SIGNIFICANCE EVALUATION OF THE FORGOTTEN CREEK SITE

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SIGNIFICANCE EVALUATION OF

THE FORGOTTEN CREEK SITE (45PI0429)

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by

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ABSTRACT

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Archaeological research has recognized the importance of montane environments in the subsistence and settlement strategies of pre-contact peoples. Yet little is understood about variation in the manner in which pre-contact peoples were using upland environments. In order to ascertain whether there is functional and/or technological variation between montane sites in comparable environmental settings, four lithic assemblages (45PI406, 45PI408, 45PI429, and 45PI438) from sites in the upper maritime forest and subalpine zone of Mount Rainier were compared. An evolutionary archaeology model was applied to define and measure variables relevant to stone tool manufacture and use. Statistically significant non-random associations were contextualized within the known environmental constraints and regional land use models for upland subsistence and settlement strategies in the southern Washington Cascades. Overall results indicate that the assemblages are dominated by debitage, and are consistent with those produced as a result of tool manufacture by semi-sedentary groups at limited activity sites. However, the assemblages differ synchronically in both technological and functional organization, indicating that local microenvironments and climate regimes significantly influenced stone tool manufacture and use.

Keywords: Archaeology, Mount Rainier, lithics, stone tools, evolutionary archaeology, statistical analysis, adaptation.

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CHAPTER I

INTRODUCTION

Since the 1970s archaeological surveys have recorded hundreds of upland pre-contact archaeological sites in the southern Washington Cascades (Lewarch and Benson 1991). However, at this time relatively few of the nearly 100 recorded upland archaeological sites in Mount Rainier National Park have undergone subsurface excavation or have had their lithic assemblages systematically analyzed (Burtchard 2003:3-4). Lewarch and Benson (1991) were able to provide detailed information on eight recorded pre-contact archaeological sites in the southern Washington Cascades, based on previous excavations and the results of lithic analysis. This was only a small fraction of the over 200 pre-contact archaeological sites that had been recorded in Gifford Pinchot National Forest when their study was carried out. They noted the lack of chronological, functional, and technological data available in comparison to the amount of recorded sites.

My goal is to add to the growing body of data on recorded upland archaeological sites in the Washington Cascades in order to increase our understanding of upland land use subsistence and settlement patterns in the Pacific Northwest. To achieve this, I have compared four lithic assemblages from excavated sites on the slopes of Mount Rainier that have undergone well-documented subsurface excavation.

Problem

The diachronic research question for this research is: Did the selective conditions under which stone tools were manufactured and used on Mount Rainier change during the Holocene Epoch? The synchronic research question is: Were the selective conditions under which stone tools were made and used variable across microenvironments on Mount Rainier? The selective conditions refer to environmental constraints that would affect the manufacture and use of stone tools. For instance, where tool-stone raw materials are scarce, highly transportable and flexible technologies could be favored relative to technologies that rely on abundant local tool-stone sources. Differences in the local selective conditions of the environment can be reflected through patterns in the archaeological record. The pattern in the distribution of obsidian artifacts suggests variation in travel routes between early and late Holocene peoples, and/or some form of relationship between stone tool heat treatment and the use of obsidian. The cost of obsidian could have been offset by the employment of stone tool heat treatment of local lithic raw materials in later assemblages.

It is possible that mountain environments have limiting selective conditions on the subsistence and settlement patterns fit to them, due to the character of their extreme environmental conditions relative to lowland habitats (Burtchard 2003;2007). Identifying the selective conditions under which people made and used stone tools provides an empirically based and theoretically informed understanding of how past people organized their technology (McCutcheon 1997). This kind of information can be used to inform hypotheses about past upland human land use practices throughout the Cascade Mountains.

The null hypotheses I employ in this research explores the application of current land use models on Mount Rainier. The null hypothesis is H_0: There will be random associations between sites across the compared dimensions. The alternate hypothesis is H_1: There will be associations between sites across the dimensions compared. Variations in the organization of technological and functional elements of the stone tool industry could be indicative of spatial variation in pre-contact settlement and subsistence strategies. Alternatively, a lack of change may be a function of strong selective pressure against variation in stone tool manufacture and use in extreme ecological settings such as upper elevation landscapes on Mount Rainier (Burtchard 2007).

To date, there have been no completed studies that have tested these hypotheses. Indeed, until the last few years, few of the recorded high elevation archaeological sites had undergone some level of subsurface excavation. Even fewer had their lithic assemblages systematically analyzed (Burtchard 2003:3-4).

Purpose

By demonstrating the information potential of the Forgotten Creek (45PI429) lithic assemblage, a recommendation was made about this site's eligibility for the National Register of Historic Places. To determine the information potential of the 45PI429 lithic assemblage, analysis proceeded in a comparable manner as previously studied archaeological sites on Mount Rainier (e.g., Vaughn 2010). The purpose of this thesis is to describe the extent to which 45PI429 lithic toolkits changed over time, and how the lithic assemblage variation at the site compares to other similar aged assemblages.

Both McCutcheon's (1997) cost-performance model and systematic paradigmatic classification have already been applied to the Sunrise Ridge Borrow Pit (45PI408) and

Tipsoo Lake (45PI406) lithic assemblages in previous research (Dampf 2002; Vaughn 2010). In the course of his research, Vaughn created an analytical key with which to compare assemblages analyzed through paradigmatic classification, to assemblages that were analyzed using other analytical protocols (Vaughn 2010:40). Following this approach, I have made a synchronic comparison of the 45PI438 (45PI438) lithic assemblage (Schurke 2011) with that of the 45PI429 assemblage, as well as the 45PI408 and 45PI406 assemblages.

The purpose of this thesis was achieved through application of the objectives described in the following pages. Similar comparisons have contributed to our understanding of past human montane land use (e.g., Dampf 2002; Lewarch and Benson 1991; Vaughn 2010).

Objective One – Application of the Models

In the Southern Washington Cascades, stone tools are usually the only artifacts found in pre-contact archaeological sites. The first objective of this research is to apply an evolutionary archaeology model as the analytical strategy guiding the investigation of the lithic assemblages. Evolutionary archaeology identifies the selective conditions under which stone tools were manufactured and used. Using an evolutionary archaeology model also allow for assessment of whether attributes are independent of environmental factors, or if they correlate with environmental factors geographically (Endler 1986; O'Brien and Lyman 2000).

In order to define the variables that will be measured within an evolutionary archaeology framework, I apply McCutcheon's (1997) cost-performance research model.

In this model, stone tool cost and performance are operationalized as a set of subvariables that are then measured with classifications. The subvariables are related to the cost of stone tool manufacture and the performance of stone tools within the selective conditions of the environment. The cost-performance model has been adapted to an upland context in previous studies (Dampf 2002, Vaughn 2010). This upland adaptation of the cost performance model is being applied to the four sites studied in this investigation.

Objective Two – Generation of the Data

Objective two is to generate the data for the 45PI429 assemblage. The variables defined by the McCutcheon's (1997) cost-performance model were operationalized into a classification system consisting of technological, functional, and rock physical property paradigms. Each of these paradigms is composed of a mutually exclusive set of dimensions. Identifying and recording the attributes of these dimensions for the stone tools in the 45PI429 assemblage generates the data for the following statistical analyses.

Objective Three – Statistical Analyses of the Data

The third objective is to identify evidence for sorting of the attribute frequencies in the lithic assemblages that may be indicative of changing selective conditions. In order to be certain of the outcomes, it is necessary to determine whether the sample s are sufficiently representative, if there is any variation present, and whether variations through time and across space demonstrate statistically significant associations. In previous research this has been accomplished by means of making statistical comparisons (Lewarch and Benson 1991; McCutcheon 1997; Schurke 2011; Vaughn 2010). The comparisons in this investigation have been made through the use of bar graphs with error bars, chi-square testing, analysis of adjusted residuals, and by measuring the effect size through applying Cramér's V. For this research, all statistical analyses will be done at a 95% confidence level ($\alpha = 0.05$). All of these specific statistical analyses formulas and techniques have been applied in previous research by Vaughn (2010), in analyzing the 45PI408 Site lithic assemblage. The continued use of these specific formulae and techniques increases the level of reproducibility of this investigation and the level of reliable comparability with the results of future research in the southern Washington Cascades.

Objective Four – Contextualizing the Results

The fourth objective is to contextualize any meaningful associations found through statistical analyses within the regional land use models for upland subsistence and settlement strategies in the southern Washington Cascades. The context for interpretations is provided through reviewing the relevant literature on these regional land use models. Also, the previous studies of pre-contact sites in the southern Washington Cascades provide a regional basis against which to compare the results of this research.

The research hypotheses will be tested based on whether the lithic tool kit that was manufactured and used in the upland environment of Mount Rainier differed between sites, alternatively, was relatively homogenous. Building an understanding of what the associations mean within the broader context of pre-contact subsistence and settlement patterns allows for a fuller understanding of past human interactions with the selective conditions of the environment in an upland context, as explained through evolutionary processes.

Objective Five – Assessing Information Potential

Objective five is establishment of the integrity and research significance of the site. The intact and clearly defined stratigraphy at the site has been well established, and the archaeology of the site can be considered representative of the past activities that occurred on the excavated surfaces. The stratigraphic integrity has allowed synchronic comparisons with other upland archaeological assemblages, adding to our knowledge of past land use in the Southern Washington Cascades. With the lack of well documented and studied upland pre-contact archaeological sites, the 45PI429 site has the potential to yield significant information in future archaeological investigations. The research potential of the 45PI429 site could be augmented, by increasing the sample size of the lithic assemblage through further excavations.

Significance

This research presents a significant contribution to our understanding of pre-contact settlement and subsistence patterns in the Southern Washington Cascades. Comparisons of excavated upland lithic assemblages are infrequent in comparison to comparisons of lowland lithic assemblages. Additionally, this research employs the use of comparable methods and techniques to previous research on upland archaeological sites in the region for further comparability. The analysis of the 45PI429 assemblage and the application of a method of converting the data generated by Sullivan and Rozen (1985) type lithic classifications to the paradigmatic classification system also created comparable data that can be used in future comparisons.

Through this research, The 45PI429, 45PI408, 45PI438, and 45PI406 lithic assemblages have all been studied using McCutcheon's (1997) cost-performance model, and the identical analytical protocol of McCutcheon's (1997) paradigmatic classification system employed by Vaughn (2010). This allows for effective identification of synchronic variation in technological and functional characteristics by means of intersite comparisons between the lithic assemblages. Additionally, the data from the 45PI438 assemblage (Schurke 2011) was incorporated through means of Vaughn's (2010) analytical key.

These comparisons will provide data that may be used in future research to ascertain whether montane land use strategies remained static throughout the southern Washington Cascades, or whether they demonstrated variation between high elevation environmental zones and throughout the ca 8000 year period represented in the lithic assemblage of the 45PI429 site. Testing the hypothesis has contributed to our understanding of human adaptation to unique environments over extended periods of time, through resource extraction and tool use. The process of testing the hypothesis has provided data that can be applied to future research of human adaptation of lithic toolkits to specific environments. An outcome of this work has been to show the information potential of the site, which provides a basis for eventual nomination to the NRHP. Nomination of the 45PI429 site would attest to the value of this site for future academic research.

CHAPTER II

STUDY AREA

There are many environmental constraints that could have influenced stone tool function and technology on Mount Rainier. The availability of resources varies greatly with elevation and environmental zone, with decreased resource availability in the high maturity habitats of lowland maritime forests (Burtchard 2003:16-17). Pre-contact peoples on the mountain would have also had to adapt to rugged terrain and unpredictable weather patterns (Burtchard 2003:49). During the mid-Holocene (9000-4400 cal yrs BP) there was a dry warm period (hypsithermal interval or xerothermic interval) of decreased precipitation (40-50% less) and slightly warmer temperatures (1-3°C increase) (Burtchard 1998a; Dunwiddie 1986; Nickels 2002:41). Based on more recent macroscopic charcoal analysis of lake sediment cores from Mount Rainier, there was also possible climate change and intermittent droughts throughout the Cascades during the late Holocene, caused by variability in the ENSO (El Niño–Southern Oscillation) cycles (Lukens 2013:91). Around 3600 cal yrs BP (Nickels 2002:45) climate conditions on Mount Rainier became cooler and wetter, followed by a shift back to warmer conditions around 2000 cal yrs BP (Dunwiddie 1986:63-65; Nickels 2002:47). These repeated climate changes have altered the vegetation boundaries throughout the Holocene, so vegetation zones were not consistent throughout the occupation of the sites (i.e., the 45PI408 site, which is currently situated in upper Northwest maritime forest could have at one point been located in the subalpine zone) (Burtchard 2003:32). During warmer, drier periods maritime forests advanced up to 200-500 meters higher in elevation, and retreated downslope during cooler wetter periods (Nickel 2002:43,47). Proximity to sources of raw material for stone tool manufacture would have also been a constraint, assuming that transporting tool stone through the rugged terrain would have been difficult (Burtchard 2003:48).

The Forgotten Creek site (45PI0429) is a high-elevation pre-contact site in Mount Rainier National Park, situated in the upper Nisqually River Valley on the southwestern slope of Mount Rainier, at about 4300 ft. elevation. The site was first recorded in Greg Burtchard and Steve Hamilton in 1995. In 2010, chipped stone artifacts were discovered subsurface context in nine of 18 constant volume sample (CVS) test pits. Further excavation the following year (2011) yielded another positive CVS unit (0N/34W) and lithic debitage from two 1x1 excavation units, excavated by Greg Burtchard, Ben Diaz, Patrick Lewis, and Diana Woolsey. 2011 excavation yielded 979 pieces of lithic debitage from two more CVS units and two 1x1 excavation units. The current total lithic assemblage from the site consists of 1,104 pieces of debitage, including a complete stone point (Columbia corner notched A, [Carter 2010]), recovered from the positive CVS units and the 1x1m excavation units. The stratigraphic context of the assemblage is currently approximated to range from 7627 cal yrs BP to present, based on associated, dated tephra layers (Burtchard 2011:16).

The assemblage was excavated from paleosols separated by tephra layers with substantial stratigraphic integrity. The oldest of these is Mount Mazama ash dating to ca. 7627 cal yrs BP; the youngest is Mount Saint Helens W tephra dating to ca 450 cal yrs BP This provides an exceptional opportunity to gain accurate diachronic data pertaining to the lithic assemblage variability; as well as to make synchronic comparisons with other sites in the region that contain similar artifact/tephra associations. Archaeological research is seldom able to obtain such accurate and detailed chronological data, especially pertaining to intersite comparisons of lithic assemblages in upland contexts (see Lewarch and Benson 1991 for an exception). This kind of information is precisely what is necessary to evaluate technological and functional characteristics that are expected in models of human land use in the southern Washington Cascade Mountains.

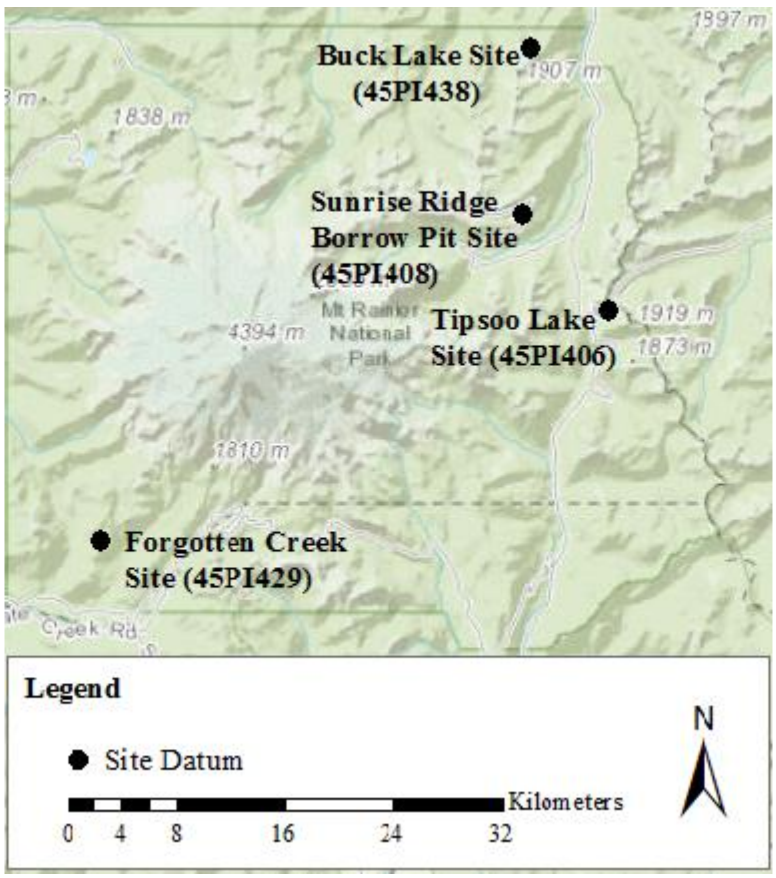

Figure 1. Location of the Sites being Compared in this Research.

The Buck Lake site (45PI438) is situated in a comparable environmental setting at 5400 ft elevation on a mountain bench landform on the northeast side of Mount Rainier

(Schurke 2011). The 45PI438 assemblage was analyzed using a free-standing typology, based on Andrefsky (2005:129), and influenced by Sullivan and Rozen (1985) and Flenniken (1986).

Lithic assemblages of two other high elevation sites on Mount Rainier, the Tipsoo Lake (45PI406) and Sunrise Ridge Borrow Pit (45PI408) sites, have been studied using identical analytical protocols as that which was applied to the 45PI429 assemblage (Vaughn 2010). The 45PI406 site is located in the Ohanapecosh drainage at about 5440 ft elevation, while the Sunrise Borrow Pit site is located in the White River drainage at 4900 ft elevation above mean sea level (Vaughn 2010:26). These sites, situated as they are on the eastern slope of Mount Rainier National Park, occupy slightly different environmental settings from the northeastern location of 45PI438, and the 45PI429 site's location on the mountain's southwestern slope.

CHAPTER III

LITERATURE REVIEW

The literature review is structured according to the objectives laid out in Chapter I, as it supplies the literature context for each. The literature review provides some of the rationale for the following methods and techniques used in the stone tool analyses of the artifact assemblages. Data from these analyses were interpreted within the context of regional land use models.

Objective 1: Application of the Models

Common to all models are their underlying analytical strategies, which are crucial in making comparisons of models and their hypotheses. The analytical strategy of this research is based on an evolutionary archaeology model. Darwinian evolutionism can be applied to solve archaeological problems by creating materialist archaeological units that account for variation. To solve archaeological problems the data used to form archaeological units must be derived from real interactions with the environment. Archaeological units must also be generated from specific information in order to address specific issues, and must be able to be generated through equally demanding standards. In this manner, Darwinian evolutionism can be used to explain observed variation in the archaeological record. When studied using a Darwinian evolutionary approach, the archaeological record provides a historical sequence of variation and lineages (O’Brien and Lyman 2000:19-21).

As such, it is recognized that the long-term study of variation (in the frequency distribution of traits) through an evolutionary archaeology model is the most effective method of detecting the selective conditions under which stone tools are manufactured and used (Endler 1986; O'Brien and Lyman: 2000). This is because functional and technological attributes directly affect population fitness through interacting with external environmental conditions (Dunnell 1978a). If differences in the selective conditions of the environment can be identified across space, whether or not those conditions are a factor of geography can be assessed.

Functional and technological attributes are isolated and defined through McCutcheon's (1997) cost-performance model where the inter-variable relationships identify archaeological expectations. For instance, cost and performance interact with natural selection in that stone tools that have lower cost as related to their manufacture within the selective conditions of the environment will outcompete more expensive ones (Vaughn 2010:35). This model has already been applied to other lithic assemblages in the Southern Washington Cascades (Dampf 2002; Vaughn 2010).

The term "cost" refers to the relative amount of energy required in stone tool manufacture. Cost includes energy expenditure in stone tool manufacture, the preparation of raw material for stone tool manufacture, and the cost of raw material acquisition. Raw material acquisition is based on factors such as raw material abundance, the distance from the raw material source to the place of manufacture, and the intended use location. The relative cost (or steps in stone tool manufacture and preparation) is based on the rock physical properties, the tool requirements, and the technology being employed to manufacture and prepare stone tools. These costs all affect tool durability and performance. Increased cost can be offset by increased performance. For example, a raw material with higher acquisition cost may decrease cost in other areas such as increased tool durability or sharpness (McCutcheon 1997:186-189).

Performance refers to how well a stone tool accomplishes the task for which it was manufactured within the environment of interaction. Performance can be based on multiple variables including the rock physical properties of the raw material being used, the available stone tool manufacture technology, and the requirements of the task being performed. These variables affect outcomes such as the amount of wear incurred through use, accidental breakage, and how well the tool performs the given task. Technology used in stone tool preparation and manufacture, such as heat treatment or tool form, can mitigate rock physical properties that cause wear and breakage, increasing tool performance during use (McCutcheon 1997:186-189).

Functional attributes (Dunnell 1978a:200) are defined through the model as those that directly interact with the environment when the tool object is used to perform specific tasks, while technological attributes are defined as the end result of the application of available technology to decrease the cost of stone tool manufacture while increasing performance for use (McCutcheon 1997).

The evolutionary approach of the cost performance model also provides the added benefit of distinguishing functional and technological attributes from purely stylistic attributes. Style, as defined by Dunnell (1978a:199) is independent of the environment and is randomly transmitted, and does not have detectable selective values. As a result, style should only be used explicitly for chronology and spatial interactions within an archaeological context.

According to Endler (1986), the ratios of the specific functional and technological attributes can be used to formulate inferences about human interactions with the selective conditions of the regional environment. These informed inferences can be made through applying an organization of technology framework (Carr 2005).

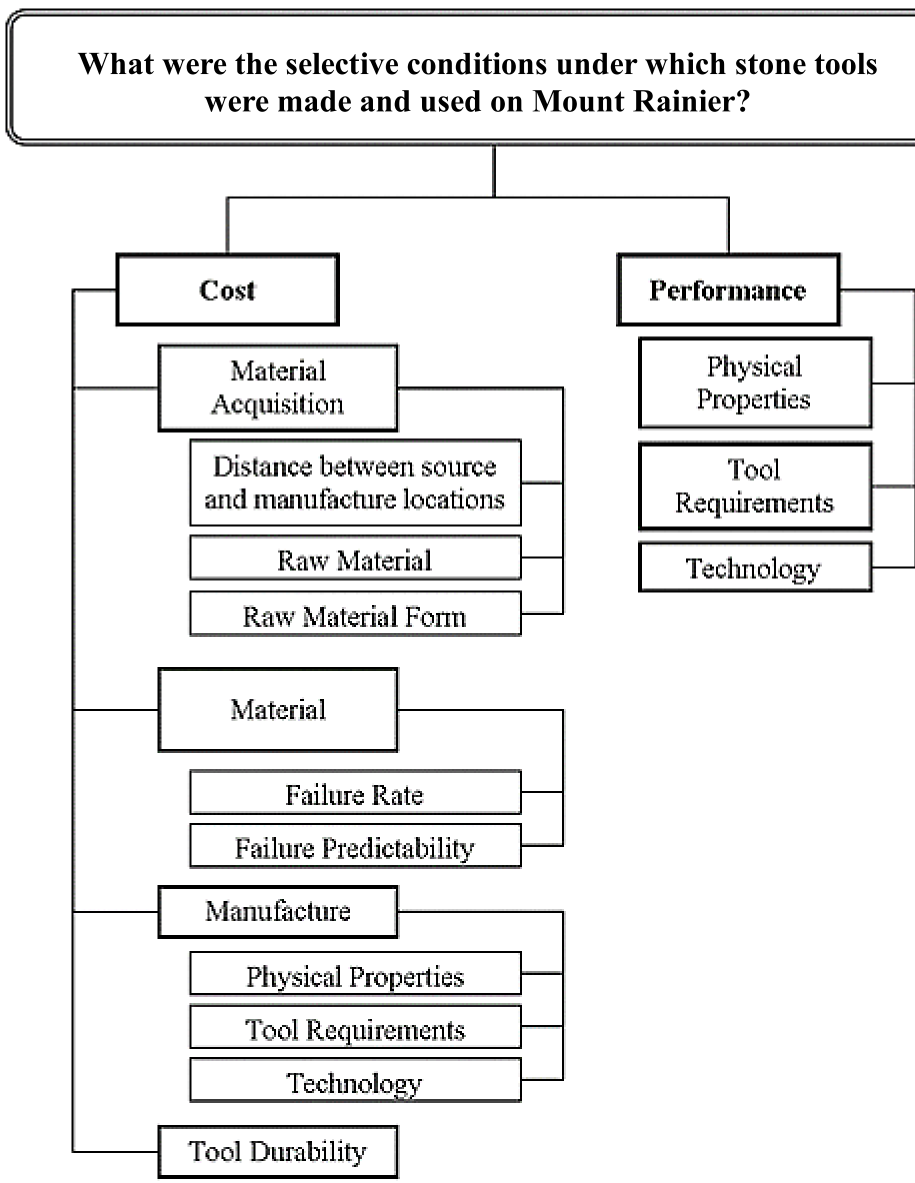

Figure 2. Cost-performance Model Adapted to an Upland Context (Vaughn 2010:34).

The technological organizations of assemblages are non-exclusive, as they are based on attributes which result from stone tool manufacture and use within the selective conditions of the environment. As such, foraging and collecting behaviors are not expected to occur independently of each other, or to show no variation across space, but rather are expected to meet the needs of environmental conditions as they vary geographically and change through time (Burtchard 2007).

Objective 2: Generation of the Data

Lipo and Eerkens (2008) created a formula to determine how significant the effects of formation processes are on measures of similarity between assemblages (Lipo and Eerkens 2008:124-125). The formula, Similarity = *f* (Preservation, Turbation, Field Methods) uses the three primary formation processes (Lipo and Eerkens 2008:125). Using this formula, it can be determined the degree to which the statistically significant associations were influenced by these formation processes.

At all sites, the pre-contact artifacts were well preserved, as the assemblages consist of stone debitage and tools. Furthermore, the sites were not heavily disturbed, with the exception of 45PI406, which is a mixed component site. Field observations and assessments of stratigraphic integrity at the 45PI408, 45PI429, and 45PI438 sites contained artifacts that were intercalated between distinct tephra layers. At each of these sites there was evidence of some post-depositional alteration, but not to the extent where large scale mixing would have resulted. However, to account for post-depositional alteration the 45PI406 assemblage is only being used in whole-site comparisons.

Additionally, bias in field methods is not a factor since all assemblages in this study were excavated in a consistent manner using 1/8-inch mesh.

While some primary formation processes may have impacted our measures of similarity, the violence done to the data is minimized because of the large sample sizes and aggregating the artifacts using stratigraphically distinct layers. Also, we performed a resampling analysis that allowed us to select only those dimensions for which we had representative attribute frequencies. Thus, we conclude that statistically significant associations are the result of sorting in the archaeological record caused by the selective conditions of the environment.

The data for the 45PI429 site was generated through systematic paradigmatic classification of the lithic assemblage. The data for the 45PI438 lithic assemblage was generated through applying McCutcheon's (1997) paradigmatic classification analytical strategy to Schurke's (2011) analysis of the 45PI438 lithic assemblage. Similar strategies were used by Vaughn (2010). The paradigmatic classification system applied in this research is derived from the methods in order to measure lithic technological organization. It consists of paradigmatic dimensions further divided into sub-variables which identify attributes that interact with the selective conditions of the environment.

Classification systems have long been applied in archaeological research as a means of gathering data from lithic assemblages (Andrefsky 1994, 2007, and 2009; Sullivan and Rozen 1985). Lithic classification systems have been shifting from essentialist typologies towards recognizing the value of measuring variation in the archaeological record (Dunnell 1978a; O'Brien and Lyman 2000). According to Dancey

(1973:44), Dunnell's (1971) paradigmatic classification system is defined as constructed classes, organized by dimensions, and defined by modes which measure phenomena. Modes consist of combined attributes, and are the manner in which the dimension being measured is present, with absence also being a mode of each dimension (Dancey 1973:44).

Dancey (1973) and Dunnell and Lewarch (1974; Dunnell 1978a) were the first to apply Dunnell's (1971) paradigmatic classification analytical strategy to generate data in the Pacific Northwest. Dancey (1973) applied paradigmatic classification to investigate the functional and technological classes of lithic assemblages in relation to microenvironments. Using this data, Dancey (1973) created a record of land use and settlement patterns in the Priest Rapids, WA area spanning the past 3000 years, much as is being done in this investigation. Paradigmatic classification was applied to the Home Valley Park site lithic assemblage by Dunnell and Lewarch (1974). The paradigm used in the analysis consisted of two technological dimensions (cores and flakes) and four functional dimensions (kind, location, shape, orientation) and their modes, and allowed for the investigation of site activities and a comparison between the Home Valley Park site assemblage with other nearby assemblages (Dunnell and Lewarch 1974).

Based on Dunnell (1971), Sullivan and Rosen (1985) developed a hierarchical key in order to create interpretation free categories. Campbell (1981) and later Sullivan and Rozen (1985) built on this premise through the creation of mutually exclusive debitage categories. However, Sullivan and Rozen's (1985) classification was intended only to identify the characteristics of debitage that can inform on reduction, and consisted of just one dimension with four modes: complete flakes, broken flakes, flake fragments, and debris.

Campbell (1981) applied the following dimensions to lithic analysis: type of fragment, amount of cortex, presence of wear, and presence of other modification. McCutcheon (1997) further developed Campbell's (1981) classification system through the addition of raw material types, platform type, completeness, thermal alteration, reduction, and rock physical property dimensions and their modes. McCutcheon's (1997) paradigmatic classification system was employed in analysis of the 45PI408 site lithic assemblage by Dampf (2002), and later for more recently excavated lithics from the same site by Vaughn (2010). Working with McCutcheon, Vaughn (2010) further enhanced the classification system through the addition of complexity dimensions and their modes, as well as dimensions and modes for the orientation of use wear.

McCutcheon's (1997) paradigmatic classification has now been applied to the 45PI406 and Mule Spring lithic assemblages by Vaughn (2010), to the 45PI408 assemblage by Dampf (2002), Vaughn (2010) and Lewis (in progress), and now also to the 45PI429 and 45PI438 lithic assemblages through this research.

Objective 3: Statistical Analyses

The bootstrapping technique of resampling has been applied by Evans (2009) to the 45LE415 and 45LE222S assemblages in the southern Washington Cascades, and by Vaughn (2010) to the 45PI408, 45LE415, 45PI406, 45LE285, 45KI435, and 42MB227 lithic assemblages, in order to evaluate the effects of assemblage sample size on later statistical tests through determining the representativeness of the sample size (McCutcheon 1997).

Bootstrapping, developed by Bradley Efron in 1979, is a non-parametric technique that assumes a random distribution of the subsample for generating the shape of distribution of a total population from subsample characteristics (Efron and Tibshirani 1993; Mooney and Duval 1993). The probability range of sample statistics such as the mean, median, and spread of distribution of the total population is approximated through the generation of synthetic data by a resampling computer program.

The *Resampler* computer program used in this research was developed to apply bootstrapping to archaeological assemblages. The program uses the raw data from the subsample provided to generate resampling curves, which show the evenness and richness of the subsample (Evans 2009; Vaughn 2010).

The representativeness of resampling curves in this study is determined by arbitrary cutoffs developed by Vaughn (2010) and applied in previous research (Kassa 2014; Vaughn 2010). Representative samples produce what is referred to as a rank 1 curve (which reaches the asymptote of the curve before or at 75% of the maximum sample size), meaning that the addition of more cases to the sample will not increase richness (Vaughn 2010; McCutcheon 1997). A curve that reaches the asymptote at the maximum sample size is referred to as a rank 2 curve, the representativeness of which has been discussed by McCutcheon (1997) and Lipo (2000). However, based on critiques by Cochrane (2002) and more recently Vaughn (2010), rank 2 curves are considered representative for the purposes of this research if they possess asymptotic shape and a standard deviation of zero (characteristics of rank 1 curves) (Vaughn 2010). However, the accuracy of these curves is questionable, and increased sample size may alter the frequency distribution of the dimension being resampled (Vaughn 2010). Curves that do not reach the asymptote prior to reaching maximum sample size are referred to as rank 3 curves and are not considered representative (McCutcheon 1997). This is taken into account during following statistical analyses.

Subsamples that were sufficiently representative as determined by bootstrapping were then analyzed through chi-square testing. Chi-square testing is a non-parametric statistical method of testing the null hypothesis (H_o: random association between the variables) by comparing observed frequencies with the frequencies that would be expected were the null hypothesis correct (Zar 1974). Based on the critical value produced by the test, the null hypothesis of random association between one or more variables can either be accepted or rejected (VanPoole and Leonard 2011:238-258; Zar 1974). Zar (1974) notes that chi-square as a test of association assumes the values being entered are a subsample of the population (Zar 1974); this is particularly well suited to archaeological research. Chi-square also produces nominal scale data, from which inferences can be made about the population the sample was taken from (VanPoole and Leonard 2011; Zar 1974).

In order to apply chi-squared testing, the sample size must contain at least 20 values, all values must be above 0, and only 20% or less of cells in the test can consist of values below 5 (Fletcher and Lock 2005). For samples that are insufficiently representative and unsuitable for chi-square testing, the log-likelihood ratio, which produces a G-value that approximates the chi-squared value, can be applied instead (Zar 1974). Log-likelihood has been applied previously to tests of association in lithic assemblages by McCutcheon (1997) and Vaughn (2010).

Cramér's V is commonly used as the subsequent measure of association between chi-squared variables. Cramér's V produces a value ranging from 0 to 1, with 0 being little if any association, and 1 being considered a perfect association (the dependent variable can be perfectly predicted).

The Cramér's V value produced based on the results of chi-squared or log-likelihood testing can then be compared with the degrees of freedom in order to estimate the effect size (see Table 1) for any statistically significant non-random association (Cohen 1988). The effect size measures the extent of the difference between the variables, consisting of small, medium, and large effect sizes. If there is a statistically significant non-random association, the effect size shows how rigorous the statistical analysis needs to be in order to see the non-random association. Large effect sizes mean that the association could be noticeable without statistical analysis, while small effect sizes mean that the association can only be seen through careful statistical analysis.

Table 1. Effect Size Conventions from Cohen 1988 (Privatera 2012:568).

	Effect Size		
$df_{smaller}$	Small	Medium	Large
1	0.10	0.30	0.50
2	0.07	0.21	0.35
3	0.06	0.17	0.29

The larger the degree of freedom is (the more independent categories are being compared), the smaller the Cramér's V value can be and still show a statistically significant (small effect size) level of association. In this way the estimated effect size accounts for sample size, while measuring the strength of the association as small, medium, or large. Following up Cramér's V with an analysis of adjusted residuals shows which observed frequencies of modes deviate the furthest from the expected frequencies, and contribute the most to statistically significant non-random associations.

Objective 4: Contextualizing the Results

Objective four is to apply previous studies of lithic assemblages from the southern Washington Cascades to contextualize the results generated by this research. This broader context provides a framework within which data is generated through lithic analysis, and from which a fuller comprehension of how pre-contact peoples were using the land is gained. The results of previous archaeological research in the southern Washington Cascades provides an important context within which to make comparisons and for assessing the results produced by this study. A review of the regional land use models allows for an understanding of how the 45PI429 assemblage fits into regional settlement and subsistence strategies, and whether the assemblage differs from what would be expected of an upland pre-contact site in the Southern Washington Cascades. Further, since this adds to our understanding of upland subsistence and settlement strategies, future research will be able to identify if land use strategies specialized to mountain environments were employed on Mount Rainier, relative to what is known about lowland subsistence and settlement strategies nearby in the region.

Paradigmatic classification was applied to temporal variation in the Pacific Northwest by Schalk and Cleveland (1983). Burtchard (1990, 1998a and 1998b) also adapted it to an upland Pacific Northwest context and applied it at Mount Hood, Mount Rainier, and John Day Fossil Beds National Monument in the Blue Mountain region of central Oregon. These land use models assume that pre-contact peoples had varying settlement and subsistence strategies, which changed over time. Theoretical justification for this diachronic view of the forager to collector dichotomy came later with the full development of these ideas by Burtchard (1998a, 1998b). The forager to collector model was updated by Burtchard (2003, 2007) in application to upland contexts like the slopes of Mount Rainier and Cascade mountains. Burtchard’s (2007) forager-collector model holds that pre-contact land-use was biased towards upper elevations where early seral stage ecologies common to mid- to high elevation would provide abundant resources as opposed to late-seral stage (low or mid-elevation) environments that offered human groups relatively little in the way of consumable biomass and thus were used less frequently. Burtchard’s studies in upland settings are important precisely because he notes that it is the patterns of human adaptation to the ecological structures in the Pacific Northwest that archaeologists should attempt to explain. His model for mountain environments is well developed, and serves as a means for defining ecological variability for the region, across which the study sites are distributed.

Burtchard (2007) also developed a spatial model for Mount Rainier intended to predict relative variation in settlement patterns and montane site types based on patterned variation in the mountain’s environmental zones and resource structure. Combined, the two models imply that while forager to collector variation occurs over time, land use patterns also occur across a landscape. The range of technological organization was wide and variation of forms is expected to be present in archaeological assemblages across the landscape and through time (Burtchard 2007:10-12). Overall, a range of resource exploitation activities have taken place on Mount Rainier, and began prior to 7627 cal yrs BP with Post-Pleistocene Foraging (ca 11000-8000 cal yrs BP) (Burtchard 2008:61). Semisedentary collecting began around 5000 cal yrs BP, which transitioned into an intensive collecting phase from 2500-400 cal yrs BP (Burtchard 2008:62), and more recently mixed hunting and gathering has occurred from 400 cal yrs BP to present (Burtchard 2008: 62).

Lewarch and Benson's (1991) research on pre-contact archaeological sites in the Gifford Pinchot National Forest shows that there appeared to have been a hiatus in occupations in the southern Washington Cascades from approximately 4000-2000 cal yrs BP (Lewarch and Benson 1991:34), during which the MSH Y tephra set was deposited. An apparent hiatus in occupation could have possibly been the result of the MSH Y tephra set obscuring the archaeological record, or due to reduced occupation caused by degradation of the environment by the pyroclastic events, which deposited the tephra layer (Lewarch and Benson 1991). Although obsidian hydration values obtained by McClure (1992:77-81) from the Beech Creek (45LE415) assemblage appeared to support Lewarch and Benson's (1991) hiatus hypothesis, these results were suggestive since skewed values and small sample size was an issue.

In studying the 45PI408 lithic assemblage, Dampf noted an increase in initial reduction stages and a decrease in terminal reduction stages among the flakes post-dating 2300 cal yrs BP (Dampf 2002:90). Dampf interpreted this as a gradual shift toward a more expedient tool production strategy. Dampf did not observe any clear associations between the proportions of fragment types present in the components (i.e., before or after 3000 cal yrs BP) at the 45PI408 site (Dampf 2002:60). Dampf (2002) interpreted this lack of association as representative of a lack of change in the land-use strategy as represented in fragment types.

Vaughn's (2010) research is summarized here to provide background information about an assemblage to which the 45PI429 site assemblage is being compared, and a brief summary of the use of statistical testing as a result of paradigmatic classification and the results it was able to provide. Vaughn (2010) investigated the 45PI408, Beech Creek, 45PI406, Packwood Lake, Mule Spring, and Naches Lithic Scatter site lithic assemblages on, or near, Mount Rainier with the expectation that they would exhibit substantial diversity in functional and technological traits across environmental zones. To test this hypothesis, Vaughn asked whether the frequency of technological and functional traits of lithic assemblages varied across the environmental zones of the southern Washington Cascades. Utilizing an analytical strategy based on McCutcheon's (1997) cost-performance model, he analyzed the lithic assemblages of the 45PI408, 45PI406, and 45KI435 sites with McCutcheon's (1997) paradigmatic classification system to generate data. The generated data underwent bootstrapping, chi-square, log-likelihood, and Cramer's V for the purpose of producing results and understanding the relationships between the variables that were measured. The results of these statistical analyses confirmed his hypothesis that the six lithic assemblages demonstrated substantial variation in traits across environmental zones.

In order to observe whether the results of previous research by Schurke (2011) at the 45PI438 site are replicated in the assemblage of the 45PI429 site, Schurke's analysis and results are reviewed here. Schurke studied the lithic assemblages from two test units which were located on the northeast side of 45PI438 in Mount Rainier National Park (Schurke 2011:7). The site had first been identified in 2004 through survey and testing.

Schurke (2011:52) applied the lithic analyses according to the stratum in which the lithics were discovered, in an attempt to link debitage characteristics with expected technological organization. This allowed Schurke to measure temporal variation of lithic technology and function within the site. The lithic analysis that Schurke employed is based on a free standing typology attributed to Andrefsky (2001, 2005), and influenced by Sullivan and Rozen's (1986) lithic classification system (Schurke 2011:53-57). Using this analytical technique, Schurke (2011:52) determined the frequency of material types, bifacial production and reduction, lithic reduction and production stages, debitage size and weight, expedient flakes, and the frequency of bipolar and blade core technologies. These frequencies of the attributes being measured were then statistically analyzed to identify the sample size, mean, median, minimum and maximum values, and the standard deviation (Schurke 2011:55)

As a result of this investigation, the site was interpreted as a repeated use residential base (Schurke 2011:8). Schurke also noted that transported bifaces (Schurke

2011:76-77, 107) and late stage bifacial tools were distributed throughout the assemblage. However, the assemblage demonstrated a higher weight in the more recent, post-MSH Yn stratum, and that the lithics from older, pre-MSH Y stratum exhibited the greatest difference from expected weights according to experimentally produced debitage (Schurke 2011:107-109).

Although Schurke (2011) employed a different analytical technique in studying the debitage from the 45PI438 site, the data from these analyses can still be incorporated and compared directly to the data from sites, which were studied using paradigmatic classification as an analytical technique. Vaughn (2010:40) demonstrated this through developing a key, which identified common analytic dimensions and their modes, and compared these across assemblages. As done by Vaughn (2010), in this study common analytical dimensions were identified between those used by Schurke (2011) in analysis of the 45PI438 assemblage, and those in the paradigmatic classification system, which has been applied to the other three sites. The comparison of common dimensions has allowed the 45PI438 assemblage to be included in the intersite statistical comparisons of variation in functional and technological attributes in the pre-MSH Y and post-MSH Y components.

In order to achieve the objective of identifying changes in technological and functional organization between assemblages, the assemblages involved in this study have been classified according to the four Sullivan and Rozen (1985) technological groups. According to Sullivan and Rozen (1985:762-766), debitage can be assigned to these four distinct technological groups based on the proportion of six technological categories within an assemblage. These technological categories are complete flakes, broken flakes, flake fragments, debris, cores, and retouched pieces.

The four technological categories are un-intensive core reduction (IA), tool manufacture (II), intensive core reduction (IB2) and core reduction and tool manufacture (IB1). A strong emphasis on stone tool manufacture (technological group II) at a site results in assemblages dominated by small, thin, non-cortical, broken flakes and flake fragments, particularly as a consequence of soft-hammer percussion (Sullivan and Rozen 1985:763-764; Neumann and Johnson 1979:83-84). Assemblages that resulted from both tool manufacture and low intensity core reduction were assigned the title Group IB1 (Sullivan and Rozen 1985:763). In Group IB1 assemblages, the proportions of modes of completeness were intermediate between complete, broken, and flake fragments, with low proportions of debris. In Sullivan and Rozen's (1985) technological group classification, assemblages that are dominated by debris are the byproducts of intensive core reduction, and are assigned the name Group IB2.

The six technological categories applied by Sullivan and Rozen (1985) were recorded for all assemblages involved in this study as modes of the attribute "completeness" in McCutcheon's (1997) paradigmatic classification. This allowed the distribution of technological attributes to be compared to the patterns of distribution provided by Sullivan and Rozen (1985:764) and summarized in Table 2, inferring the technological organization of each component within each assemblage, and of each assemblage as a whole.

Table 2. Technological Groups from Sullivan and Rozen (1985:763).

	Technological Group			
Artifact Category	IA	IB1	IB2	II
Complete Flakes	53.4	32.9	30.2	21.0
Broken Flakes	6.7	13.4	8.1	16.8
Flake Fragments	16.0	35.3	34.7	51.3
Debris	6.1	7.9	23.0	7.3
Cores	14.7	2.8	2.0	0.6
Retouched Pieces	3.1	7.5	2.0	3.1

Objective 5: Assessing Information Potential

Dampf (2002) provided information useful in achieving the fifth objective, which is to confirm the future research potential of the 45PI429 site and eligibility for future recommendation to the National Register of Historic Places (NRHP). According to Dampf (2002), archaeological sites are underrepresented on the NRHP, with less than 10% of NRHP listings being archaeological sites (Sprinkle 1995). There are four NRHP criteria for evaluation of the significance of a structure, site, or object, with Criterion D being the one under which most archaeological sites are qualified (Andrus and Shrimpton 2002). Criterion D is the yielding of, or potential to yield, information important to our understanding of history or prehistory (Andrus and Shrimpton 2002). According to Dampf (2002) the ability of an archaeological site to meet the requirements of Criterion D is measured through its ability to provide information that can be used to answer questions pertinent to current research.

For a property to be listed it must also pass evaluation for integrity as well as significance, which is defined by NRHP publications as the ability of a property to convey its significance (Andrus and Shrimpton 2002). For archaeological sites, this is based on a site's potential to yield data, rather than on the overall condition of the site (Andrus and Shrimpton 2002). Archaeological sites nominated to the NRHP under Criterion D are understood to have undergone cultural and natural processes that alter the deposited materials and their spatial relationships. Information potential and integrity as determined for the 45PI408 by Dampf (2002) were based on whether or not the site possessed the stratigraphic integrity and context for the lithic assemblage to be studied and provide data that answered the research questions. As a result, Dampf (2002) drafted a form nominating the 45PI408 site to the NRHP. Based on the stratigraphic integrity, the data yielded through analysis of the 45PI429 assemblage, and the potential for further data obtained through future research of the 45PI429 assemblage, the 45PI429 site is eligible to be nominated to the NRHP under Criterion D.

CHAPTER IV

MEASURING TECHNOLOGICAL AND FUNCTIONAL VARIATION BETWEEN FOUR MONTANE LITHIC ASSEMBLAGES ON MOUNT RAINIER, WASHINGTON

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MEASURING TECHNOLOGICAL AND FUNCTIONAL VARIATION BETWEEN FOUR MONTANE LITHIC ASSEMBLAGES ON MOUNT RAINIER, WASHINGTON

Joy D. Ferry and Patrick T. McCutcheon

ABSTRACT

Archaeologists have recognized the importance of montane environments in the subsistence and settlement strategies of pre-contact peoples in the past few decades. Four lithic assemblages (45PI406, 45PI408, 45PI429, and 45PI438) from sites in the upper maritime forest and subalpine zone of Mount Rainier were compared. Little is understood about functional and/or technological variation between montane sites in comparable environmental settings. An evolutionary archaeology model was applied to define and measure variables relevant to stone tool manufacture and use. Statistically significant non-random associations were contextualized within the known environmental constraints and regional land use models for upland subsistence and settlement strategies in the southern Washington Cascades. The assemblages were dominated by debitage are consistent with those produced as a result of tool manufacture at limited activity sites. However, the assemblages differ synchronically in the frequency and type of use wear, as well as reduction trajectories for tool manufacture, indicating that local climate regimes and microenvironments and significantly influenced stone tool manufacture and use.

INTRODUCTION

Increased funding and research in recent decades has enabled archaeological surveys recording hundreds of upland pre-contact archaeological sites in the southern Washington Cascades (e.g., Andrews 2008; Burtchard 1995; Dampf 2002; Lewarch and

Benson 1991; Meirendorf 1986; Vaughn 2010). Efforts to understand prehistoric subsistence and settlement patterns in montane landscapes have significantly increased within Mount Rainier National Park resulting in the documentation of nearly 100 archaeological sites (Burtchard 2007:3-4). However, the amount of functional and technological data available remains low (particularly for intersite comparisons) in comparison to the large amount of recorded pre-contact archaeological sites in the southern Washington Cascades (Andrews 2008:1; Vaughn 2010:2).

With the purpose of increasing our understanding of upland land use subsistence and settlement patterns in the Pacific Northwest, this research adds to the growing body of data on excavated upland archaeological sites in the Washington Cascades. Our general strategy is to ascertain how people used upland landscapes and whether those efforts contained a "mountain lithic tool kit" or whether this type of material culture was varies more by microenvironment.

The research question is: What were the selective conditions of the variable microenvironments on Mount Rainier, under which stone tools were made and used? The selective conditions in the past were made up of the environmental constraints (effects of the environment) that influenced stone tool manufacture and use at each site. It is possible that mountain environments have limiting selective conditions on the subsistence and settlement patterns, due to the character of their extreme environmental conditions relative to lowland habitats (e.g., annual snow fall). Identifying the selective conditions under which people made and used stone tools provides an empirically based and theoretically informed understanding of how past people organized their stone tool technology (McCutcheon 1997).

The research hypothesis is tested with data from four lithic assemblages from the upland environments of Mount Rainier. Significant inter-variable relationships indicated through non-random associations, are explained within the implied environmental conditions (inferred from paleoclimate data) and hypotheses of existing pre-contact subsistence and settlement models. This contributes to a scientific understanding of past human interactions with the selective conditions of the environment in an upland context, as explained through evolutionary mechanisms.

Previous studies of pre-contact sites in the southern Washington Cascades provide a regional basis against which to compare the results of this research (Andrews 2008; Burtchard 2003, 2007; Dampf 2002; Schurke 2011; Vaughn 2010). Following the approaches applied in previous research by McCutcheon (1997), Dampf (2002), and Vaughn (2010), I have made a synchronic comparison of the analyzed artifacts from the Buck Lake (45PI438) (Schurke 2011), Forgotten Creek (45PI429), Tipsoo Lake (45PI406), and Sunrise Ridge Borrow Pit (45PI408) (artifacts recovered prior to 2011 fieldwork) lithic assemblages.

STUDY SITES

The assemblages being compared in this research are all from pre-contact archaeological sites on the slopes of Mount Rainier (see Figure 1). The 45PI429 site is situated on the southwestern slope of Mount Rainier in the upper Nisqually River Valley, at about 4300 ft. elevation in the Pacific Silver Fir and Mountain Hemlock zones of the upper Northwestern maritime forest (Vaughn 2010:19). The assemblage was excavated from tephra layers with substantial stratigraphic integrity.

The 45PI438 site is situated on a mountain bench landform on the northeastern slopes of Mount Rainier in the Mountain Hemlock and subalpine parkland meadow zones of the upper maritime forest (near the subalpine zone) at 5400 ft. elevation, (Schurke 2011). The 45PI406 site is located in the Mountain Hemlock and subalpine meadow zones, on the western slope of Mount Rainier in the Ohanapecosh drainage at about 5440 ft. elevation.

The 45PI408 site is also located on the eastern slope of Mount Rainier, in the White River drainage at 4884 ft. elevation above mean sea level in the Mountain Hemlock zone of the upper Northwest maritime forest (Vaughn 2010:19, 26). These sites occupy slightly different environmental settings on different slopes of Mount Rainier, with drier, grassy parklands on the northeastern side of the mountain due to the rain shadow effect (Burtchard 2007:4). Lush, herbaceous meadows that are resource rich occur mostly on the southern and western slopes of Mount Rainier (Burtchard 2003:27).

Mount Rainier is formed of layers of andesitic rock, deposited as lava flows on top of the Tatoosh pluton geological formation, which was formed between the early Miocene and late Pliocene, and is composed largely of granitic rock (granodiorite) (McCutcheon and Dampf 2002:7; Burtchard 2007:3-4; Fiske et al. 1963:40, 63, 90).

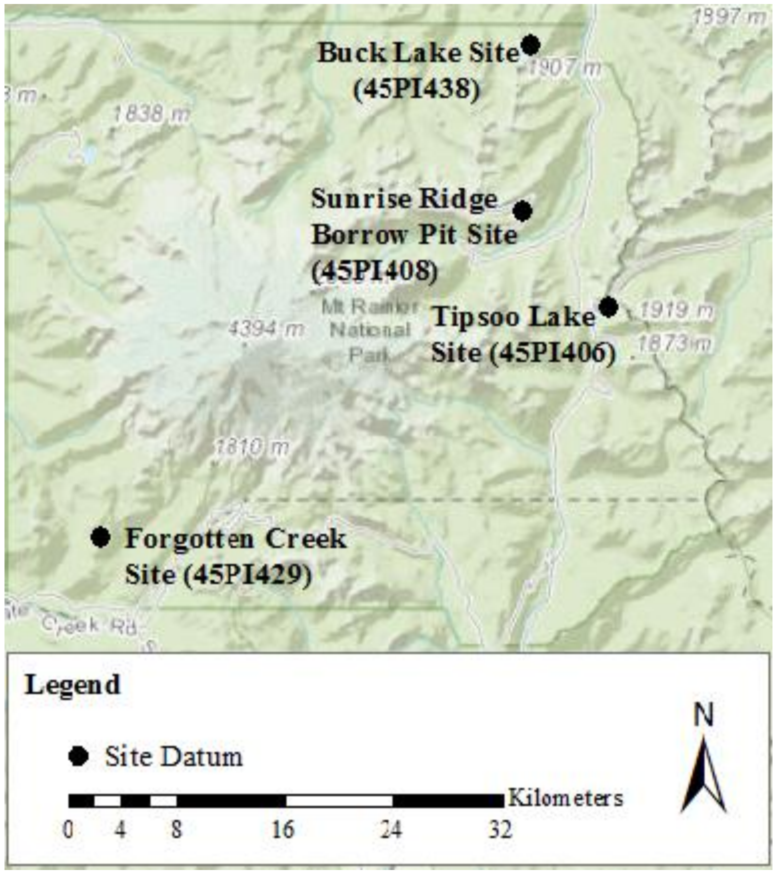

Figure 1. Locations of the Sites being Compared in this Research.

ENVIRONMENT

Within the past 10,000 years series of pyroclastic events from Mount Rainier, Mount Saint Helens, and Mount Mazama have deposited layers of tephra, illustrated in Figure 2, that have been well studied and dated, the most recent of which was deposited approximately 150 years ago (Mount Rainier tephra layer X) (Mullineaux 1974; Sisson and Valance 2008). This kind depositional context is precisely what is necessary to evaluate changes in lithic technology and function across space and through time, as the tephra marker beds are wide spread and the same ones are found across a number of microenvironments in the southern Washington Cascade Mountains.

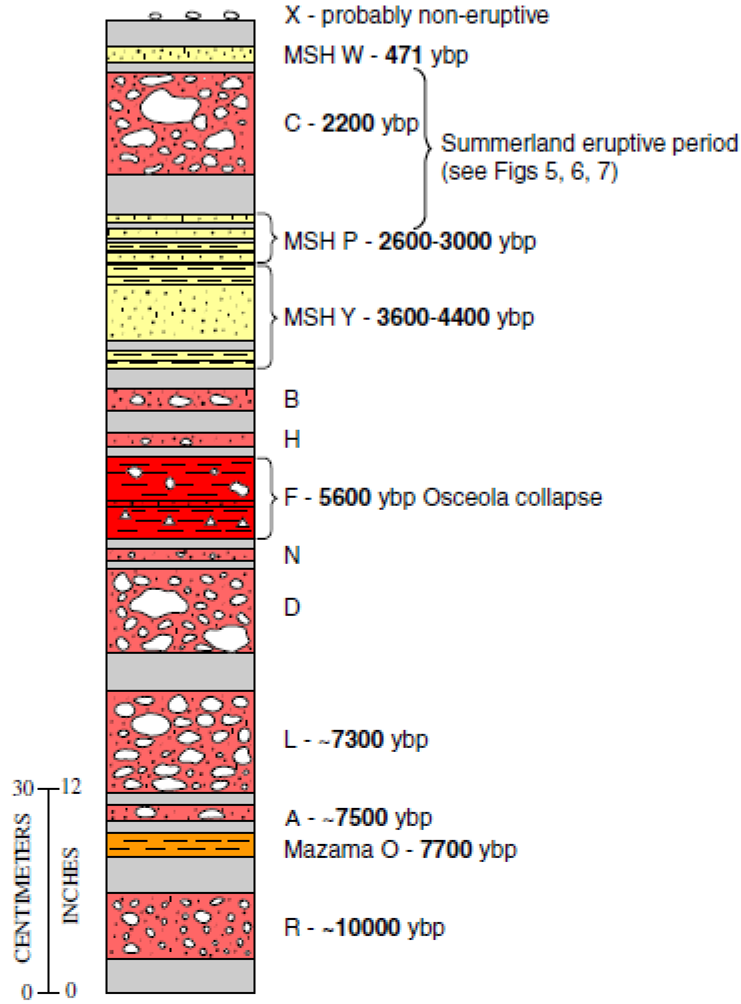

Figure 2. Tephra layers on Mount Rainier from Sisson and Valance (2008:6).

Burtchard (2007:1-4; 2003:3-28) covers the environment of Mount Rainier in great depth. Because of the unique geological landscape of Mount Rainier, the environmental characteristics vary widely with elevation and moisture levels, with late seral stage environments decreasing at higher elevation (Burtchard 2007:4, 2003:4). This, at least in part, creates distinct environmental gradients on the slopes of Mount Rainier, which were divided into five main zones by Burtchard (2007:4, 2003:28): low to mid-elevation Northwestern maritime forests, river systems and associated floodplains, subalpine parkland, alpine tundra, and permanent snowfields and glaciers. The availability of resources varies greatly with elevation and environmental zone, with decreased resource availability in the late seral stage or mature habitats of lowland maritime forests (Burtchard 2003:16-17).

The majority of pre-contact archaeological sites recorded in the park are located in the upper Northwestern maritime forest and subalpine parkland zones, which are considered the most resource rich habitats due to the vegetative resources provided to mammals by the early seral stage patchy subalpine forest and open wet meadows (Burtchard 2003:28, 2007:3-4). The vegetative resources in the subalpine zone lead to a greater diversity and abundance of game animals (Burtchard 2003:28). The role of fire in these environmental zone is a critical factor in maintaining open land scapes (Burtchard; Dunwiddie; Nickels).

History of pre-contact fire regimes are available, obtained from lake core sediment data (Lukens 2013; Tweiten 2007). Lake core sediment data shows that prior to 4000 cal yrs BP (Tweiten 2007:9) vegetation in the area had a more open structure and consisted mainly of pines. After 4000 cal yrs BP, tree cover was denser, and fir became the dominant vegetation (Tweiten 2007:9). The forest around Buck Lake temporarily returned to more open structure following the deposition of the MSH Y tephra layer (4400-3000 cal yrs BP) (Tweiten 2007:9), possibly as a result of the pyroclastic event. According to macroscopic charcoal counts in the sediment core data, there was also a (inferred) increase in anthropogenic burning in the area, around 2700 cal yrs BP (Tweiten

2007:9). As Burtchard (2003:17, 21) notes, important food plants for mammals (e.g., huckleberry) increase in frequency when fir forests are disturbed by fire.

ASSEMBLAGES

All assemblages are from pre-contact sites on the slopes of Mount Rainier that have undergone well-documented subsurface excavations. The current total lithic assemblage from 45PI429 consists of 1,104 pieces of debitage, including a complete stone point (Columbia corner notched A [Carter 2010]). The stratigraphic context of the assemblage ranges from 7627 cal yrs BP to present (see Table 1) based on the associated, radiocarbon dated tephra layers (Burtchard 2011:16; Mullineaux 1974, 1996).

Table 1. Division of Cultural Components According to Tephra Layers (Mullineaux (1974:25).

Cultural Component	Calibrated Years BP	Sites		
		45PI429	45PI438	45PI408
Post-MSH Y (tephra layers X through P)	Present-3000	X	X	X
MSH Y tephra set (lower tephra bed, tephra layer MSH Yn, and upper tephra beds)	4400-3000	X	-	X
Pre-MSH Y (tephra layers B through R)	4400-7627	X	X	-

Only a sub-sample of the 45PI438 assemblage has been analyzed and is used for statistical comparisons in this study. The portion of the assemblage compared here consists of 2,354 pieces of stone debitage, and were analyzed in previous research effort (Schurke 2010). The assemblage was excavated from the pre-MSH Y and post-MSH Y tephra components (Schurke 2010). The 45PI438 assemblage was analyzed using a free-standing typology, based on Andrefsky (2005:129), and influenced by Sullivan and Rozen (1985) and Flenniken (1986). Comparisons to the 45PI438 assemblage using the current classifications were accomplished using an analytical key explained below (see also Vaughn 2010).

Lithic assemblages of two other high elevation sites on Mount Rainier, the 45PI406 and 45PI408 sites, have been studied using identical analytical protocols as the ones applied to the 45PI429 assemblage (Vaughn 2010). The 45PI408 site is a pre-contact site, and the assemblage is composed of 4,452 pieces of stone debitage, excavated 1997 to 2001, and analyzed and reported previously (Lewis et al, 2011; Vaughn 2010). While the MSH Y tephra layer was present at 45PI408, there were very few artifacts recorded below it. However, there was a pronounced Mount Rainier C tephra layer above it and that tephra marker bed separated two substantial parts of the lithic assemblage and has been used in past studies to demarcate separate archaeological components (Lewis et al. 2011) As a result, the recorded tephra layers allowed for the assemblage to be separated into a MSH Y and a post MSH Y component for the purposes of this research.

The 45PI406 assemblage consists of 867 pieces of stone debitage, and is from a mixed component site with mixed stratigraphic integrity. Excavators noted the presence of historic artifacts in some excavation units, as well as mixed tephra layers due to bioturbation and freeze/thaw (McCutcheon 2014, personal communication). As a result, the assemblage was not segregated into components, but instead, is limited to whole site comparison with the other sites in this research.

METHOD

An evolutionary archaeology model is applied in this research as the analytical strategy guiding investigation of the lithic assemblages. When studied using a Darwinian evolutionary approach, the archaeological record provides a historical sequence of variation and lineages (O'Brien and Lyman 2000:19-20).

Darwinian evolution can be applied to solve archaeological problems by creating materialist archaeological units that measure variation (O'Brien and Lyman 2000:20). To solve archaeological problems, the units of analysis must define classes that will measure the results of people interacting with their environment. Archaeological units must also be generated from specific information in order to address specific issues, and must be able to be generated through equally demanding standards (O'Brien and Lyman 2000:21). In this manner, Darwinian evolution can be used to generate explanations for observed variation in the archaeological record (O'Brien and Lyman 2000:20).

Using an evolutionary archaeology model also allows assessment of whether the modes of the dimensions are independent of environmental factors, or if they exhibit a non-random association with geographically variable environmental factors (Endler 1986; O'Brien and Lyman 2000). As such, it is recognized that the long-term study of variation (in the frequency distribution of traits) through an evolutionary archaeology model is the most effective method of detecting the selective conditions under which stone tools are manufactured and used (Endler 1986; O'Brien and Lyman: 2000).

Functional and technological variables are patterned by the demands of the environment of interaction or natural selection, while style is patterned by a different mechanism (e.g., cultural transmission). This is because rather than being influenced wholly by the selective conditions of the local environment, style is transmitted through contact, trading, and the movement of people (Lyman 2008:11). Cultural transmission of style occurs through the mechanisms of acceptance, integration, social status, and within social systems in which information can be exchanged (Lyman 2008:16). As a result, style, defined by Dunnell (1978a:200) as stochastic, should only be used explicitly for chronology and spatial interactions within an archaeological context.

If there are no selective conditions detected in an analysis of technological and functional variables, sorting could be explained through other mechanisms such as cultural transmission. For instance, if no selective conditions are detected, differences in stone tool assemblages could be the result of stylistic differences between groups using the slopes of Mount Rainier. Projectile point styles are one trait that is a stylistic difference patterned by cultural transmission. However, there may be other culturally transmitted differences such as the color of the tool stone used, particular set ups on cores, or shapes of flakes that do not affect performance. Also, as noted in McClure (1992:80), due to the many incongruent stylistic classification schemes for the southern Washington Cascades, it is nearly impossible to make direct comparisons of style between studies. This research seeks to identify the conditions that caused selective differences, that is, the environmental context that causes differences in technology and function. Thus, an analysis of functional and technological variables better achieves the objectives of this research.

Functional variables (Dunnell 1978a) are those that directly interact with the environment when the tool is used to perform specific tasks, while technological variables are defined as the end result of the application of available technology to decrease the cost of stone tool manufacture while increasing performance for use (McCutcheon 1997).

In order to define the variables that will be measured within an evolutionary archaeology framework, McCutcheon's (1997) cost-performance research model was applied. The cost-performance model has been adapted to an upland context and employed in previous studies (Dampf 2002, Vaughn 2010).

The evolutionary approach of McCutcheon's (1997) cost-performance model provides the benefit of being exclusively concerned with the relative cost and performance variables in stone tool manufacture and use. In those places where non-random relationships occur, the relationships could be the result of natural selection acting on those individuals using the stone tools. Because the approach of McCutcheon's (1997) technique employs paradigmatic classification, the variation in stone tool manufacture and use is measured, and the paradigms can be used to generate data that reveals where selective conditions created subtle differences in stone tool manufacture and use.

In McCutcheon's (1997) cost-performance model, the inter-variable relationships between cost and performance variables (and their sub-variables) are used to identify what might be found (archaeological expectations) given different variable states. The structure of the environment affects the nature of the lithic assemblage that result from human land use (Ingbar 1994; Teltser 1991:372-373). For example, if raw material is rare, that will have implications for the range of forms found and in this case could result in lithic assemblages with more evidence of highly curated stone tools. Non-random associations of cost and performance variables across different microenvironments could identify differences in selective conditions that past peoples adapted to in past environments.

Cost variables are based on the relative amount of energy required in stone tool manufacture. Cost includes energy expenditure in the preparation of raw material for stone tool manufacture, the cost of raw material acquisition, and stone tool manufacture. Raw material acquisition is based on factors such as raw material abundance, the relative distance from the raw material source to the place of manufacture, and the intended use location. The relative cost (or steps in stone tool manufacture and preparation) is interrelated with rock physical properties, tool requirements, and the technology being employed to prepare and manufacture stone tools. In the model, changes in one variable (e.g. increased cost) can be offset by changes in the other variable (e.g. increased performance). For example, a raw material with higher acquisition cost may decrease cost in other areas such as increased tool symmetry or edge sharpness (McCutcheon 1997).

Performance variables are based on how well a stone tool accomplishes the task for which it was manufactured within its environment of interaction. The selective conditions of performance can be identified through looking at the inter-variable relationships between the rock physical properties of the raw material being used, the available stone tool manufacture technology, and the requirements of the tasks being performed. These variables affect outcomes such as the amount of wear incurred through use, accidental breakage, and how well the tool performs the given task. Technology used in stone tool preparation and manufacture, such as heat treatment, can reduce durability and/or mitigate rock physical properties that cause wear and breakage, resulting in increasing tool performance during use, but causing the tool to wear faster (McCutcheon 1997). With all other variables (e.g., performance) being equal, stone tools that have lower costs as relative to their performance will outcompete more expensive ones (Vaughn 2010:35).

Lipo and Eerkens (2008:124-125) created a formula to determine how significant the effects of formation processes are on measures of similarity between assemblages. The formula, Similarity = *f* (Preservation, Turbation, Field Methods) uses the three primary formation processes (Lipo and Eerkens 2008:125). Using this formula, it can be determined the degree to which the statistically significant associations were influenced by these formation processes.

At all sites, the pre-contact artifacts were well preserved, as the assemblages consist of stone debitage and tools. Furthermore, the sites were not heavily disturbed, with the exception of 45PI406, which is a mixed component site. Field observations and assessments of stratigraphic integrity at the 45PI408, 45PI429, and 45PI438 sites contained artifacts that were intercalated between distinct tephra layers. At each of these sites there was evidence of some post-depositional alteration, but not to the extent where large scale mixing would have resulted like at 45PI406. To account for the post-depositional alterations at 45PI406, this assemblage is used only in whole-site comparisons. Additionally, bias in field methods is not a factor since all assemblages in this study were excavated in a consistent manner using 1/8-inch mesh.

While some primary formation processes may have impacted our measures of similarity, the violence done to the data is minimized because of the large sample sizes and aggregating the artifacts using stratigraphically distinct layers. Also, we performed a resampling analysis that allowed us to select only those dimensions for which we had representative attribute frequencies. Thus, we conclude that statistically significant associations are the result of sorting in the archaeological record caused by the selective conditions of the environment or natural selection.

MODEL FOR COMPARISONS

Comparisons of the post MSH Y component at all three sites attempt to isolate artifacts that are a result of the post MSH Y occupations, which would have occurred on the surface of the MSH-Yn tephra layer. Recently obtained obsidian hydration values from the Beech Creek assemblage indicate constant use throughout the Holocene, beginning before 7500 cal yrs BP, and ending around ca. 500 cal yrs BP (Mack et al. 2010:128,130-131). Tweiten (2007:9) noted that cultural materials became more abundant in the archaeological record following the deposition of the MSH Yn tephra layer between 3350-3400 cal yrs BP, possibly as a result of reduced seral stage (Tweiten 2007:9). This indicated that at some sites there was no significant hiatus in occupation or use during the period in which the MSH Y tephra set was deposited. It is beneficial to this research to take into account this more recent evidence from Mack et al. (2010) that if there were a hiatus in occupation, it could have been brief enough that it did not greatly affect the contiguity of the archaeological record, and that occupation possibly occurred directly on the newly created surfaces of the MSH Y tephra layers.

As such, artifacts recorded as excavated from the MSH Y tephra layer have been separated into a distinct component for synchronic statistical comparisons. This was possible because the date range of the MSH Y tephra layers is known, the MSH Y tephra layers were clearly identified at the 45PI429 and 45PI438 sites, and an equivalent component was identified at the 45PI408 site. As the sample size of the 45PI429 assemblage is limited, all of the artifacts are considered as providing data vital to the full understanding of the archaeological record, so all artifacts excavated from the 45PI429 site have been analyzed in this research.

In a 2011 analysis of the 45PI438 assemblage, artifacts that were excavated from within the MSH Y tephra layer were not analyzed. Rather, the MSH Y tephra layers were used as a buffer between the pre-MSH Y and post-MSH Y components (Schurke 2011). Therefore lithics from the MSH Y component of the 45PI438 assemblage are not used in comparisons in this study.

The lithic assemblage excavated from the 45PI408 during the 1997-2001 field seasons was attributed to having been excavated from either above or below MR-C, which was always present and distinguishable due to its marked color and texture. Also, only a negligible amount of artifacts were found below the MSH Yn tephra layer in the 45PI408 site. As such, the components within the 45PI408 assemblage are labeled "Above MR C" (present-4400 cal yrs BP), or "Below MR C" (4400-7627 cal yrs BP) (Mullineaux 1974:25). Despite the lack of being delineated by the MSH Yn tephra layer, the Below MR C component of the 45PI408 includes the MSH Y tephra set, and the radiocarbon dates ranges are comparable to those of the MSH Y component in the 45PI429 assemblage.

TECHNIQUES

In the southern Washington Cascades, stone tools are usually the only artifacts found in pre-contact archaeological sites. Detailed studies of upland artifact assemblages have described lithic assemblage variability using standardized lithic analysis methods (e.g., Schurke 2011; Vaughn 2010), allowing comparisons between assemblages. Additional use of these analytical keys contributes to the development of a general picture of stone tool manufacture and use in upland contexts.

The paradigmatic approach taken here is a lithic classification system that was previously applied to pre-contact assemblages from Mount Rainier National Park by Dampf (2002) and Vaughn (2010). Each classification is multi-dimensional. These classificatory schemes have been in use in the Pacific Northwest Region region for over 40 years (Campbell 1981; Dampf 2002; Dancey 1973; Dunnell and Lewarch 1974; Lewis et al. 2014; Vaughn 2010). The 45PI429 assemblage was analyzed using the same set of paradigmatic classifications used in Vaughn's (2010:40) analysis to generate data on technological, functional, and the rock physical property dimensions. Quality control for lithic analysis of the 45PI429 assemblage consisted of randomly selecting a 10% sample for reanalysis. In a comparison of reanalysis to the original analysis there was less than 6% divergence.

The 45PI438 site lithic assemblage is the only assemblage in this research that was not originally analyzed using paradigmatic classification system. To create comparable data for the purpose of synchronic comparisons between sites, the data that Schurke (2011) provided was translated to McCutcheon's (1997) paradigmatic classification system. Translation was accomplished by identifying equivalent dimensions to those in McCutcheon's (1997) paradigmatic classification from those provided in the "Lithic Debitage Analysis Data Entry Codes" in Appendix B of Schurke's (2011) master's thesis. Dimensions with equivalent definitions to those in McCutcheon's (1997) paradigmatic classification were assigned to those equivalent classes (Schurke 2011:123-125).

There were some dimensions of the paradigmatic classification that were not identified or measured in Schurke's (2011) research, but that were identified and measured through paradigmatic classification of the other assemblages. These were amount of dorsal cortex, other modification, and thermal alteration. Rock physical property or functional (use-wear) analyses also were not applied to the 45PI438 assemblage. Of the dimensions that were equivalent, fewer classes of these dimensions were measured than are measured using McCutcheon's (1997) paradigmatic classification. For example, only flakes, and not any other fragment types (e.g., bifaces, cores, etc.) were analyzed.

The dimensions that were not addressed in the current available analysis of the 45PI438 lithic assemblage, combined with the less diverse measurements of the classes of these dimensions, limits the direct synchronic comparisons that can be made between the 45PI438 assemblage and the other assemblages. However, the comparisons that can be made from the available data are highly valuable in understanding the upland pre-contact archaeological record, as well as demonstrating the flexibility of the paradigm in that other classifications can be accurately translated to the paradigmatic classification system, albeit at a lower analytical resolution (Vaughn 2010).

The proportions of technological and functional dimensions present in the pre-MSH Y, MSH Y, and post-MSH Y components for each assemblage were compared within components between the 45PI429, 45PI438, and 45PI408 assemblages. The frequencies for the modes of each dimension were compared as an initial identification of variation in order to guide the following statistical analysis.

Resampling protocol established by Vaughn (2010:56-60) was followed to ensure that non-random associations would not be driven by sample sizes. This technique uses "Resampler," a statistical program that applies bootstrapping to display the representativeness of a sample without drawing assumptions about the population from which the sample was obtained (Cochrane 2002; Lipo and Eerkens 2008; Mohr et al. n.d.; Mooney and Duvall 1993; Vaughn 2010). Resampler graphs are assigned to one of three types of cumulative frequency, each of which has mutually exclusive, quantitative characteristics established by Vaughn (2010:56-60): Rank 1, Rank 2, and Rank 3. Based on Vaughn's (2010:56-60) protocol, Rank 1 curves indicate that the results of statistical comparisons can be considered conclusive because they are based on a sufficiently representative sample, Rank 2 curves indicate that the results of statistical comparisons can be considered suggestive, and Rank 3 curves are excluded from statistical comparisons because they are insufficiently representative.

In order to identify the technological organization of assemblages, the debitage from the assemblages involved in this study has been classified according to the four Sullivan and Rozen (1985) technological groups. According to Sullivan and Rozen (1985:762-766), debitage can be assigned to these four distinct technological groups based on the proportion of six technological categories within an assemblage, the characteristic proportions of which are shown in Table 2 (1985:762-766). These technological categories are complete flakes, broken flakes, flake fragments, debris, cores, and retouched pieces. The four technological groups are unintensive core reduction (IA), tool manufacture (II), intensive core reduction (IB2) and core reduction and tool manufacture (IB1).

Table 2. Average Artifact Category Percentages of Technological Groups. From Sullivan and Rozen (1985:763).

	Technological Group			
Artifact Category	IA	IB1	IB2	II
Complete flakes	53.4	32.9	30.2	21.0
Broken flakes	6.7	13.4	8.1	16.8
Flake fragments	16.0	35.3	34.7	51.3
Debris	6.1	7.9	23.0	7.3
Cores	14.7	2.8	2.0	0.6
Retouched pieces	3.1	7.5	2.0	3.1

Non-random associations between the modes of dimensions were identified through chi-squared testing, or log-likelihood testing when sample sizes were insufficient for chi-squared testing (VanPoole and Leonard 2011:238-253; Zar 1974). When non-random associations were identified, nonparametric test ($\chi2$ or g values) were used to assign Cramér's V values. The values (based on the χ_2 or g values) compared with the degrees of freedom measured the effect size (Cohen 1988:115-116). In this manner, the effect size was corrected for sample size. If there is a statistically significant non-random association, the effect size is a measure of non-randomness that augments the interpretation of chi-square/log likelihood statistical comparisons.

RESULTS

Technological Groups (Completeness and Platform Type)

Each lithic assemblage was assigned to one of Sullivan and Rozen's (1985) technological groups in order to identify distinct patterns through time in the technological organization of the assemblages (Sullivan and Rozen 1985:763-764). As shown in Table 3, the most common technological group was II (tool manufacture), followed by technological group IIB (intensive core reduction). The technological group 1B2 is a mix of core reduction and tool manufacture (Table 3). Technological organization of the assemblages varies among sites. For instance, the pre-MSH Y component of the 45PI429 assemblage is a mixed tool manufacture and core reduction technological group, whereas the 45PI438 assemblage is indicative of intensive core reduction. The post-MSH Y component of the 45PI438 assemblage contains a large frequency of debitage, indicative of intensive core reduction, which differs from the technological organization of the 45PI429 and 45PI408 assemblages, both of which resemble tool manufacture technological groups. The pre-MSH Y component of the 45PI429 assemblage differs from the later components in that the proportions of modes of completeness closely resembled those of a Group (IB1) assemblage, with many small thin, non-cortical flakes. Uniquely, the 45PI438 assemblage is assigned to intensive core reduction, as debris makes up a significant proportion of lithic debitage in the sample and across components.

Table 3. Technological Groups of the Assemblages (Sullivan and Rozen 1985:763).

	Assemblage			
Component	45PI429	45PI438	45PI408	45PI406
Whole site	II	IB2	II	II
Post-MSH Y	II	IB2	II	-
MSH Y	II	-	II	-
Pre-MSH Y	IB1	IB2	-	-

Statistical Comparisons

Statistical comparisons were made among the filled class frequencies as seen in Table 4, which shows the counts by dimensions and their modes for each assemblage. While Table 4 shows counts for whole assemblages (coarse-grained) these frequencies were also used for comparisons between sites within the post-MSH Y, MSH Y, and pre-MSH Y components.

Table 4. Counts of Modes Compared for Whole Assemblages.

		Sites			
Dimension	Mode	45PI406	45PI408	45PI429	45PI438
Raw Material	Chert	682	4168	1037	2279
	Obsidian	36	40	3	-
	Igneous	41	200	17	75
Completeness	Whole Flake	7	67	74	227
	Broken Flake	148	1310	528	129
	Flake Fragment	592	2797	413	1249
	Debris	15	71	58	749
Thermal Alteration	Lustrous /Non-lustrous	12	229	272	281
	Lustrous Only	690	3075	647	661
	High Temperature	48	365	50	52
Reduction Class					
	Initial	2	11	10	57
	Intermediate	90	32	261	335
	Terminal	-	1089	282	-
	Bifacial Thinning	20	61	-	-
	Bifacial Resharpening	33	94	24	-
Use Wear	Present	218	619	34	-
	Absent	814	3833	1070	-
Platform Type	Cortical	21	-	1	5
	Simple	92	14	255	303
	Faceted	447	71	94	46
	Bifacial	117	53	12	-
	Fragmentary	2146	584	354	-
	Pressure	360	19	112	-
	Technologically Absent	25	1	20	-

The null hypothesis for all comparisons was that differences between assemblages in variable environmental zones are random. Non-random associations potentially revealed the effects of sorting in the archaeological record as patterns in the distribution of the modes of each dimension. Our argument is that sorting was caused by apparent selective conditions that influenced stone tool manufacture and use at the sites. Table 5 summarizes the results of seven coarse-grained (whole site) comparisons, where seven out of eight comparisons resulted in statistically significant non-random associations that rejected the null hypothesis (a comparison of fragment type between the four assemblages resulted in acceptance of the null hypothesis).

Table 5. Statistically Significant, Non-Random Coarse-Grained Associations.

Dimension	Assemblages	Cramér's V ($\chi 2$)	*df*	Strength of Association
Thermal Alteration	45PI406 45PI408 45PI429	0.2	2	Small
Use Wear	45PI406 45PI429 45PI408	0.13	1	Small
Completeness	45PI406 45PI408 45PI429 45PI438	0.31	3	Large
Platform Type	45PI406 45PI408 45PI429	1.25	9	Large
Reduction Class	45PI406 45PI408 45PI429 45PI438	0.52	4	Large

Table 5 (Continued).

Dimension	Assemblages	Cramér's V ($\chi 2$)	*df*	Strength of Association
Complexity of Dorsal Surface	45PI438 45PI406	0.76	1	Large
Raw Material	45PI406 45PI408 45PI429 45PI438	0.1	3	Small

Rejection of the null hypothesis by the majority of coarse-grained comparisons indicates that there is abundant evidence for sorting in the attribute frequencies across filled stone tool manufacture classes. Resampling results ensure that some level of representativeness was present in all comparisons, and lacking site formation or recovery technique biases that could bias frequencies, the these initial whole-site comparisons show that technology is significantly variable across space.

In the synchronic comparisons shown in Table 6, sample sizes were frequently insufficient for chi-squared testing, in which case log likelihood test results were substituted. No non-random associations resulting from synchronic comparisons indicated a large strength of association. Out of a total of 31 coarse-grained and synchronic statistical comparisons, 17 of these resulted in a rejection of the null hypothesis. A minimum of one half to a maximum of 100% of cell values contributed to the rejection of the null hypothesis.

Table 6. Statistically Significant, Non-Random Synchronic Associations.

Component	Dimension	Assemblages	Statistically Significant Association	χ2 or g Value > p	Cramér's V (χ2 or *g*)	*df*	Strength of Association
Pre-MSH Y	Raw Material	45PI429 45PI438	*G*	31.10	0.31	2	Medium
	Completeness	45PI429 45PI438	*G*	33.44	0.36	3	Medium
MSH Y	Reduction Class	45PI429 45PI408	*G*	132.10	0.35	4	Medium
	Thermal Alteration	45PI429 45PI408	χ^2	53.35	0.13	2	Small
	Completeness	45PI429 45PI408	*G*	120.40	0.19	3	Small
Post-MSH Y	Thermal Alteration	45PI429 45PI408	χ^2	32.22	0.18	2	Small
	Use Wear	45PI429 45PI408	χ^2	38.31	0.18	1	Small
	Raw Material Type	45PI429 45PI408 45PI438	*G*	85.38	0.11	2	Small
	Reduction Class	45PI429 45PI408	χ^2	66.15	0.41	4	Medium
	Completeness	45PI429 45PI408 45PI438	χ^2	657.67	0.32	3	Medium

Use Wear

In a comparison of use wear between sites, the 45PI429 assemblage had a lower presence of use wear than the 45PI406 and 45PI408 assemblages. Analysis of residuals shows that the non-random association between assemblages for wear was driven by both the presence and absence of use wear in all assemblages (See Use Wear in Table 4 for the frequency of use wear present in each assemblage).

In both the post-MSH Y component the proportion of use wear was significantly higher in the 45PI408 assemblage than in the 45PI429 assemblage (Table 4). Analysis of the residuals shows that the non-random association between the assemblages in the post-MSH Y component was driven by both presence and absence of Use Wear in the 45PI408 and the 45PI429 assemblages.

Overall, the most frequent functional wear types were very low in diversity, only differing in the shape of wear for all assemblages. All wear in the most frequent functional wear types in all components of the 45PI406, 45PI408, and 45PI429 assemblages consisted of unifacial chipping on a convex, concave, or straight angular edge (in relative order of frequency).

Raw Material

Chert was present in significantly higher frequencies than all other raw material types combined in all assemblages, as shown in Table 7. According to analysis of the residuals, non-random association between components of the assemblages for raw material type was driven by greater and lower than expected frequencies, for all types of raw material in all assemblages, except obsidian in the 45PI429 assemblage.

Table 7. Coarse-Grained Raw Material Distribution for All Sites.

	45PI408	45PI438	45PI406	45PI429
Chert	94%	97%	89%	98%
Obsidian	1%	-	5%	-
Igneous	4%	3%	5%	2%
Other	1%	-	1%	-
Grand Total	100%	100%	100%	100%

In a comparison between the 45PI408, 45PI429, and 45PI438 assemblages in the post-MSH Y component, the 45PI408 assemblage has a 6% lower proportion of chert than the other assemblages. Association was driven by higher frequencies of all Raw Material types than expected in the 45PI408 assemblage, and lower frequencies of all Raw Material types than expected in the 45PI438 assemblage.

In the MSH Y component of the 45PI429 and 45PI408 assemblages, comparisons show no significant variation in the distribution of Raw Material types in both assemblages. Analysis of residuals shows that the non-random association between the 45PI429 and 45PI408 assemblages was driven by higher and lower than expected frequencies of Raw Material types.

In a comparison of the 45PI429 and 45PI438 assemblages in the pre-MSH Y component, the 45PI438 assemblage has a significantly higher proportion of chert (21%) than the 45PI429 assemblage. All cell values had significantly contributed to the rejection of the null hypothesis (See Table 8)

Of note, due to the distance from the source (Obsidian Cliffs in Oregon), in the 45PI429 assemblage obsidian was present in the highest frequency in the pre-MSH Y component, in a lower frequency in the MSH Y component, and completely absent from the post-MSH Y component.

Table 8: Residuals for Synchronic Comparisons

Component	Dimension	Modes	Residuals > 1.96	Residuals < -1.96
Pre-MSH Y	Raw Material	Chert	45PI438	45PI429
		Obsidian	45PI429	45PI438
	Completeness	Broken flakes	45PI429	45PI438
		Debris	45PI438	45PI429
MSH Y	Reduction Class	Initial	45PI429	45PI408
		Intermediate	45PI429	45PI408
		Terminal	45PI408	45PI429
		Bifacial Resharpening	45PI408	45PI429
		Bifacial Thinning/ Reduction	45PI408	45PI429
	Thermal Alteration	Lustrous/ Non-lustrous	45PI429	45PI408
		Lustrous Only	45PI408	45PI429
	Completeness	Whole flake	45PI429	45PI408
		Broken flake	45PI429	45PI408
		Flake fragment	45PI408	45PI429
		Debris	45PI429	45PI408
Post-MSH Y	Thermal Alteration	Lustrous/ Non-lustrous	45PI429	45PI408
		Lustrous Only	45PI408	45PI429
	Use Wear	Absent	45PI429	45PI408
		Present	45PI408	45PI429
	Raw Material Type	Chert	45PI438	45PI408
		Obsidian	45PI408	45PI438
		Igneous	45PI408	45PI438

DISCUSSION

Variation

Frequencies of the modes present variety among the assemblages: both within similarly aged components of the assemblages (synchronically), and between components within each assemblage (diachronically). Synchronic differences between assemblages (See Tables 6 and 8) indicate concurrent variation in selective conditions of the environment at the sites where stone tools were manufactured and used, while diachronic variation indicates changes in the selective conditions or in the technological and functional solutions to particular selective conditions. The largest variations are summarized in Table 9 within the context of the selective conditions of the environment that were acting on stone tool manufacture and use at the four study sites.

Around 4400 cal yrs BP the incidence of heat treatment in the 45PI429 assemblage increased dramatically, and increasingly unimodal distribution indicates strong directional selection for lustrous only flake scars on early and late reduction stage flakes. Strong directional selection for heat treatment late in the reduction stage occurred more recently in the 45PI408 assemblage, during 3000 cal yrs BP to present. Directional selection for heat treatment in the assemblages could be based on decreasing the cost of stone tool manufacture, since heat treatment decreases the fracture toughness of some types of chert (McCutcheon 1997:31). The environmental effect of the local abundance of, and proximity to, chert tool stone sources was likely a contributing factor in the selection of using a material that requires heat treatment (Vaughn 2010:95).

Table 9. Summary of Variation between Assemblages and Through Time.

				Tipsoo Lake (45PI406)	Buck Lake (45PI438)	Sunrise Ridge Borrow Pit (45PI408)	Forgotten Creek (45PI429)
				(W) 5440 ft.	(NE) 5400 ft.	(W) 4884 ft.	(SW) 4300 ft.
				Subalpine meadow	Subalpine meadow	Upper Northwestern maritime forest	Upper Northwestern maritime forest
Component	Age		Environment	Mountain Hemlock	Subalpine Fir	Mountain Hemlock	Pacific Silver Fir
Post-MSH Y: MSH P to Surface	3000 cal yr BP** to present[4]	Late Holocene: 4000 yr cal BP to present	Little Ice Age: 550-250 cal yr BP[1] Medieval Climate Anomaly: 1000-700 cal yr BP[1] Neoglacial Period: 2800-2300 yr cal BP	Tool manufacture; Most use wear; Lowest diversity in types of wear; Highest proportion of obsidian	Intensive core reduction; Dominated by flake fragments; Decrease in intermediate reduction; Obsidian absent	Pronounced tool use; Slight increase in tool manufacture; Directional selection for heat treatment in late reduction stage	Increase in tool use; Increase in tool manufacture; Directional selection for heat treatment in early and late reduction stages
MSH Y: Y tephra set (deposition of MSH Yn tephra ca. 3650 cal yr BP[2]*)	4400-3600 cal yr BP[4]				–	Greatest technological and functional diversity	Tool manufacture only; Dramatic increase in heat treatment
Pre-MSH Y: MR B to O tephra (Mazama)	>7627-4400 cal yr BP[5]	Middle Holocene: 8000-4000 cal yr BP	Warmer and drier period[3]		Intensive core reduction; Highest proportion of igneous; Obsidian absent	–	Intermediate core reduction and tool manufacture; 15% obsidian

[1]Goosse et al. 2012:1; [2]Mullineaux 1996:8; [3]Whitlock 1992; *Or 3690-3890 cal yr BP (Mullineaux 1996:8); **2990-3170 cal yr BP (Mullineaux 1996:8); [4]Sisson and Valance 2008:6; [5]Zdanowicz 1999

The absence of obsidian at 45PI429 and 45PI438 after its initial appearance appears to be a directional shift away from non-local, high quality tool stone. The significant decrease in igneous rock at 45PI429 and 45PI438 after 4400 cal yrs BP could be related to the increase occurrence of heat treatment. Since the 45PI438 and 45PI406 assemblages are primarily composed of chert, and heat-treated artifacts dominate the 45PI406 assemblage, this relationship suggests that similar environmental conditions of raw material type and availability influenced selection for heat treatment in the assemblages.

The transition of the 45PI429 assemblage from an intermediate core reduction and tool manufacture technological organization, to a primarily tool manufacture focused technological organization also occurred around 4400 cal yrs BP. The abrupt change in technological organization and the increase in heat treatment were concurrent with regional shifts in climate around 4000 cal yrs BP, from the xeric conditions of the middle Holocene to the more mesic climate of the late Holocene (Whitlock 1992).

The shift in technological organization could have been an adaptation to the effects of a cooler moister climate, such as expansion of the subalpine zone. This would have necessitated stone tools optimal for exploiting local resources, rather than being transported unfinished to another location for resource exploitation. The series of pyroclastic events resulting in the deposition of the Y tephra set from 4400-3000 cal yrs BP significantly altered the regional environment (Dunwiddie 1986). Changes in the selective conditions during and after the deposition of the Y tephra set, such as types and abundance of vegetation, would have influenced stone tool function and technology as people living on the mountain adapted to the changing environment.

Unlike that of the 45PI429 assemblage, the organization of technology in the 45PI408 and 45PI438 assemblages was stable through time (stabilizing selection against initial and terminal reduction flakes from 4400 cal yrs BP to present). Differences between the 45PI408 and 45PI438 assemblages are present at other scales of our analysis; the former was assigned to tool manufacture technological type, while the latter assemblage was typical of intensive core reduction technological type. This suggests that the local selective conditions that influence stone tool manufacture at the 45PI408 and 45PI438 sites differed from each other and from those at the 45PI429 site. It appears that some other selective condition is driving the stabilizing selection in reduction trajectory class similarities.

From 3000 cal yrs BP to present, the frequency of traits associated with tool manufacture in the 45PI429 and 45PI408 assemblages increased, such as directional selection against initial and terminal reduction flakes, and directional selection for intermediate reduction flakes. This indicates that either initial reduction was occurring elsewhere, there was a raw material characteristic that accounted for the lack of cortex, or a combination of both. Conversely, in the 45PI438 assemblage the proportion of faceted platforms increased in frequency between 4400 and 3000 cal yrs BP to present, while simple platforms decreased markedly (8%) and intermediate reduction flakes decreased (7%), indicating directional selection against simple platform types and intermediate reduction flakes.

The increasingly divergent technological organization of the assemblages indicates that not only were there different selective conditions acting on the assemblages, but that either adaptation to these conditions were becoming more specialized, or that different selective conditions at the sites became more pronounced over time.

The incidence of use wear in both the 45PI429 and 45PI408 assemblages increased around 3000 cal yrs BP, suggestive of potential adaptations to an environment that was becoming increasingly conducive to tool use for resource exploitation at the site of manufacture, due to continued increases in resource abundance and diversity.

Although use wear was not present in high enough frequencies to make statistical comparisons, it is important to take into account the differences and similarities in the types and frequencies of use wear present, as functional organization is essential in understanding past human land use and subsistence strategies. Frequency counts of the distribution of use wear, and the types of use wear present, are available for the 45PI429, 45PI408, and 45PI406 assemblages. Conclusions about the functional organization of the assemblages are preliminary and viewed within the context of what is known about the technological organization of the assemblages.

In a whole-site analysis of the 45PI406 assemblage, the most common type of wear was concave shaped unifacial chipping. The slightly higher proportion of use-wear among the 45PI406 artifacts indicates that the site was both the location of stone tool manufacture and activities such as low-intensity specialized resource exploitation. The 45PI406 assemblage presented the lowest diversity in filled classes of use wear, with only 7 types of use wear identified. The low diversity in types of use wear and the prominence of wear on concave edges shows less diverse uni-directional use of stone tools on objects smaller than the tools, which maybe indicating a more limited range of resource exploitation activities (Dunnell 1978b). Low diversity in use-wear types could be based on local environmental effects such as low diversity of local resources (e.g. few resources being dominant in an area) or activities focused on a few specific resources. Additionally, it was possible that the 45PI406 location was focused on other activities like tool stone raw material trade. The 45PI406 site is located at a crossroad of trails at the crest of the Cascade Mountains (Vaughn 2010). Non-local obsidian made up 5% of the 45PI406 lithic assemblage, which was at least twice as frequent there compared to the other assemblages here (Vaughn 2010).

The 45PI408 assemblage had the highest incidence of use-wear out of the assemblages, as well as the strongest directional selection for use wear (12% of artifacts in the MSH Y component and 21% of the artifacts in the post-MSH Y component). The 45PI408 assemblage also contained the greatest diversity in classes of wear, with 34 filled classes of wear identified. Unifacial chipping is the most frequent type of wear in both components of the 45PI408 assemblage and was concave, convex, and straight (in that relative order of frequency). The higher occurrence and greater diversity of wear, along with evidence of stone tool manufacture in the 45PI408 assemblage, suggests that this was a mixed activity site. The types of use wear indicate that stone tools were used in varied ways. The high diversity and frequency of use wear could be the result of environmental effects, such as a high abundance and diversity of resources at the site. The increase in the proportion of artifacts with use wear from the MSH Y to post-MSH Y components indicates directional selection for tool utilization at the site. Directional selection for tool use at the site could be based on a decreased need to transport manufacture stone tools away from the site. This could be the result of environmental effects such as an increase in the abundance of local resources, or a decrease in resources elsewhere.

In the 45PI429 assemblage only 4% of artifacts in the pre-MSH Y component, and 3% of artifacts in the MSH Y and post-MSH Y components exhibited any use-wear. There were 14 filled classes of wear in the whole assemblage, which were distributed nearly equally (less than 1% of artifacts had any single type of wear). The commonality between wear types was that the majority of the wear included unifacial chipping. The low incidence of use wear and the even distribution of the types of wear through time indicates a consistent use of this landform for tool manufacture and the transportation of those tool forms elsewhere for use (Andrews 2008:49). The very low incidence of use wear in the assemblage is consistent with the 45PI429 site having been a limited activity site focused mainly on tool manufacture.

Raw Material

The distribution of raw materials was similar within all assemblages in both whole site comparisons and in synchronic comparisons within components. This result suggests that selective conditions affecting procurement cost may have influenced the diversity of raw materials used in tool manufacture. The dominance of chert in all components of all sites indicates that the selection for chert over other available raw materials appears to be based on lower costs of procurement and manufacture. Although chert tool stone quarry sites near to the sites being studied here have not yet been identified; however, based on the regional geology it is likely that tool stone sources are readily available on the slopes of Mount Rainier, or in the river valley gravel bars leading up to the mountain.

Sources of tool stone are variable on the slopes Mount Rainier. For instance, the Tatoosh Pluton formation is made of largely granodiorite that contains precipitate pockets of chert. Volcanic rock from Mount Rainier contains dacite, a fine-grained rock, and is exposed in many areas of the park (Fiske et al. 1963:41-42). Surface geology includes irregularly distributed types of rock that vary greatly in texture, mineral composition, and alteration, including fine-grained rock documented along the park boundary west of Mowich Lake. Raw materials for stone tool manufacture could have been procured from exposed areas of the Tatoosh Pluton geological formation. In personal communication with Dr. Patrick McCutcheon on the 21st of November, 2014, and with Greg Burtchard on the 14th of November, 2014, it was noted that chert sources are known to occur in the northeastern and northwestern quadrants of the Park. Tatoosh Pluton chert has been identified at the Frozen Lake Site (45PI407), and can be readily seen in the trail that leads to the Mount Fremont Lookout, where there are reports of "jasper" on Mount Fremont (near 45PI407), as well as at Berkley Rockshelter (45PI303) on Skyscraper Mountain. The Pyramid Peak Quarry Site was recorded (2007) in the northwestern side of the park near Pyramid Mountain, and there is exposed knapable stone near the 45PI429 site on Tum Tum Mountain (Burtchard 2003:48; Burtchard et al. 2007a:1-6).

The low frequency of fine-grained volcanic tool stone materials in all of the assemblages can be attributed to higher procurement cost, higher cost of manufacture, lower fracture predictability, and inferior performance (Vaughn 2010:86; McCutcheon

1997:196). Without larger sample sizes of these types of artifacts, it is difficult to determine the range of stone tool manufacture and uses for fine-grained volcanic rocks.

Obsidian from the 45PI406, 45PI408, and 45PI429 assemblages has been sourced to non-local obsidian sources as distant as central Oregon. Previous research summarized in Table 10 sourced obsidian from the 45PI408 and 45PI406 assemblages, noting that Obsidian Cliffs in Oregon seemed to be the most frequent source of obsidian (Vaughn 2010:65).

Table 10: Obsidian Counts and Sources for the 45PI406 and 45PI408 Assemblages (Vaughn 2010:65).

	Assemblage	
Source	45PI406	45PI408
Brown's Bench/ Bickleton Ridge	2	1
Elk Pass	3	
Indian Creek		1
Glass Buttes I		1
Newberry Volcano	14	6
Obsidian Cliffs	8	17
Quartz Mountain		14
Unknown		3
Whitewater Ridge	6	
Total	33	43

An obsidian flake from the pre-MSH Y component of the 45PI429 assemblage was also sourced to Obsidian Cliffs in Oregon. The obsidian debitage in the 45PI429 assemblage is very small (≤ 0.11 g), as is expected due to the high cost of transporting obsidian far from the source (Parry and Kelly 1987). Proximity to sources of raw material for stone tool manufacture would have been an environmental constraint, assuming that transporting tool stone through the rugged terrain would have been difficult (Burtchard 2003:48).

The high cost of procurement for obsidian could be offset by obsidian's fracture predictability (low cost of manufacture) and edge sharpness (increased performance). Obsidian was only present in the earliest components of the 45PI408 and 45PI429 assemblages, and was completely absent from the 45PI438 assemblage. The stratigraphic pattern in the distribution of obsidian artifacts could indicate variation in travel routes between early and late Holocene peoples, and/or some form of relationship between stone tool heat treatment and the use of obsidian (Hansen and McCutcheon 2013). The use of obsidian is thought to have changed during the Holocene Epoch in the Cowlitz River Valley, with Elk Pass obsidian used prior to 8200 years ago (Mack et al. 2010:146). Conversely, the small amount of obsidian present and the isolation of the obsidian to the pre-MSH Y component of the 45PI429 assemblage could indicate that the procurement and use of obsidian at the 45PI429 site was an idiosyncratic event, unrelated to overall stone tool manufacture and use strategies later in time.

CONCLUSIONS

Many of the changes in functional and technological organization of the assemblages, and the level of diversity between assemblages, can be attributed to the selective conditions of the environment in which stone tools were manufactured and used. Based on what is known from paleoclimate studies and the recorded tephra layers, we have identified at least some selective conditions under which prehistoric peoples adapted to the environment on Mount Rainier. Those selective conditions are presented here as equally contributing factors.

1. Previous research has acknowledged that the deposition of the MSH Y tephra layers could have disrupted prehistoric use of the mountain through changing the availability and abundance of resources (Dunwiddie 1986; Lewarch and Benson 1981; Tweiten 2007). Based on the increase in technological and functional diversity in all assemblages after 4400 yrs cal BP, it is likely that the combined series of pyroclastic events that produced the Y tephra set had a much larger impact on adaptations to the montane environment of Mount Rainier than previously understood.
2. Some changes in the composition and abundance of resources on Mount Rainier around 4400 yrs cal BP can be linked to neoglacial cooling (Dunwiddie 1986:65). The shift to a mesic climate would have necessitated a change in resource acquisition strategies, adapting to the resources that would have become more abundant in the cooler moister climate, or possibly the employment of techniques (e.g., anthropogenic burning [Lukens 2013; Tweiten 2007]) to maintain diverse environments.
3. Large variations between the assemblages indicate that the selective conditions of local microenvironments on the mountain significantly influenced stone tool manufacture and use taking place at the sites. These microenvironments, created by variations in moisture (the southern and western slopes are more resource rich), seem to have uniquely influenced the manufacture and use of stone tools at each site.

The pre-contact regional land use and settlement model for the Southern Cascades overall is supported by the technological and functional organization of the assemblages

(Burtchard 1998a: 111-112; Lewarch and Benson 1991:38). The evidence from the sites being studied in this research largely support Burtchard's (2007:9, 27-34) prehistoric regional land use model, of mixed activity sites resulting from patterns of semi-sedentary settlement and subsistence throughout the Holocene across Mount Rainier.

RECOMMENDATIONS

Results were limited by small sample sizes, illustrating the need for further research of assemblages from high elevation archaeological assemblages in the Southern Washington Cascades. Diachronic conclusions are suggestive because of the limitations on the data. The size of the assemblages were insufficient to make statistical comparisons between components within sites, particularly for the 45PI429 assemblage of which the pre-MSH Y component consisted of only 47 pieces of debitage. Further excavation at the 45PI429 site would increase sample sizes, allowing for a comprehensive investigation of change over time. More robust sample sizes will be necessary to formulate more detailed explanations of why these sites differed in technological and functional organization over time and between environments. Additionally, it would be beneficial to apply the research strategy first developed by McCutcheon (1997) and later modified in these upland contexts. The implementation of these recommendations in future research would greatly enhance our understanding of pre-contact subsistence and settlement patterns in the Southern Washington Cascades.

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CHAPTER V

RECOMMENDATIONS

Results were limited by small sample sizes, illustrating the need for further research of assemblages from high elevation archaeological assemblages in the Southern Washington Cascades. Diachronic conclusions are suggestive because of the limitations on the data. The size of the assemblages were insufficient to make statistical comparisons between components within sites, particularly for the 45PI429 assemblage of which the pre-MSH Y component consisted of only 47 pieces of debitage. Further excavation at the 45PI429 site would increase sample sizes, allowing for a comprehensive investigation of change over time. More robust sample sizes will be necessary to formulate more detailed explanations of why these sites differed in technological and functional organization over time and between environments.

The 45PI429 site is a valuable archaeological resource and as such should be recommended for listing on the NRHP. This will aid in protecting the stratigraphic integrity of the dated tephra layers at the site, and encourage further excavation and research based on the results indicating that the assemblage may be unique in that it is the only assemblage exhibiting changes in technological organization over time.

The 45PI438 assemblage was the only assemblage with directly equivalent components to those of the 45PI429 assemblage, based on the presence of the comparable tephra layers and intact stratigraphy. It would be beneficial to an analysis of diachronic changes in functional and technological organization if the sample size was increased. The previously excavated artifacts from the MSH Y component of the site have yet to be analyzed, and their analysis using McCutcheon's (1997) paradigmatic classification would allow the assemblage to be more directly compared to the other previously analyzed assemblages from Mount Rainier.

The difference in analytical protocol used for the 45PI438 assemblage resulted in data gaps (dimensions such as thermal alteration, reduction class, and use wear were not recorded). To increase comparability between assemblages and with the results of previous research, I recommend that the identical analytical protocol of McCutcheon's (1997) paradigmatic classification be used for artifacts excavated from archaeological sites in the southern Washington Cascades

Our understanding of the relationship between assemblage composition and proximity to tool stone sources would benefit from the location of quarry sites. Raw material sources could be located through pedestrian survey in an attempt to locate quarry sites near residential or task specific sites. Future excavation should also take into account excavated volume and artifact density, to provide additional contextualization. The implementation of these recommendations in future research of lithic assemblages in the southern Washington Cascades would greatly enhance our understanding of pre-contact subsistence and settlement patterns in the Southern Washington Cascades.

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