The raw data was calibrated using known obsidian standards with a method developed by Jeff Ferguson and Bruker for the detection of optimal elements, including: Mn, Fe, Zn, Ga, Th, Rb, Sr, Y, Zr, and Nb, with Rb, Sr, Y, Zr, and Nb proving the most useful in identifying sources. The calibration file used was from 2011 and thus predates the current version of this calibration. Each object was scanned three times at 180 dead-time-corrected seconds for each scan, shifting the sample after each scan and averaging the three to provide a final value and minimize the effects of surface morphology. Before each session, after turning on the device, a standard sample of obsidian with known values was analyzed and compared with previous scans to determine the degree of stability for the device and to provide a base value from which to calibrate the results. As results vary between XRF machines, all artifacts were scanned on the same device with the same settings as the reference samples.

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