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THE WESTERN STEMMED POINT TRADITION: EVOLUTIONARY PERSPECTIVES ON CULTURAL CHANGE IN PROJECTILE POINTS DURING THE PLEISTOCENE-HOLOCENE TRANSITION

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The Western Stemmed Point Tradition:
Evolutionary Perspectives on Cultural Change in Projectile Points During the Pleistocene-Holocene Transition

Chairperson: Dr. Anna Marie Prentiss

Abstract

In this thesis I analyze the cultural techniques of Paleoindians in North America by examining the diversification and fusion of stemmed projectile point traditions using an evolutionary analysis. The Western Stemmed Point tradition has an extensive regional and temporal distribution throughout the Intermountain West and High Plains during the Paleoindian period. In an effort to determine how stemmed projectile point technologies relate to each other, I applied a phylogenetic approach to construct heritable patterns of projectile point histories. By measuring the physical traits of those points and using a macro-evolutionary theoretical approach, changes in artifact form can be acquired and heritable processes understood. This process was further complicated by our understanding of how culture is learned and shared. Techniques can be learned as individual units or even as sets of units, resulting in the differential persistence of individual traits. This analysis indicated that projectile point traits for blade and haft characteristics evolved in a mosaic fashion creating distinct patterns of vertical and horizontal transmission across space and time. Furthermore, the haft characteristics created important results that support the eastward expansion of stemmed projectile point traditions from the west.

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Chapter 1: Background

1.1 Introduction

The purpose of this thesis is to examine early stemmed projectile point technologies during the Paleoindian period in North America. This was a time at or shortly after the initial peopling of the Americas ranging from near 13,000-7,000 years before present (BP). There is substantial variation among the projectile point styles that crop up during this time but what they all have in common is a stemmed basal section. This functional marker makes them very distinct from other tool traditions contemporaneous with stemmed points, such as Clovis and Folsom points that utilize a very different hafting technique. But there still remains a whole host of variation seen among these stemmed traditions. Regional cultural complexes include Great Basin varieties, Cody Complex, and Windust which all fall under the moniker of Western Stemmed Point Tradition (WSPt).

Stemmed projectile point technology from this time was very widespread across the western half of North America, with stemmed points ranging from Alberta, Canada to southern California and from Oregon to Colorado. This wide range has led to many regional definitions to explain the variety of styles. An example of this regional variation of points with similar functional traits includes Haskett styles typically found between northern Utah and Idaho and Agate Basin styles found in the High Plains of Wyoming and Colorado. These two point styles, while they each have similar hafting techniques are separated by the Rocky Mountains. Is this an example of regional cultural differences from one tradition or separate unrelated cultural traditions?

The remaining chapter will discuss the issue of using an evolutionary analysis to understand the problem of material culture and how an analysis of Western Stemmed projectile points will serve as an example to address this issue. A phylogenetic approach will be used to test the proposed hypotheses for how projectile points evolved on the landscape. In the following chapter I will discuss the theoretical framework (cultural evolution) I used to develop these hypotheses. This chapter will describe the history of cultural evolutionary theory, the background to how evolutionary archaeology applies, the underlying transmission theory of cultural evolution, as well as a few critiques of this theory.

In chapter 3, I provide my materials and methods as well as the justification for why I have chosen them. The materials are composed of morphological characteristics of projectile points from across western North America that has been collected from various literary sources. The methods for analyzing these data will offer statistical tests for alternative approaches to phylogenetic analysis. The subsequent chapter will contain the results and interpretation of these analyses. This will be followed by a summary of my results and the conclusion.

1.2 Material Culture

The persistence and change of cultures has been a topic of discussion for decades. Using a macro-evolutionary approach, the persistence and change of material culture can be explored to provide a better understanding for variations in tool technology across space and time (Boyd et al, 1997; Holden and Shennan, 2005). The smallest units of cultural knowledge are stored in the brain. These cultural elements make up the package of traditional knowledge (Boyd et al, 1997; Holden and Shennan, 2005).The logical package of knowledge that individuals have stored in their brain is learned from other individuals/teachers that can be acquired as individual units or as sets of units (Boyd et al, 1997; Eerkens and Lipo, 2007, 2008; Kuijt and Prentiss, 2009). This acquired knowledge is then stored and manipulated by the learner and because people are incapable of perfect replication, this results in errors that lead to new sources of variation. These new sources of variation, as well as deliberate innovations, are crucial to evolution by providing new material on which to operate. Differential adoption of cultural elements gives rise to descent in which derived elements appear. It is through those patterns that we can begin to understand cultural macroevolution. If a vertical pattern of transmission is prominent it will have a stronger branching phylogenetic signal, which has been suggested by many to play a major role in the change in cultural patterns over time (Bowser and Patton, 2008; Mesoudi and O'Brien, 2009; Prentiss et al, 2014; Tehrani and Collard, 2002).

Evolution of projectile points is a particular challenge because there are so many regional styles classified under the same cultural tradition or as completely separate traditions. What transmission processes are contributing to these regional styles and what is the mechanism for change in the archaeological record? Some have suggested that a progression in some forms of these artifacts can actually result from the cultural transmission process (O'Brien et al, 2001, 2002; Shennan, 2008).

1.3 Western Stemmed Point Tradition

Historically, literature on early Paleoindian culture has largely focused on Clovis culture due to the large volume of evidence for Clovis technology, but because of this historical focus on Clovis the presence of additional non-Clovis populations is often overlooked. Paleoindian populations in the intermountain region have previously been characterized as being descendent of a Clovis-first tradition (Beck and Jones, 2010; Haynes Jr. 1987; Whitley and Dorn, 1993). The appearance of morphologically distinct stemmed points from the Northwest contemporaneous with Clovis culture and the high prevalence of stemmed projectile points in the High Plains is suggestive of an alternative ancestor for these points (Beck and Jones, 2010, 2012; Lohse and Moser, 2014; Pitblado, 2011).

The temporal position and origination of the Western Stemmed Point tradition (WSPt) has been debated for several years. In recent years, WSPt has become more widely recognized and accepted as a separate tool tradition that was contemporaneous with Clovis culture and new evidence has surfaced that places WSPt earlier than Clovis (Chatters et al, 2012; Jenkins et al, 2012; Lohse and Moser, 2014). Previous research has indicated multiple variants of the stemmed point; however there is a lack of consensus as to whether they are all representative of the WSPt cultural group (Beck and Jones, 2010; 2012; Fiedel and Morrow, 2012; Irwin and Wormington, 1970; Lohse and Moser, 2014; Pitblado, 2011). These types include, among others, Windust, Lake Mohave, Silver Lake, Hell Gap and Haskett (Lohse and Moser, 2014). Understanding how these types relate to each other is important for the discussion about the peopling of North America and early migration theories (Beck and Jones, 2010; Pitblado, 2011).

Variation in styles of WSPt are represented by regional differences, as for example, Windust style on the Columbia Plateau (Ames et al, 1981, 1998, 2010; Beck and Jones, 2010; Chatters et al, 2012; Lohse and Moser, 2014, Rice, 1972) or Lake Mohave style in the Great Basin (Beck and Jones, 2010; Haynes, 1996; Warren, 1967). Of course, WSPt is not limited to one point type; like Clovis traditions, projectile points carry variation throughout assemblages within sites and across regions (O'Brien et al, 2001, 2014). On the other hand, there isn't always clear continuity when labeling these different styles, and assemblages are often incomplete. The classification of lithic styles, including that of WSPt, does not have a universal, explicit definition of adequately classifying projectile points (Lohse and Moser, 2014). Both WSPt and Clovis typologies have typically been defined based on selective characteristics used to diagnose their type which differ from one assemblage to the next, for example using basal shape in one scenario and blade shape in the other (Lohse and Moser, 2014; O'Brien et al, 2014). If characteristics are to be used to classify points there should be some level of uniformity to describe them, and this goes for WSPt as well.

The WSPt occurred during the transition from the Pleistocene to the Holocene during the Paleoindian stage in North America, approximately 13,000-7,000 years before present (BP) within the intermountain region from the Cascades to the Rocky Mountains (Chatters et al, 2012; Jenkins et al, 2012; Lohse and Moser, 2014). The WSPt technology includes shouldered and unshouldered stemmed projectile points and are always made using flakes (Ames, 2005; Beck and Jones, 2010, 2012; Davis, 2001; Erlandson and Braje, 2011; Green et al, 1998; Jenkins et al, 2012; Lohse and Moser, 2014). These cultural elements make up a broader package of traditional knowledge that is transmitted via cultural transmission processes, i.e. social learning, and drawn upon when people produce projectile points (Boyd et al, 1997; Holden and Shennan, 2005).

We know very little about the Paleoindian populations and their cultural history, but through the analysis of the archaeological data we can begin to discern the cultural evolution of Paleoindian culture. While blending processes are generally accepted as strongly contributing to cultural transmission and change, it doesn't account for all variation or new innovations because blending actually leads to reduced variation (Beck and Jones, 2010; Collard et al, 2006; Mesoudi, 2011). Explaining the evolution and patterns of descent of projectile point technology during the Paleoindian period in western North America provides a valuable and informative way to draw inferences about ancient populations. Analysis of artifact evolution allows for one to make inferences about the history, migration patterns, and technological innovations of a people we know very little about.

The Intermountain and High Plain regions are marked by significant variation in morphological and technological projectile point tool traditions. There are many types of stemmed point tool traditions but the relationship between these artifact lineages is unclear; currently, there are many competing arguments to explain how they connect. For example, some scholars disagree about which points should be included within the Western Stemmed Point tradition (Beck and Jones, 2010; Galm et al, 2011, 2013, 2015; Lohse and Moser, 2014). The traditional view, encompassed by Beck and Jones, (2010) has typically included all stemmed points from the intermountain west within WSPt, including Lind Coulee, Haskett, Windust and Great Basin points such as Silver Lake. These stemmed points, except Windust and Silver Lake varieties, are generally characterized by long contracting stems. Their theory is that Paleoindians arrived in the Northwest from Siberia via the coast and that all these projectile point varieties are a part of a greater stemmed point complex (Beck and Jones, 2010). Although a distinction between the Columbia Plateau tradition and Great Basin tradition sometimes referred to as the Western Pluvial Lakes Tradition described further below, is still made (Beck and Jones, 1988, 2010; Lohse and Moser, 2014).

The Columbia Plateau, which mainly produces Lind Coulee, Windust, and Haskett points, has been the principal location of WSPt excavations. The oldest sites from this region have been Paisley Five-Mile Point Caves (Paisley Caves) and Cooper’s Ferry, radiocarbon dated to over 12,000 uncalibrated years BP (Davis et al, 2011; Gilbert et al, 2008). The oldest dated points from these sites have been associated with the WSPt due to the presence of typical stemmed projectile points and are shown in Figure 1. Paisley Caves is located on the periphery of the Columbia Plateau and Great Basin in southern Oregon and contains the oldest evidence of human occupation in the west (Gilbert et al, 2008; Jenkins et al, 2012). Cooper's Ferry is located in northern Idaho near the Salmon River and represents one of the earliest occupations of WSPt on the northern Columbia Plateau (Davis, 2001; Davis et al, 2014). Four complete stemmed points, which closely resemble those of the Lind Coulee site, were recovered from inside a pit feature dated 11,500-11,000 years BP (Davis et al, 2014). Some consider Lind Coulee (Figure 1) to be a part of the Windust Phase (Beck and Jones, 2010; Leonhardy and Rice, 1970 referenced in Davis et al, 2014) while others consider Lind Coulee points to be likely ancestors to Windust points (Daugherty, 1956; Rice, 1972; Schuknecht, 2000).

The Windust Phase, as it has been best documented at the Marmes Rockshelter site, is among the largest Paleoindian assemblages in North America dating to 10,000-8,000 years B.P. (Rice, 1972). When this assemblage is compared to others on the Columbia Plateau, such as the Lind Coulee assemblage, there appears to be a significant amount of evolutionary relatedness (Daugherty, 1956; Rice, 1972). The proposition that Lind Coulee could be ancestral to the Windust Phase assemblage has been difficult to test because there is no consensus on what the prehistory of the Columbia Plateau looked like and what approach[1] should be used to analyze it (Beck and Jones, 2010; Daugherty, 1962; Lohse and Moser, 2014; Rice, 1972; Schuknecht, 2000).

While Marmes Rockshelter was not used in this paper due to poor clarification of which points were associated with which strata layers and radiocarbon dates, Windust style points from Hatwai (Phase 1) were utilized to represent this point style, and are shown in Figure 1 (Ames et

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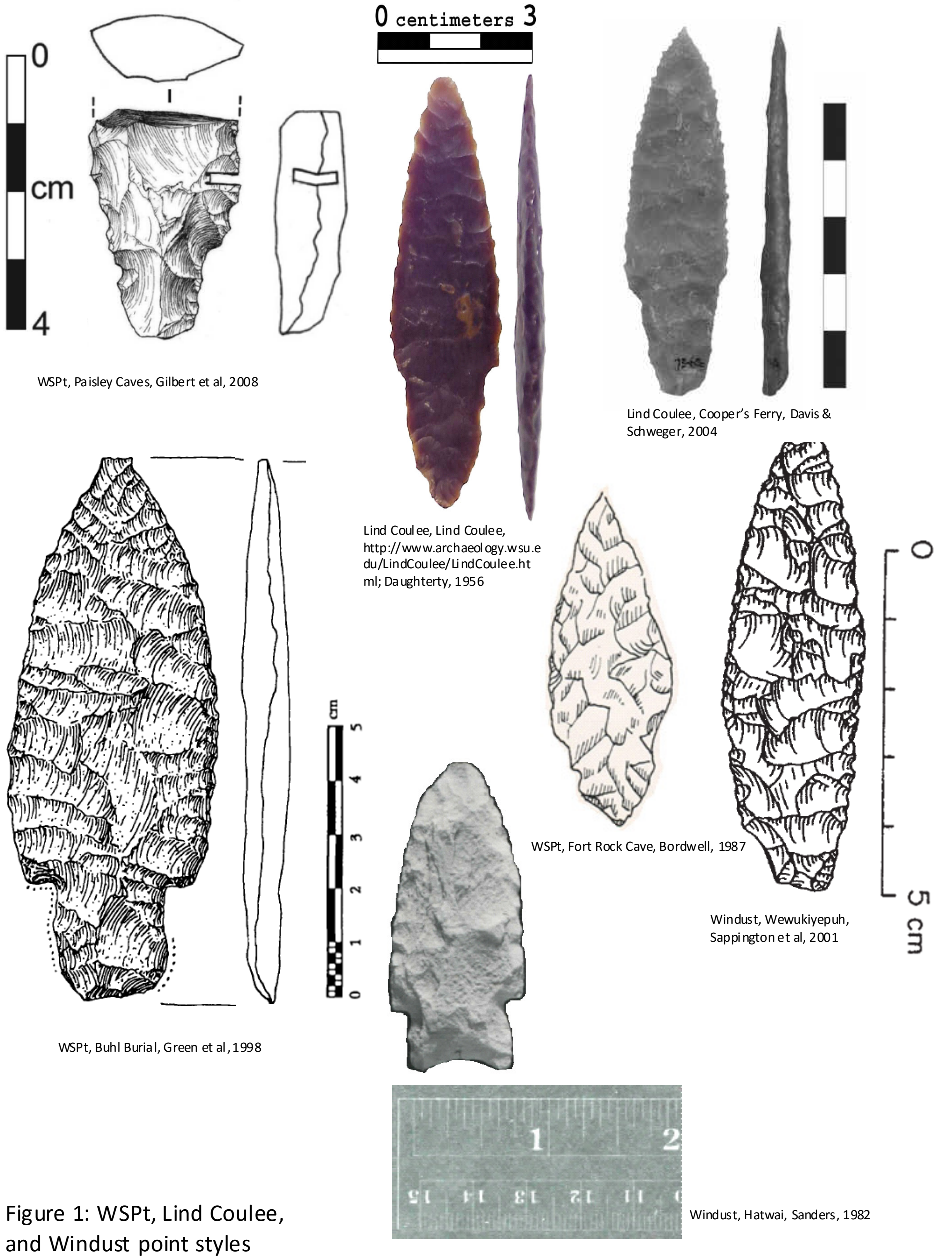
[1] *Rice (1972) discusses two approaches to understanding the prehistory of the Columbia Plateau. One looks at how cultures adapt to new environmental settings and how this leaves patterns of cultural elements that were adaptive to those settings and the other view is evolutionary processes creating slow, gradual changes in technology. These viewpoints concerning gradual, evolutionary change and adaptive cultural patterns both acknowledge that there are relationships between different cultural types within and outside the Plateau but differ in how and the extent to which they are related.

al, 1981; Sanders, 1982). While these points are usually considered to be a phase of the WSPt, the Hatwai style is different from other WSPt point because of their concave bases (Lohse and Moser, Sanders, 1982). Two additional points, recovered from Wewukiyepuh in northern Idaho, were identified as Windust due to their lanceolate form, slight shoulder and concave bases (Schuknecht, 2000; Sappington and Schuknecht, 2001). Both of these sites are located on the northern Columbia Plateau along a river system and date within the time frame of the Windust Phase (Schuknecht, 2000; Sanders, 1982).



WSPt, Paisley Caves, Gilbert et al, 2008

Lind Coulee, Lind Coulee, http://www.archaeology.wsu.edu/LindCoulee/LindCoulee.html; Daughterty, 1956

Lind Coulee, Cooper's Ferry, Davis & Schweger, 2004

WSPt, Buhl Burial, Green et al, 1998

WSPt, Fort Rock Cave, Bordwell, 1987

Windust, Wewukiyepuh, Sappington et al, 2001

Windust, Hatwai, Sanders, 1982

Figure 1: WSPt, Lind Coulee, and Windust point styles

The Windust phase has also been compared to assemblages outside the Plateau, for example the Fort Rock Cave and Danger Cave assemblages have been suggested to display some resemblance to the Windust Phase assemblage (Rice, 1972). Danger Cave is found in the Great Basin in northwest Utah and has lanceolate stemmed points with concave bases that share a large resemblance to Marmes Rockshelter and Hatwai points that date to between 9,789-8,960 years BP (Jennings, 1957). Fort Rock Basin is located on the northern-most edge of the Great Basin by the Columbia Plateau in Oregon and includes Fort Rock Cave, Connley Caves and Cougar Mountain Cave, all of which have a long history of occupation (Bedwell, 1973; Cressman, 1957). The earliest assemblage associated with a date of 13,200 BP at Fort Rock Cave is represented by a Mohave-like projectile point (P10). Other points (Figure 1), associated with a date of 10,200 BP, was not characterized as any one specific typology but all were found in units predating a Mount Mazama ash fall on site (Bedwell, 1973). While these resemblances are not as strong as others on the Plateau they are suggestive of cultural similarity both throughout the Plateau and the greater intermountain region (Rice, 1972).

The Haskett style has also been found on the Columbia Plateau but mostly comes out of the Great Basin in southern Idaho and Utah (Duke, 2015, Galm and Gough, 2008; Russell, 1993). This point style, with their long tapering stems, is morphologically distinct from Windust styles which make it typologically complex. Consequently, archaeologists have a hard time coming to an agreement on whether it should be included in WSPt (Pitblado, 2003; Galm et al 2011, 2013, 2015; Lohse and Moser, 2015). Two sites from Utah and one from central Washington with classic Haskett styles have been selected to represent this type, which is shown in Figure 2.

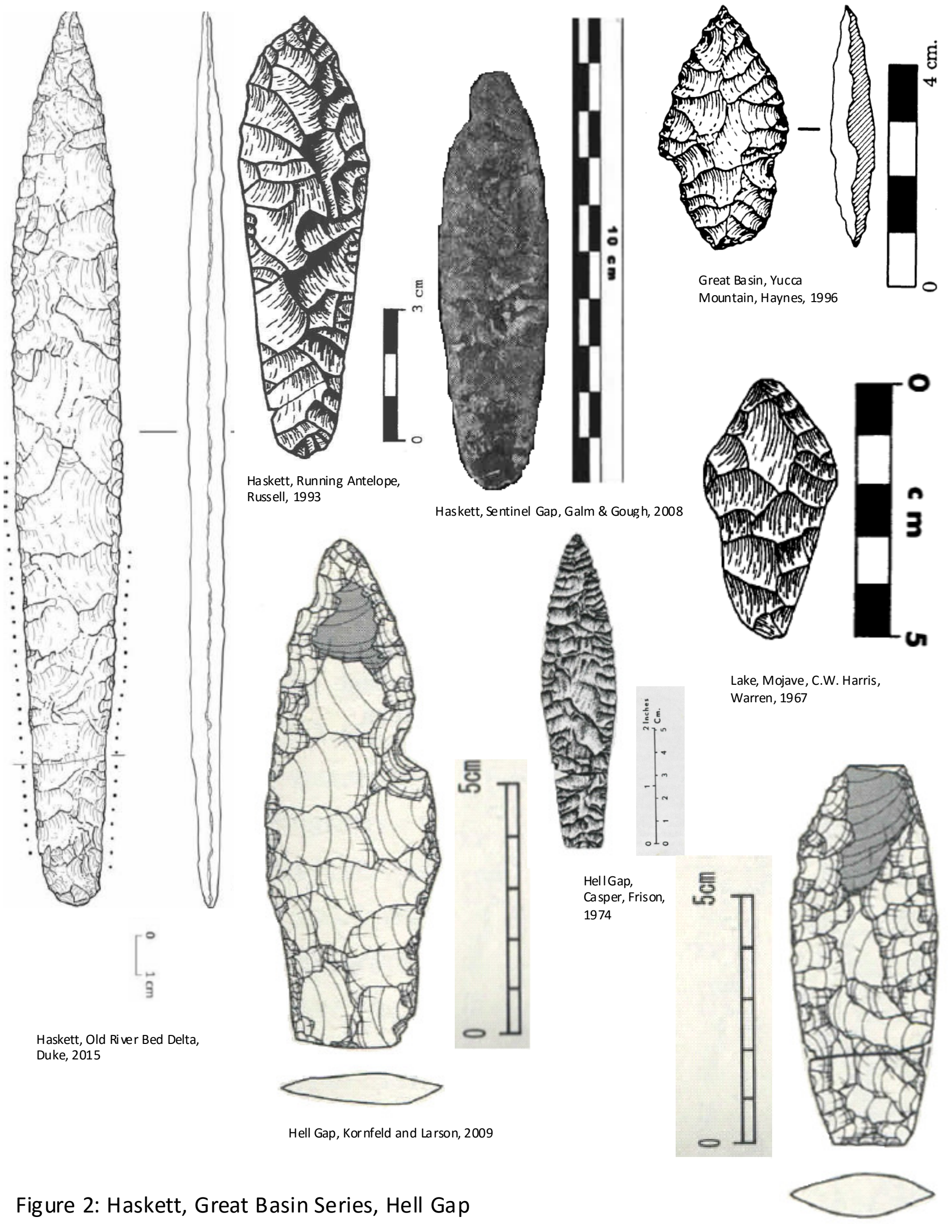
The Sentinel Gap site is located west of the Columbia River and while some aspects of this site show similarities to Marmes Rockshelter and Lind Coulee sites (bone needles and Cascade Phase points), other stemmed projectile points resemble Haskett style points (Galm and

Gough, 2000; Gough and Galm, 2002). Radiocarbon dates from this site and the Haskett associated points place them squarely within the time frame of the Windust Phase (Galm and Gough, 2008). Since Sentinel Gap represents the only clear documentation of Haskett on the Columbia Plateau and because of its close proximity to other Windust-Western Stemmed sites, these points were included in this assay and are featured in Figure 2.

The Western Pluvial Lakes Tradition is sometimes used to distinguish stemmed points on the Great Basin from the Columbia Plateau (Beck and Jones, 1988, 2010). This was in part due to the pattern of occupation where these toolkits have been found adjacent to ancient pluvial lakes in the Great Basin. However, they are not always found near those pluvial lakes and other styles have been placed within this tradition, such as Lind Coulee, Haskett, Great Basin Stemmed, for instance Lake Mohave and Silver Lake, and many others (Beck and Jones, 1988, 2010). Beck and Jones (1988) have even suggested that a factor for vast typological variation may be accounted for by resharpening; whereas Amick (2004) asserts that stemmed traditions were not entirely isolated, even from the Columbia Plateau to the Great Basin, and that similarities across them likely suggest an ancestor-descendent relationship.

The San Dieguito Complex is another ill-defined tradition in the Great Basin that originates from California (Creutz and Moriarty, 1963). There are many questions that surround the nature of these points, in part because there have been many different names assigned to it over the years and a lack of clear stratigraphy. A great example illustrating the San Dieguito complex is the C.W. Harris site which has been very useful for providing new insights for the Great Basin stemmed series (Warren, 1967). The Lake Mohave and Silver Lake components at C.W. Harris date to over 8,000 BP and fits right within the height of Great Basin Paleoindian culture that has been thoroughly documented by Smith Creek Cave, Danger Cave, and Sunshine

Locality (Bryan, 1979; Jennings, 1957; Jones et al, 1996). At Smith Creek Cave, stemmed points are associated with the Great Basin series, however it has been noted that it also contained points that resembled the Cascade series, which is assumed to be derived from Windust and has been well documented at Marmes Rockshelter (Bryan, 1979; Rice, 1972). The Lake Mohave and Silver Lake components from C.W. Harris and Yucca Mountain site #26NY7920 (hereafter referred to as Yucca Mountain) are pictured in Figure 2.



Haskett, Old River Bed Delta, Duke, 2015

Haskett, Running Antelope, Russell, 1993

Haskett, Sentinel Gap, Galm & Gough, 2008

Great Basin, Yucca Mountain, Haynes, 1996

Lake, Mojave, C.W. Harris, Warren, 1967

Hell Gap, Casper, Frison, 1974

Hell Gap, Kornfeld and Larson, 2009

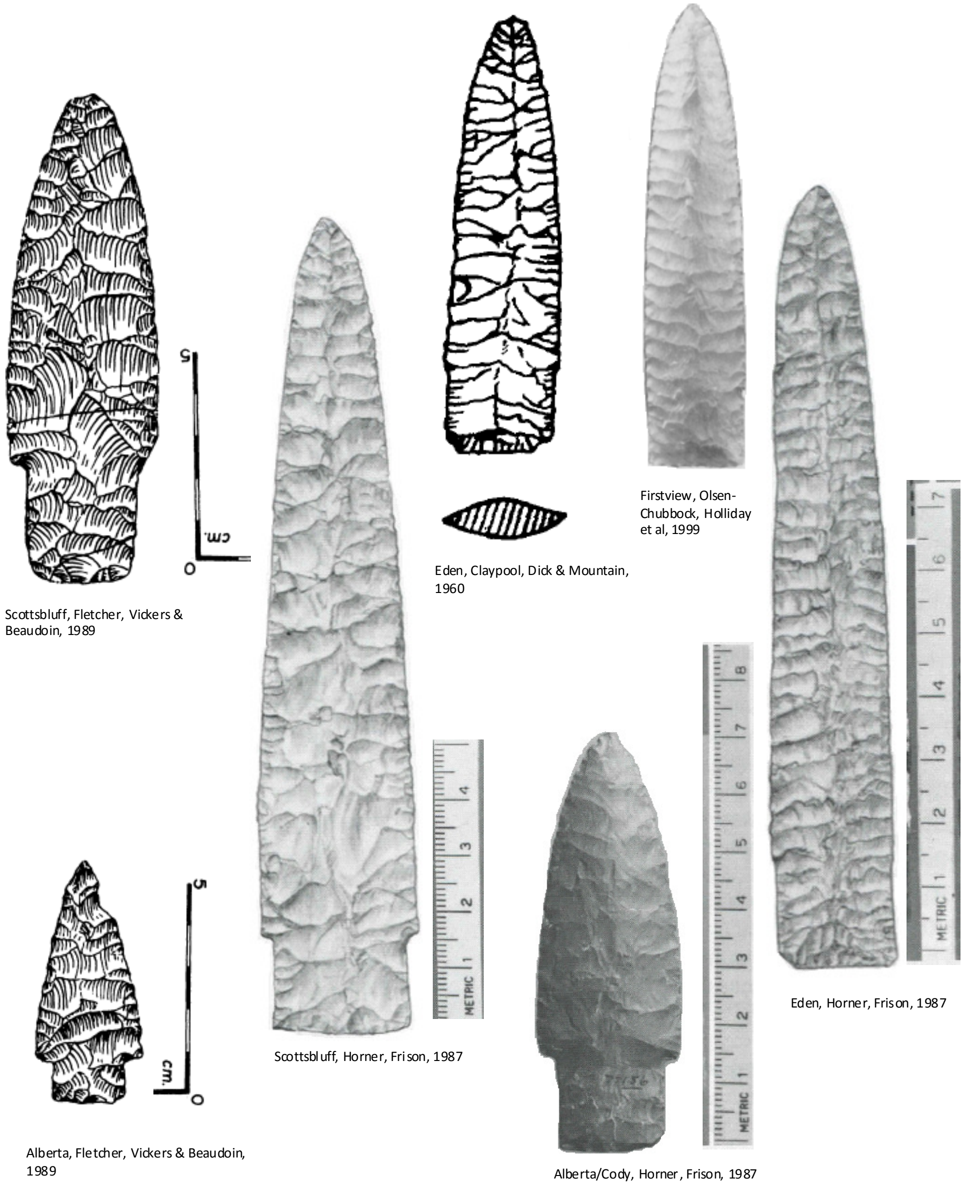
Agate Basin, Kornfeld and Larson, 2009

Figure 2: Haskett, Great Basin Series, Hell Gap and Agate Basin point styles.

Additional noteworthy resemblances between Haskett, Agate Basin and Hell Gap types could be indicative of further potential relationships (Galm and Gough, 2008; Duke, 2015). Some of the oldest dates for stemmed technology on the high plains come from the Agate Basin site and date between 11,840±130 – 10,200±2,000 B.P. (Frison and Stanford, 1982). Agate Basin points have been compared to Haskett Type II points from Southern Idaho and Utah because of notable stylistic similarities between them, such as the smooth transition of blade into a tapering stem with no true shoulder, as well as their association with hunting large game is indicative of possible cultural relatedness (Duke, 2015; Galm et al, 2015; Pitblado, 2003). An additional concern is the relationship of Agate Basin points to Hell Gap points; unfortunately the Agate Basin site Hell Gap type projectile points are not well dated in relation to the Agate Basin type points (Frison, 1974). From the Hell Gap site, Agate Basin type points represent an older stratigraphic layer, with possible admixture of Hell Gap points, providing further evidence that Agate Basin types may be older than Hell Gap types (Bradley, 2009; Pitblado, 2003). This has led some to believe that Hell Gap points are derived from the Agate Basin tradition with Hell Gap representing the first "true" stem point on the High Plains (Bradley, 2009; Pitblado, 2003).

The organization of the Cody Complex from the High Plains has undergone many changes since it was established but can broadly be portrayed as a multifaceted stemmed tool tradition characterized by a lot of a variation (Bamforth, 1991; Bradley, 2009; Bradley and Frison, 1987; Bonnichsen and Keyser, 1982; Pitblado, 2003). While this variation is typically split into three varieties, most will agree to a certain extent that all Alberta/Cody, Scottsbluff and Eden points can be included in this projectile point tradition, while Alberta points are considered by some to be ancestral to the Cody Complex (featured in Figure 3) (Bamforth, 1991; Bradley and Frison, 1987; Bonnichsen and Keyser, 1982; Pitblado, 2003; Wheat et al, 1972). Alberta/Cody (types I and II) and classic Alberta points are likely a chronological precursor to Scottsbluff and Eden points, which has led some to include them within it (Bradley, 2009;

Bradley and Frison, 1987; Bamforth, 1991; Pitblado, 2003). The inclusion of Firstview types in the Cody Complex has not been agreed upon either (Pitblado, 2003; Wheat et al, 1972). Wheat et al (1972) suggested that Fairview points should be grouped together with Kersey, San Jon and Plainview points to create the Firstview Complex (Bonnichsen and Keyser, 1982), whereas others consider Eden and Firstview as being more closely similar and placed within the Cody Complex (Pitblado, 2003; Wheat et al, 1972). Pitblado (2003) lumps Eden and Firstview types together to describe them, assuming that they are closely related due to their close similarities. Eden points are often also described as closely resembling Scottsbluff points, sometimes even considered a more refined version of them. Regardless, they are almost always considered as part of the late


Scottsbluff, Fletcher, Vickers & Beaudoin, 1989

Eden, Claypool, Dick & Mountain, 1960

Firstview, Olsen-Chubbock, Holliday et al, 1999

Scottsbluff, Horner, Frison, 1987

Eden, Horner, Frison, 1987

Alberta, Fletcher, Vickers & Beaudoin, 1989

Alberta/Cody, Horner, Frison, 1987

Figure 3: Cody Complex and Firstview point styles

stage Cody Complex Tradition (Bradley and Frison, 1987; Pitblado, 2003; Wheat et al, 1972).

All these inconsistencies and disagreements in labeling projectile point typologies leads to questions regarding if these points represent the same cultural tradition or it they are separate unrelated cultural complexes. The temporal span for the projectile points from the figures above have been illustrated in Figure 4 below. This leads to questions regarding if these points represent a continuum of an ever-evolving tradition or if they represent a multitude of different artifact lineages throughout the Paleoindan period. We know very little about these populations and their cultural history, but through the analysis of the archaeological data, by phylogenetics, for example, we can begin to discern patterns and processes in the cultural evolution of Paleoindians (Prentiss and Lenert, 2009). Explaining the evolution and patterns of descent of projectile point technology during the Paleoindian period across western North America provides a valuable and informative way to understand ancient populations and infer about their past. For example, analysis of artifact evolution allows for one to make inferences about their history, migration patterns, and technological innovations. As will be shown, a phylogenetic approach for interpreting western stemmed points can provide valuable information that will enhance our understanding of prehistoric America.

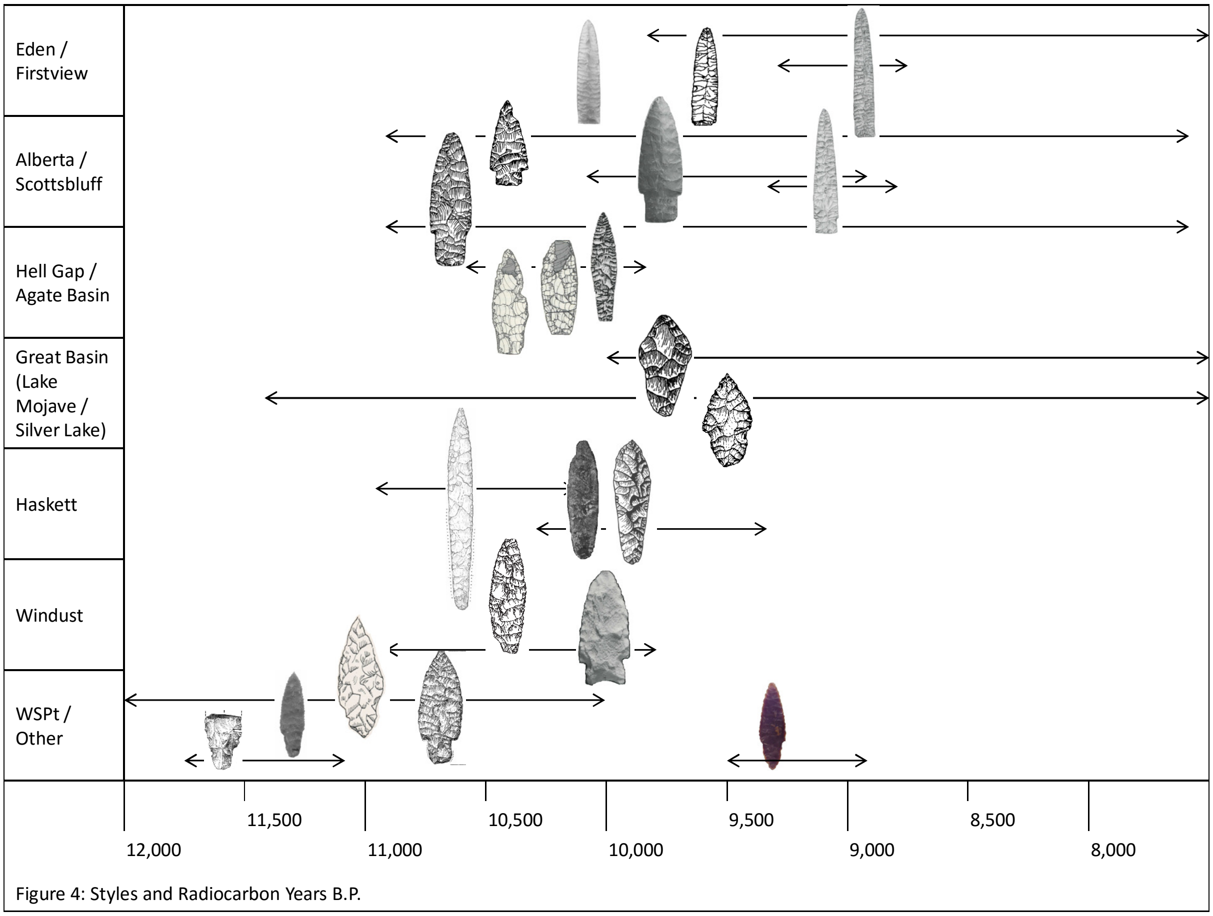


Figure 4: Styles and Radiocarbon Years B.P.

1.4 Phylogenetic Analysis

A cladistic approach to phylogenetic analysis will test three main hypotheses about descent with modification relationships. My first hypothesis is the potential pattern of transmission of stemmed projectile points resulted from a vertical pattern of descent with modification through time. The vertical transmission model views cultural change through the passing on of traditions through the community, such as from mothers to daughters, which expand and split (Jordan, 2015; Jordan and Shennan, 2009). The daughter populations that split off carry the traditions with them consequently continuing the cycle. If correct, the differential persistence of stem point variation will result in a strong branching cladogram that correlates with a directional change through time. A second hypothesis would result in a pattern of transmission in stemmed projectile points following a spatial, geographical gradient. This result would also establish a vertical pattern of descent with modification; however it would pattern spatially, independent of time, creating clades representing regional styles or migration patterns.

A third hypothesis focuses on the idea that cultural diffusion and continuity of cultural knowledge flows between neighboring populations. The proximity effect has been given a lot of credit for leading to higher increases of blending between styles because regions and people are not completely isolated. This increase in sharing and borrowing of culture across populations means that point styles more spatially close will share more similarities than those farthest apart, producing a clinal affect. For example, Metcalf and McDonald (2012) have suggested that borrowing occurred among different, co-occurring regional styles in the Wyoming Basin due to the presence of obsidian from the same source in the Great Basin being found across regional boundaries. Delacorte and Basgall (2012) agree that interactions and borrowing between neighboring groups across regions were common, but occurred in a more north to south pattern rather than east to west. Processes such as these create blending and borrowing of cultural traits across populations. That is why I propose that stemmed projectile points variations are the result of horizontal transmission processes causing a blending effect, reflected by a higher prevalence of homoplasies.

Chapter 2: Theoretical Background

2.1 Introduction

This chapter details the theoretical framework in which this paper is based. Evolutionary archaeology is grounded in a cultural evolutionary stance to examine the archaeological record. It is underpinned by transmission theory which elucidates the processes of vertical and horizontal transmission which is vital to our understanding of evolutionary archaeology and phylogenetics is provided as an example of one approach to evolutionary archaeology. Finally, a critique to the cultural evolutionary framework is provided.

2.2 History of Cultural Evolutionary Theory

The theory of cultural evolution is used to study how culture has shaped human behavior and how cultural changes occur. In order to understand my employment of this theory, a brief history is necessary. Julian Steward's conception of cultural evolution was an ecological approach to cultural change more effectual than a biological approach. He believed that the natural environment determined change due to a strong systemic relation between humans and the environment (Binford, 1962; Lyman and O'Brien, 1997; Steward, 1967). Furthermore, Steward believed historical sequences were unrelated to each other. In other words, although similar traditions do occur in two different societies, the two cultures could be distinct (Binford, 1962; Steward, 1967).

This is contrasted by Leslie White's theory which did not consider the environment to be as relevant to culture as a whole; rather, he believed that all beings have a set of characteristics that are required for its existence and function (Lyman and O'Brien, 1997). For humans, these characteristics took the form of culture, which White described as the “extrasomatic means of adapting to ones environment” (Binford, 1962; Johnson, 1999; Lyman and O’Brien, 1997). According to his theory, material culture and technological changes are the main features that evolve, shape our social organization, and determine our ideological behavior (Peace, 1993; Trigger, 1989). White believed that there was a progression of cultural transmission and heritability that led to cultural change, thereby drawing a distinction between historical and evolutionary events (Harding et al, 1960; Peace, 1993). White considered evolution to be the temporal-spatial process or sequence of development that created historical events, and that any events throughout time that shared similarities were due to chance (Harding et al, 1960; Lyman and O’Brien, 1997).

Sahlins and Service have described a resolution to the controversy between White and Steward’s diffusion versus independent invention debate (Lyman and O’Brien, 1997; Peace, 1993; Sahlins and Service, 1960). They argue that although modifications in different species occur due to adaptive or functional variation, homologous structures can nonetheless be traced to their origins. This is why biological and cultural evolution can be incorporated within one total view of evolution. This is differentiated by the cultural traits can be passed along multiple lines of transmission creating a diffusion of cultural variation (Sahlins and Service, 1960). Sahlins and Service go on to portray ‘specific evolution’ as one type of evolution where cultures undergo adaptive modifications, or change in response to problems that affect their survival (Harding et al, 1960; Lyman and O’Brien, 1997; O’Brien and Holland, 1990). It is these adaptive modifications that can be viewed as phylogenetic change and are crucial to our current framework for cultural evolutionary theory.

The individuals that have those survival enhancing traits are the individuals more likely to pass those traits on to their offspring, thus ensuring the inheritance of those traits. The basic tenet of evolution refers to change over time; specifically, it seeks to explain the change in phenotype frequencies and mechanism of change, or in the case of cultural evolutionary theory (CET), the change in frequency of cultural traits (Barton, 1997; Cavalli-Sforza, 1997). In order for a change in trait frequencies to occur three preconditions must be present, these include variation, competition, and inheritance (Mesoudi, 2011; Shennan, 2008). Having enough variation in a population requires there to be multiple characteristics of an individual trait. This allows for competition between individuals who possess those differing traits and therefore selection of traits that enhance survival.

2.3 Evolutionary Archaeology

Culture-Historical Archaeology (CHA) grew in response to and as a challenge to the cultural evolutionism theories popular during the mid 1920's (O'Brien and Lyman, 2000; Tigger, 2006). An increased awareness of geographical variability in the archaeological record meant an increased attention on variability and geographical distribution of artifacts, leading to the establishment of CHA (Moore, 1994; Tigger, 2006). Culture historians were most concerned with measuring the passage of time, similar to paleobiologists, to explain evolutionary history of cultural lineages, and to classify cultures using units or sets of artifacts to explain how they were related in space and time (O'Brien and Lyman, 2000; Teltser, 1995). They approached this goal by identifying similarities within cultures as homologous structures that resulted from diffusion, migration and evolutionary descent with modification (O'Brien and Lyman, 2000; Trigger, 2006). This allowed for culture historians to ask questions and infer about cultural relatedness and change (O'Brien and Lyman, 2000; Teltser, 1995).

This background has influenced our current approaches to evolutionary archaeology. By applying a cultural evolutionary framework to archaeology it allows for archaeologists to understand the patterned variation in the archaeological record and what accounts for the changes in it. Culture elements are highly variable and are the representative form of behavior that all persons have acquired through individual learning throughout one's lifetime (Dunnell, 1996:64; Richerson and Boyd, 2005). When observing the material record, archaeologists view this variability as being continuous (Dunnell,1996:64). Since not everyone can know all possible skills, there is competition between what knowledge of material forms are passed on via cultural transmission (Mesoudi, 2011; Rindos, 1996). If we suppose that cultural traits are indeed heritable then we can began to regard changes as being caused through selective processes, like natural selection and drift.

Changes in culture can be observed in the archaeological record but have also been observed in transformations of cultures today. A number of ethnoarchaeological studies have observed functional and stylistic aspects of cultural phenomena, such as pottery and textiles, being inherited by younger generations and passed on via transmission processes (Bowser and Patton, 2008; Eerkens and Lipo, 2008; Tehrani, 2002). The sharing of culture through the diffusion and borrowing of ideas affects the evolution of culture because culture is not restricted to a vertical transmission system, unlike biology (Mesoudi and O'Brien, 2009; Moore, 1994). Through diffusion and borrowing, culture can be horizontally transmitted to any number of people or cultural groups, thus providing people with additional sources of heritable variation (Collard et al, 2006; Durham, 1992; Mesoudi and O'Brien, 2009; Moore, 1994).

A key factor in the selection of traits is whether or not these traits affect fitness, but selection can occur on stylistic traits too. While style doesn't necessarily affect survival, it has been found to be affected by selective mechanisms (Bowser and Patton, 2008; Eerkens and Lipo, 2008; Eldredge, 2009; Tehrani, 2002). If we accept that material elements of our culture are the representation of behavior and are in fact heritable, then it is reasonable that evolutionary mechanisms such as selection, drift and flow can operate on such materials even if those traits do not directly affect the fitness of the population (Dunnell, 1996; Bowser and Patton, 2008). Since we cannot measure the actual behaviors, if those traits are identifiable and measurable in the record we can observe the remnants of their behaviors by measuring the phenotypes of material artifacts, which serve as comparable elements to physical traits observed in biology (O'Brien, 1996:109).

The scale of analysis is important for recognizing which theoretical framework one should apply. Primarily evolutionary processes and selection operate on variations of traits within populations but they can also operate on more complex cultural scales (Leonard and Jones, 1996; Rindos, 1996). Analysis at this scale involves use of a macro-evolutionary approach. A macro-evolutionary framework is a means of applying CET to archaeology to look at "time-like" processes for cultural change, i.e. transmission processes. CET is best applied to archaeology for asking questions regarding large-scale cultural change and its reflection on behavioral systems (Barton, 1997; Boone and Smith, 1998; Mesoudi and O'Brien, 2009). One method of applying macro-evolutionary theory to culture is through the use of cultural phylogenetics or cladistics (Mesoudi and O'Brien, 2009). This method examines behavioral systems by looking at the phenotypes expressed in their culture (Barton, 1997; Boone and Smith, 1998; Chatters and Prentiss, 2005; Mesoudi and O'Brien, 2009). It is the patterned distributions of these traditions that comprise the archaeological record. Explaining macro-scale variation similarities and change of material artifacts has been a major goal of archaeologists since its inception as a subdiscipline of anthropology (Teltser, 1995). By measuring the degree of variation in artifacts, archaeologists can measure changes over time and the differential persistence of variants (Eerkens, 2007; Schiffer, 1996; Teltser, 1995).

2.4 Cultural Transmission Theory

Cultural transmission processes are an important facet of culture change that, regardless of which process is employed, understand that material forms are heritable and can be observed in the archaeological record (Eerkens, 2007; Mesoudi and O'Brien, 2009; O'Brien et al, 2001; Temkin and Eldredge; 2007). Identifying the transmission histories and measuring the degree of variation of materials allows archaeologists to establish a pattern of variation to understand the forces directing that pattern of descent (Mesoudi and O'Brien, 2009; Shennan, 2008). In order to understand how this is possible a clear understanding of how transmission theory functions is necessary.

In order for the transmission of culture to occur, we must agree that the behaviors and knowledge of how to produce a cultural object must be inheritable. Social learning is a mechanism of inheritance, wherein an individual will learn different means of acting, thinking, and knowledge from others, such as grandparents, teachers, peers, and church members (Richerson and Boyd, 2005; Rindos, 1996; Shennan, 2008; Washburn, 2001). Put simply, individuals will observe a behavior and then emulate it through copying and reproduction, therefore acquiring that knowledge but with differences from errors and innovations of their own making (Eerkens and Lipo, 2007; Shennan, 2008; Washburn, 2001). When this occurs, those unintended copying errors or new innovations from intended change become sources for new variation in the population on which selective pressures can operate (Shennan, 2008).

This process of cultural transmission at the scale of the individual is important because it has ramifications at the scale of population, which is the focus of evolutionary archaeology. Since cultural transmission is subjected to evolutionary processes, via variation, selection and competition, evolutionary archaeologists seek to analyze the patterns of the differential persistence of that transmitted material (Eerkens and Lipo, 2007; Lipo et al, 1997). There are two main methods of transmission that result in different patterns of variation: ethnogenesis and phylogenesis (Tehrani and Collard, 2002).

Ethnogenesis, the borrowing and blending of cultural knowledge between populations, results in the horizontal transmission of ideas and traditions leading to new sources of variation (Eerkens and Lipo, 2007; Tehrani and Collard, 2002). These tokogenetic signals are best represented through graphs that can highlight multiple sources of inheritance. On the other hand, phylogenesis occurs when these outside sources are weak and vertical transmission plays a stronger role (Eerkens and Lipo, 2007; Tehrani and Collard, 2002; Temkin and Eldredge, 2007). Under this paradigm, cultural evolution occurs when populations split off and give rise to daughter populations resulting in a sequential division and change of cultural material (Eerkens and Lipo, 2007; Shennan, 2008; Tehrani and Collard, 2002). These multiple routes of transmission and inheritance lead to different consequences that provide the patterning of cultural change through time that archaeologists and ethnoarchaeologists can observe and measure using phylogenetics (Shennan, 2008).

2.5 Phylogenetics: An Example of Evolutionary Archaeology

In recent years, cladistics has increased in popularity as one approach to the study of the evolution of cultural data (Mesoudi and O'Brien, 2009). Cladistics was originally developed by biologists to reconstruct evolutionary histories of species based on their morphological, behavioral, or genetic similarities (Cavalli-Sforza, 1997; Mesoudi and O'Brien, 2009; Temkin and Eldredge, 2007). Through the process of transmission and innovations, new forms and copying errors occur, leading to the branchiness that characterizes phylogenetics (Prentiss et al, 2016; Shennan, 2008). The use of the phylogenetic approach to create evolutionary histories was applied to identify homologies by measuring the physical characteristics of the cultural material in question (Mesoudi and O'Brien, 2009; O'Brien and Lyman, 2000). These approaches help archaeologists interpret the material record by measuring changes in artifact form to make sense of processes of cultural transmission, diversification, and transformation (Chatters and Prentiss, 2005; Collard et al, 2006; O'Brien and Lyman, 2000; Teltser, 1995).

To construct this pattern of transformation and diversification of cultural descent, a phylogeny can be made by measuring the relationships of phenotypic traits. This process can be analyzed by measuring the temporal and spatial frequencies of traits in the material record which can be depicted using phylogenetics. Phylogenetics operates by measuring the phenotypes or physical traits of the taxa (material artifacts) (Teltser, 1995). These outcomes are often reflected in a branching tree diagram that indicates relatedness due to descent with modification (Collard et al, 2006; Mace and Holden, 2005; Mesoudi and O'Brien, 2009). These phylogenies are useful for measuring relationships because they can calculate the lengths of changes between modifications and divergences between primitive and ancestral traits as well as designating the respective nodes on a cladogram where taxa shared the most recent ancestor (Mace and Holden, 2005; O’Brien et al, 2014). Phylogenetics functions as a means for constructing heritable patterns of material culture providing patterned results of descent with modification that the cultural artifacts history can then be inferred from (Mace and Holden, 2005; O’Brien et al, 2001; Temkin and Eldredge, 2007).

The process of cladistics uses statistical methods to test data for best fit scenarios of relatedness by measuring for homoplasies and synapomorphies in the data (Collard et al, 2006; Mace and Holden, 2005). Homoplasies are the result of tokogenetic signals, from blending and borrowing of characteristics between cultures causing reticulations in phylogenetic analyses (Collard et al, 2006; Prentiss et al, 2016). Additional evolutionary processes that could be affecting the phylogenetic results, is that of mosaic evolution. This entails different segments of a phenotype changing or evolving independently of each other (Prentiss et al, 2016). In evolutionary archaeology this process could have profound effects on how we analyze and interpret patterns the material record, such as projectile points. An example of this process in projectile points would be hafting characteristics evolving at an independent rate from blade characteristics. There have been a number of studies that have indicated different traits of a material artifact will evolve at different rates (Dagg, 2011; Eldredge, 2009; Prentiss et al, 2016). These considerations must be recognized when proceeding with evolutionary archaeology analyses.

2.6 Critique

There have been a number of concerns and critiques regarding evolutionary archaeology that one must consider. Some have critiqued evolutionary archaeology because it does not inquire about the relationships between human behavior and material culture, such as in behavioral archaeology (Dunnell, 1996; O'Brien and Lyman, 2000; Teltser, 1995). This critique's real concern is that evolutionary theory cannot explain causation for cultural trends and can only explain basic questions of what is occurring, but this is a rather narrow perception of evolutionary archaeology (Dunnell, 1996). Identifying the transmission histories and measuring the degree of variation of materials is important for allowing archaeologists to establish a pattern of variation and understand the forces directing that pattern (Rindos, 1996; Shennan, 2008). This model serves as a means to interpret the past and understand cultural phenomena, not to provide an explanation for the ultimate cause (Dunnell, 1996).

Since cladistics is drawn from biology, it is an assumption of this approach that the forces of natural selection and mutation of traits are also applicable to the forces inherent in cultural evolution. Processes like the mode of transmission, inheritance, and natural selection are frequently regarded as directing the force of change (Cavalli-Sforza, 1997; Dunnell, 1996; Teltser, 1995). In biology, this process acts on the phenotypes of an organism that is expressed by the genotype, through which the force of selection on phenotypes is what leads to a change in gene frequencies overtime (Futuyuma, 2010; Gould, 1984). In our material culture, the phenotypes are the physical, observable traits of objects that natural selection acts upon. Inherent in this theory is the need for randomness and recombination of genetic variation that is acted upon by natural selection (Gould, 1984; Mayr, 1991). Natural selection is a mechanism that acts on traits that are considered to be advantageous to the individual's reproductive success. This mechanism makes assumptions about the rate of changes, presuming that variation in culture occurs in gradual, small transformations over long periods of time. If this were true than it should be observable in the archaeological record; however, this lack of gradual change can be remedied under the punctuated equilibrium model purported by Gould (Dunnell, 1996; Gould, 1984; Mayr, 1991). This model doesn't deny that natural selection and gradual changes occur but that evolutionary changes often result in branching events (Dunnell, 1996; Gould, 1984).

Additionally, there are a number of other mechanisms that affect cultural change such as random drift, and biased transmission (Kimura, 1983; Mesoudi, 2011; Richerson and Boyd, 2005). Drift is when the frequency of traits in a population change due to chance, caused by random, undirected forces and recently, genetic drift has been given a more prominent role than selection forces in directing the change in gene frequencies (Futuyuma, 2010; Gould, 1984; Kimura, 1983; Richerson and Boyd, 2005; Shennan, 2008). This begs the question that if evolutionary change is more directed by genetic drift in biology, so too it might be in culture and there would be no need for competition between advantageous traits that increased ones chance of survival. Genetic drift is considered the foremost mechanism of neutral theory that proposes genetic mutations are neutral and all variants are equally capable of efficiently promoting the survival and reproduction of an organism (Gould, 1984; Kimura, 1983; Kuhn, 2004). In archaeology, questions about what drives change frequently regard stylistic variants that don't obviously affect "fitness" and therefore have no "selective value" (Dunnell 1996; O'Brien and Leonard, 2000). Ethnoarchaeologists have found that style is actually selected for and follows a phylogenetic pattern, but may instead reflect a pattern indicating reasons other than strictly teacher-learner relationships and be selected for due to political strategies or social identity (Bowser and Patton, 2008; Eerkens and Lipo, 2008; Tehrani and Collard, 2002).

In order for evolution to occur there must be a mechanism to introduce new material into a population. This occurs through recombination, independent innovations, and mutations such as copying errors to allow for enough transmutations and therefore enough "genetic" material. Some have argued that evolutionary change can seldom be based upon the competition for traits because mutations are rarely seen as a source of variation, therefore limiting the rate of evolution (Futuyuma, 2010).

Furthermore, some critics take issue with the process of transmission and the supposition that cultures could be bounded enough to create strong lines of vertical transmission (Moore, 1994). The application of cultural evolutionary theory to interpreting material culture is assumed to work because cultural inheritance is understood to have a strong vertical transmission pattern that evolves in such a way that modification may occur during the cultural transmission processes (Mace and Holden, 2005; Mesoudi and O'Brien, 2009; Moore, 1994; Temkin and Eldredge, 2007). However, the fluidity of borders and blending that occurs between them has been observed by field workers from ethnographic and linguistic studies that have identified the strength of peer's and outsider's influence on one's behavior (Bowser and Patton, 2008; Moore, 1994).

Phylogenetics works best when there is a strong presence of vertical transmission. However, if this transmission process is weak then it becomes more difficult to trace historical processes using cladistics and is even thought to make this approach contradictory (Moore, 1994; Temkin and Eldredge, 2007). This premise makes using cladistics a weak approach because it makes showing those gradual, small changes from parent populations to daughter populations as well as making it more difficult to understand the forces directing diversification of culture over time (Dunnell, 1996; Moore, 1994).

2.7 Test Expectations

A potential pattern of transmission of stemmed projectile points resulted from a vertical pattern of descent with modification through time. If correct, the differential persistence of stem point variation will result in a branching cladogram that correlates with a directional change through time. If this is correct, a phylogenetic analysis will produce a statistically strong branching tree with a pattern of stemmed point variations creating a directional change of variability through time. This would require the differential persistence of stemmed point variation to correlate with time (frequencies of characters being produced changes over time), regardless of geographical location, thus providing a pattern of vertical transmission model of stemmed point technology.

The second hypothesis would result in a pattern of transmission in stemmed projectile points following a spatial, geographical gradient. This result would establish a vertical pattern of transmission; however it would pattern spatially, independent of time, creating clades representing regional styles or migration patterns. If this is correct, a phylogenetic analysis will produce a branching tree that follows regional or stylistic patterns. Stemmed point variability will correlate with stylistic typologies.

The final hypothesis focuses on the idea that cultural diffusion and continuity of cultural knowledge flows between neighboring populations and therefore stemmed point variations will be the result of horizontal transmission processes caused by a blending effect. A phylogenetic analysis will produce a tree with a high degree of reticulations reflected by a higher prevalence of homoplasies, especially among taxa closely geographically located. A high degree of homoplasies would be observed through low CI and RI scores and high delta and Q-residual scores.

Chapter 3: Projectile Point Data

3.1 Introduction

In order to answer questions of evolutionary descent of stemmed projectile point technology, various projectile point data was collected and analyzed. Identifying which site assemblages would be most useful was the first step in determining which individual projectile points would be analyzed and described using morphological characteristics. After all points had been assigned character states and detailed in a dataset table, various analytical methods were described for how and why they were chosen to test the hypotheses.

3.2 Materials

The data for this analysis were compiled of written sources from twenty assemblages across western North America and are listed below in Table 1 and illustrated in Figure 5. These assemblages include stemmed projectile points contemporaneous with dates for WSPt between 12,000-7,000 years BP. These sites were selected for this project because they are located throughout the Columbia Plateau, Great Basin, and High Plains regions and are radiocarbon dated to within the timeframe of WSPt. The Paisley Caves site in southern Oregon was selected as the out-group for the phylogenetic analysis due to reports of these caves containing human coprolites dating to 12,300 ^{14}C BP thus making this among the oldest known sites in the west containing stemmed projectile points (Gilbert et al, 2008; Jenkins et al, 2012).

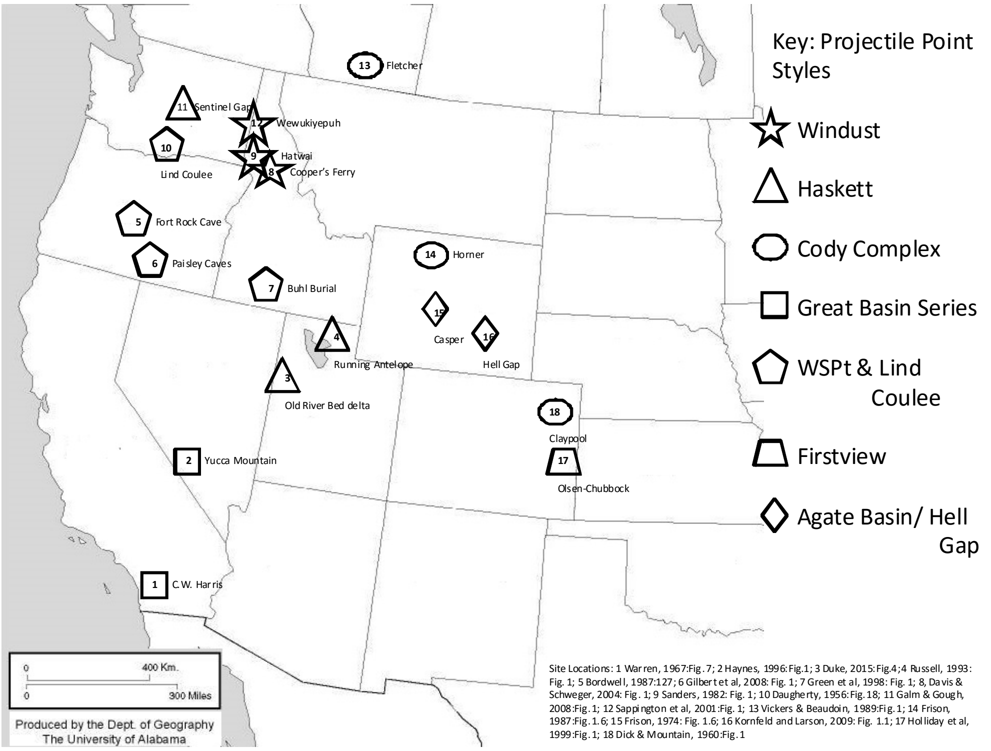
The individual stemmed projectile points from site assemblages were chosen based on the presence of adequate documentation and quality of photographs to allow sufficient analysis of morphological characteristics. In addition, stemmed points were selected based on their locality within the stratigraphic soil layers of the site that were associated with radiocarbon dates between 13,000-7,000 years BP.

A variety of projectile point variations were chosen from different regions which allows for a comparison of a multitude of point styles. The classification methods of these points lack consistency and clarity of what attributes are used to define them, but generally point styles are applied by geographical location and based on some defining characteristics. The point types listed in Table 1 were supplied by literary sources and provided in order to compare styles in later discussion. The original database includes 125 individual total points, wherein 24 modal points have been identified/selected from those illustrated in Table 2. The modal trait is the average behavior in a population and these behaviors exhibited by an individual are what is exemplified as traits in the artifacts (Eerkens and Lipo, 2007). The modal point serves as the average behavior for the characteristics for each projectile point represented in each site's assemblage. The Modal Point ID's listed in Table 1 are used later as the taxa identifier used in the analytical results in Chapter 4.

Table 1: Site and Point Type Data

Sites Points were Collected From	Points Included	Modal Point ID	Point Type	Dated 14C years Before Present (BP)	Citation
Paisley Caves, OR	3	PC_WS	Western Stemmed (out-group)	11,815 ± 25 - 11,070 ± 25	Jenkins et al, 2012:224 Fig. 1 a-c
Buhl Burial, ID	1	BB_WS	Western Stemmed	10,675 ± 95	Green et al, 1998:449 Fig. 10
Lind Coulee, WA	7	LC_WS	Western Stemmed	9,400 ± 940, 8,518 ± 460, 8,700 ± 400	Daugherty, 1956:245-247 Fig. 18 1-7, Fig. 19 1-3, Fig. 20 1-2; Tushingham and Curewitz, 2014: http://www.archaeology.wsu.edu/lindcoulee/index2.htm: Fig. 45GR97-0093, 0095, 0123, 0127, 0128, 0130, 0131
Cooper's Ferry, ID	4	CF_W	Windust Phase - Western Stemmed	11,410 - 11,370	Davis et al, 2014:606 Fig. 8
Wewukiyepuh, ID	2	W_W	Windust	10,390 ± 40 – 10,270 ± 50	Sappington and Schuknecht, 2001:359 Fig. 3a, b
Running Antelope, UT	5	RA_H	Haskett	10,000 ± 300- 9,860 ± 300	Russell, 1993:81 Fig. 2a-e
Old River Bed delta, UT	4	ORB_H	Haskett	11,000 – 10,200	Duke, 2015:110-111 Fig. 1 FS#57, Fig. 2A FS#43, 2B FS#520, Fig. 3 FS#1
Sentinel Gap, WA	7	SG_H	Haskett	10,180 ± 40	Galm and Gough, 2008:212 Fig. 2 cat. no. 637, 1254, 282, 1220, 728, 216 Fig. 3 cat. no. 670, 743
Hatwai I	8	Hw_W	Windust	10,800 - 9,800	Ames et al, 1981:97-98 Fig. 14; Sanders, 1982

C.W. Harris, CA	14	CWH_MS	Lake Mohave & Silver Lake (San Deguito Complex)	10,000 - 6,000	Warren, 1967: Fig. 3g, h, k; Fig. 4i-l, o-r; Fig. 5e, f, h; Stringer-Bowser et al, 2010
Fort Rock Cave, OR	7	FRC_WS	Western Stemmed	13,200 ± 720 - 10,200 ± 230	Bedwell, 1973: Fig. 15 P10, Fig. 17 P16, Fig. 18 P17
Yucca Mountain, NV	3	YM_MS	Lake Mohave (Great Basin)	11,500 – 7 ,000 OR 10,460 – 4,200	Haynes, 1996:112 Fig.3 a, b, c
Fletcher, Alberta	4	F_Al	Alberta	11,000 – 7,000	Forbis, 1968:4-5 Fig. 1 a-e, i-l; Vickers and Beaudoin, 1989; Wormington and Forbis, 1965
	4	F_S	Scottsbluff		
Olsen Chubbuck, CO	6	OC_F	Firstview	10,150 ± 150	Wheat et al, 1972:128-129 Fig. 37a, f-h; Fig. 38c,f; Holliday et al, 1999
Hell Gap, WY	6	HG_HG	Hell Gap	10,240 ± 300	Bradley, 2009:265-269, 275-277 Fig. 17.6s, t, m; Fig. 17.8 e-k; Fig. 18.1 7, 9; Fig. 18.2 16, 17, 19; Fig. 18.3 1, 3; Haynes Jr., 2009
	5	HG_AB	Agate Basin	10,260 ± 95	
Claypool, CO	5	Cp_E	Eden	10,000 – 7,000	Dick and Mountain, 1960:228 Fig. 4 CI-1, CI-2, CI-10, CI-6, CI-5
Casper, WY	5	Cs_HG	Hell Gap	10,000	Frison, 1974:72-74 Fig. 1.35a, b, d; Fig. 1.36a; Fig. 1.37 b
Horner, WY	10	Hn_AC	Alberta/Cody I (Horner I) & Alberta/Cody II (Horner II)	10,000 & 9,000 – 9,400	Bradley and Frison, 1987:202-215 Fig. 6.1a-c, e-j; Fig. 6.3; Fig. 6.6a-b; Fig. 6.7 a-f; Fig. 6.10a-d, h
	6	Hn_S	Scottsbluff (Horner I)	9,400 – 9,000	
	5	Hn_E	Eden (Horner I)		



Site Locations: 1 Warren, 1967:Fig.7; 2 Haynes, 1996:Fig.1; 3 Duke, 2015:Fig.4;4 Russell, 1993: Fig. 1; 5 Bordwell, 1987:127; 6 Gilbert et al, 2008: Fig. 1; 7 Green et al, 1998: Fig. 1; 8, Davis & Schweger, 2004: Fig. 1; 9 Sanders, 1982: Fig. 1; 10 Daugherty, 1956:Fig.18; 11 Galm & Gough, 2008:Fig.1; 12 Sappington et al, 2001:Fig. 1; 13 Vickers & Beaudoin, 1989:Fig.1; 14 Frison, 1987:Fig.1.6; 15 Frison, 1974: Fig. 1.6; 16 Kornfeld and Larson, 2009: Fig. 1.1; 17 Holliday et al, 1999:Fig.1; 18 Dick & Mountain, 1960:Fig.1

Figure 5: Site locations.

3.3 Methods

Characteristics were selected based on morphological traits that are considered to affect their functionality, such as blade shape for penetration and basal form for hafting techniques. In addition, traits that were least likely to be affected and distorted by resharpening were included as character states in this database. This database is comprised of seven character states and these include, Blade Shape, Shoulder Shape, Stem Shape, Basal Shape, Transverse, Flaking Pattern, and Flake Size. These character states are defined as follows:

I. Blade Shape- the overall blade shape, whether leaf-shaped blade (0) or straight blade (1).
II. Shoulder Shape- Angular Shoulder (0) (gentle slope into stem), No Shoulder (1) (no identifiable concave or convex shouldering), Convex Shoulder (2) (convex/bulge), Square Strong (3) (~90° angle), Square Weak (4) (weak indentation).
III. Stem Shape- contracting (0) or straight (1) stem.
IV. Basal Shape- the shape of the base, convex (0), concave (1), or straight (2).
V. Transverse Cross-Section- lenticular (0) (oval), subdiamond (1) (between oval and diamond shape), diamond (2) (pronounced median ridge).
VI. Flaking Pattern- the direction of flake scars, Irregular (0) (random directions), Incomplete Horizontal (1) (scars all go in horizontal direction, but don't meet up at median), Collateral (2) (scars are parallel horizontal and meet up at median).
VII. Flake Size- the size of flake scars, Random (0) (scars are wide and narrow), Wide (1) (majority of scars are wider), Narrow (2) (majority of scars are narrower).

The characters chosen were selected based on the expectation that these components of the points were likely to be included in cultural transmission processes due to the assumption that these components would affect the point's functionality and therefore be included within the logical package of knowledge that is transmitted (Kuijt and Prentiss, 2009; Prentiss, 2009). Therefore these traits would be susceptible to the most change over time as a result of cultural transmission. Examining variation in this manner requires running cladistic models to test for effects of analogous and homologous traits and all things equal should create a strong phylogenetic signal (O'Brien et al, 2014).

For many years cladistics have been used in biology to construct heritability relationships to create phylogenetic trees (O'Brien et al, 2001, 2002). Applying this concept to archaeological data has been a fairly recent phenomenon. Constructing phylogenies from a set of taxa and their characteristics is a useful tool for indicating possible modes of cultural transmission within and between groups to create a picture of relatedness based on similarities among those character states, the assumption being that the more similar two artifacts are the more historically related they are assumed to be (Eerkens and Lipo, 2007; O'Brien et al, 2001, 2002). Relationships between cultural artifacts are harder to distinguish than biologic relationships because cultural transmission is messier and can transmit through either branching or blending processes. Blending processes assume that similarities and differences are due to the diffusion of ideas across cultures and the differential adoption of traits which until recently has been widely considered to be the dominant form of cultural transmission (Collard et al, 2006; Mace and Holden, 2005). The branching bifurcating tree model has been applied to various cultural phenomena (Coward, 2008; Mace and Holden, 2005; Jordan and Shennan, 2009; Larsen, 2011, Lycett, 2009; O'Brien et al, 2014; Prentiss et al, 2014; Tehrani, 2011) and it assumes descent with modification plays a significant role in defining relationships among cultures.

The full database of 125 points was characterized using the seven characters with the modal characteristics of the points from each assemblage, which are listed under each set of points provided in Table 1. Various methods of phylogenetic analyses were then run on the refined modal data set (Table 3) of 24 points described in Table 2 using PAST (Paleontological Statistics Software Package for Education & Data Analysis) 2.17c (Hammer et al, 2001). In an effort to determine if hafting characteristics evolved independently from blade characteristics and therefore resulted in mosaic evolution, the modal data was split into two data sets, one with only blade characteristics (blade shape, cross-section, flake pattern, and flake size shown in Table 4 and the other with only hafting characteristics (shoulder shape, stem shape, and base shape) shown in Table 5.

Table 2: Total Data Set

Site &Figure #	Taxa	Blade	AngularShoulder	NoShouldering	ConvexShoulder	SquareShoulder	Stem	ConvexBase	Concave Base	LenticularCS	SubdiamondCS	IrregularPattern	IncompleteHorizontal	RandomFlakes	WideFlakes
Paisley Caves, OR	A	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	B	0	1	0	0	0	0	1	0	1	0	1	0	1	0
Fig. 1	C	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	Modal	0	1	0	0	0	0	1	0	1	0	1	0	1	0
Buhl Burial, ID	BB_WS	0	0	0	0	1	0	1	0	1	0	0	1	1	0
Fig. 10	Modal	0	0	0	0	1	0	1	0	1	0	0	1	1	0
Lind Coulee, WA	45GR97.131	0	1	0	0	0	0	1	0	1	0	0	1	1	0
	45GR97.95	0	0	0	0	1	1	?	?	1	0	0	1	1	0
Fig. 18 1-8	45GR97.93	?	1	0	0	0	0	1	0	1	0	0	1	1	0
	45GR97.100	1	1	0	0	0	0	?	?	1	0	?	?	?	?
	45GR97.127	0	0	0	0	1	0	1	0	1	0	0	1	1	0
	45GR97.130	?	1	0	0	0	0	1	0	1	0	?	?	?	?
	45GR97.128	0	1	0	0	0	0	1	0	1	0	?	?	?	?
	45GR97.123	1	0	0	0	1	0	1	0	1	0	0	1	1	0
	Modal	0	1	0	0	0	0	1	0	1	0	0	1	1	0
Cooper's Ferry, ID	73-626	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	73-628	0	1	0	0	0	0	1	0	1	0	1	0	1	0
Fig. 8	73-627	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	73-629	0	1	0	0	0	?	?	?	1	0	1	0	1	0
	Modal	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	a	?	?	?	?	?	0	0	1	?	?	1	0	1	0
Wewukiyepuh, ID	b	0	0	1	0	0	0	0	1	1	0	1	0	1	0
Fig. 3	Modal	0	0	1	0	0	0	0	1	1	0	1	0	1	0
Running Antelope, UT	a	0	0	1	0	0	0	1	0	0	1	1	0	1	0
	b, c d, e	?	?	?	?	?	0	1	0	0	1	1	0	1	0
	Modal	0	0	1	0	0	0	1	0	0	1	1	0	1	0
Old River Bed delta, UT	FS#57	1	0	1	0	0	0	1	0	0	1	1	0	1	0
	FS#43 (A)	1	0	1	0	0	0	?	?	0	1	1	0	1	0
Fig. 2	FS#520 (B)	1	0	1	0	0	0	1	0	0	1	1	0	1	0
Fig. 3	FS#1	1	0	1	0	0	0	1	0	0	1	1	0	0	1
	Modal	1	0	1	0	0	0	1	0	0	1	1	0	1	0

Sentinel Gap, WA	637	1	0	1	0	0	0	1	0	0	1	0	0	0	1
	1254	1	0	1	0	0	0	1	0	1	0	0	0	0	1
	282	1	0	0	1	0	0	1	0	1	0	?	?	?	?
	1220	?	?	?	?	?	0	1	0	1	0	0	1	1	0
	728	?	0	1	0	0	0	1	0	1	0	0	0	0	1
	670	?	?	?	?	?	0	1	0	?	?	0	1	0	1
	743	0	0	1	0	0	0	1	0	?	?	1	0	1	0
	Modal	1	0	1	0	0	0	1	0	1	0	0	0	0	1
Hatwai I, ID	b	1	1	0	0	0	0	?	?	1	0	1	0	1	0
Fig. 15	c	1	0	0	0	1	1	0	1	1	0	1	0	1	0
	e	0	0	0	0	1	1	0	1	1	0	1	0	1	0
	f	0	1	0	0	0	?	?	?	1	0	1	0	1	0
	g	0	0	0	0	1	0	0	0	1	0	1	0	1	0
	h	0	0	0	0	1	1	0	0	1	0	1	0	1	0
	i	1	0	0	0	1	1	0	1	1	0	1	0	1	0
	k	0	1	0	0	0	?	0	1	1	0	1	0	1	0
	Modal	0	0	0	0	1	1	0	1	1	0	1	0	1	0
C.W. Harris, CA	g	0	0	0	1	0	0	1	0	1	0	1	0	1	0
	h	0	1	0	0	0	?	?	?	1	0	0	1	0	0
Fig. 3	k	0	1	0	0	0	0	1	0	1	0	0	1	1	0
Fig. 4	i	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	j	0	0	0	1	0	0	1	0	1	0	1	0	1	0
	k	0	0	0	1	0	0	1	0	1	0	1	0	1	0
	l	0	0	0	1	0	0	1	0	1	0	1	0	1	0
	o	0	1	0	0	0	0	?	?	1	0	0	1	1	0
	p	0	1	0	0	0	0	1	0	1	0	0	1	1	0
	q	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	r	0	0	0	1	0	0	0	0	1	0	1	0	1	0
Fig. 5	e	0	0	0	1	0	0	1	0	1	0	1	0	1	0
	f	0	0	0	1	0	0	1	0	1	0	1	0	1	0
	h	0	0	0	0	1	0	1	0	1	0	1	0	1	0
	Modal	0	0	0	1	0	0	1	0	1	0	1	0	1	0
Fort Rock Cave, OR	35LK1 10-9/2	0	1	0	0	0	0	1	0	1	0	1	0	1	0
	Surface	0	1	0	0	0	0	1	0	1	0	0	1	1	0
Fig. 17 P16	Surface	0	1	0	0	0	0	1	0	1	0	1	0	1	0
Fig. 15 P10	35LK1 11-10/3	0	1	0	0	0	0	1	0	0	1	1	0	1	0
Fig. 18 P17	35LK1 10-9/2	0	0	0	0	1	0	1	0	0	1	1	0	0	1
	Surface	0	1	0	0	0	0	1	0	0	1	1	0	0	1
	Surface	0	0	0	0	1	0	1	0	0	1	0	1	0	1
	Modal	0	1	0	0	0	0	1	0	0	1	1	0	1	0

Yucca Mountain, NV	a	0	0	0	0	1	?	?	?	?	?	1	0	1	0
	b	0	1	0	0	0	0	1	0	?	?	0	1	1	0
Fig. 3	c	0	1	0	0	0	0	1	0	?	?	1	0	1	0
	Modal	0	1	0	0	0	0	1	0	?	?	1	0	1	0
Fletcher, Alberta	a	0	0	0	0	1	1	0	0	?	?	0	1	0	1
	b	0	0	0	0	1	1	0	0	?	?	0	1	0	0
Fig. 1	c	0	0	0	0	1	1	0	0	?	?	1	0	1	0
	d	0	0	0	0	1	1	?	?	?	?	0	1	0	1
	e	?	?	?	?	?	1	0	0	?	?	?	?	?	?
Alberta	Modal	0	0	0	0	1	1	0	0	?	?	0	1	0	1
	i	0	1	0	0	0	1	0	0	?	?	0	1	0	0
	j	1	0	0	0	1	1	0	0	?	?	0	1	0	0
	k	?	0	0	0	1	1	?	?	?	?	1	0	0	1
	l	0	0	0	0	1	1	0	0	?	?	0	1	1	0
Scottsbluff	Modal	0	0	0	0	1	1	0	0	?	?	0	1	0	0
Olsen Chubbuck, CO	a	1	0	0	0	0	1	0	0	0	1	0	0	0	0
	f	0	0	0	0	0	1	0	1	0	1	0	0	0	0
Fig. 37	g	1	0	0	0	0	1	0	1	0	1	0	0	0	0
	h	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Fig. 38	c	1	0	0	0	0	1	0	0	0	1	0	0	0	0
	f	1	1	0	0	0	1	0	0	0	1	0	0	1	0
	Modal	1	0	0	0	0	1	0	0	0	1	0	0	0	0
Hell Gap, WY	u	0	0	0	1	0	0	0	0	?	?	?	?	?	?
Fig. 17.6	v	0	0	1	0	0	0	0	0	?	?	?	?	?	?
Fig. 17.8	g	1	0	1	0	0	0	1	0	?	?	?	?	?	?
Fig. 18.3	h, 1	0	0	0	1	0	0	0	0	1	0	1	0	1	0
	i	0	0	0	1	0	0	?	?	?	?	?	?	?	?
	j	0	0	1	0	0	0	?	?	?	?	?	?	?	?
	k	0	0	0	1	0	0	?	?	?	?	?	?	?	?
Hell Gap	Modal	0	0	0	1	0	0	0	0	1	0	1	0	1	0
Fig. 17.6	s	1	0	1	0	0	0	1	0	?	?	?	?	?	?
	t	0	0	1	0	0	0	1	0	?	?	?	?	?	?
	m	1	0	1	0	0	0	0	0	?	?	?	?	?	?
Fig. 17.8	e	1	0	1	0	0	0	1	0	?	?	?	?	?	?
	f	0	0	1	0	0	0	0	0	?	?	?	?	?	?
Fig. 18.1, 2, 3	9, 16, 3	-	-	-		-	-	-	-	1	0	1	0	1	0
Agate Basin	Modal	1	0	1	0	0	0	1	0	1	0	1	0	1	0
Claypool, CO	Cl-1	1	0	0	0	0	1	0	0	0	0	0	0	0	0

Fig. 4	Cl-2	1	?	?	?	?	?	?	?	0	0	0	0	0	0
	Cl-5	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	Cl-6	1	1	0	0	0	1	0	0	0	0	0	0	0	1
	Cl-10	1	0	0	0	0	1	0	0	0	1	0	0	0	1
	Modal	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Casper, WY	a	0	0	0	1	0	0	0	0	1	0	0	1	0	0
Fig. 1.35	b	0	0	0	1	0	0	0	0	1	0	0	1	0	0
	d	0	1	0	0	0	0	0	0	1	0	1	0	1	0
Fig. 1.36	a	0	0	0	1	0	0	0	0	1	0	0	1	0	0
Fig. 1.37	b	0	0	0	1	0	1	0	0	1	0	0	1	0	1
	Modal	0	0	0	1	0	0	0	0	1	0	0	1	0	0
Horner, WY	a	0	0	0	0	1	1	0	1	1	0	0	1	0	1
Fig. 6.1	b	0	0	0	0	1	1	?	?	1	0	0	1	0	1
	c	0	0	0	0	1	1	0	0	1	0	0	1	0	1
	e	0	0	0	0	0	0	0	0	1	0	0	1	0	1
	f	0	0	0	0	1	1	0	0	1	0	0	1	0	1
	g	0	0	0	0	0	1	0	0	1	0	0	1	0	1
	h	0	0	0	0	1	1	?	?	1	0	0	1	0	1
	l	0	0	0	0	1	1	?	?	1	0	0	1	0	1
	j	0	0	0	0	0	1	?	?	1	0	0	1	0	1
Fig. 6.6	a	1	0	0	0	0	1	0	0	1	0	0	1	0	1
	b	0	0	0	0	1	1	0	0	1	0	0	1	0	1
	Modal	0	0	0	0	1	1	0	0	1	0	0	1	0	1
Fig. 6.7	a	1	0	0	0	1	1	0	0	0	1	0	1	1	0
	b	1	0	0	0	1	1	0	0	0	1	0	1	0	1
	c	1	0	0	0	1	1	0	0	0	1	0	1	1	0
	d	0	0	0	0	0	1	0	0	0	1	0	0	1	0
	e	1	0	0	0	1	1	0	0	0	1	0	0	0	1
	f	0	0	0	0	0	1	0	0	0	1	0	1	1	0
	Modal	1	0	0	0	1	1	0	0	0	1	0	1	1	0
Fig. 6.10	a	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	b	1	0	0	0	0	?	0	0	0	0	0	0	0	0
	c	1	0	0	0	0	?	0	0	0	0	0	0	0	0
	d	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	h	1	0	0	0	0	1	0	0	0	0	0	0	0	0
	Modal	1	0	0	0	0	1	0	0	0	0	0	0	0	0

Table 3: Modal Data Set

Taxa	Blade	AngularShoulder	NoShouldering	ConvexShoulder	SquareShoulder	Stem	Convex Base	ConcaveBase	LenticularCS	SubdiamondCS	IrregularPattern	Incomplete Horizontal	RandomFlakes	WideFlakes
PC_OG	0	1	0	0	0	0	1	0	1	0	1	0	1	0
BB_WS	0	0	0	0	1	0	1	0	1	0	0	1	1	0
LC_WS	0	1	0	0	0	0	1	0	1	0	0	1	1	0
CF_W	0	1	0	0	0	0	1	0	1	0	1	0	1	0
W_W	0	0	1	0	0	0	0	1	1	0	1	0	1	0
RA_H	0	0	1	0	0	0	1	0	0	1	1	0	1	0
ORB_H	1	0	1	0	0	0	1	0	0	1	1	0	1	0
SG_H	1	0	1	0	0	0	1	0	1	0	0	0	0	1
Hw_W	0	0	0	0	1	1	0	1	1	0	1	0	1	0
CWH_MS	0	0	0	1	0	0	1	0	1	0	1	0	1	0
FRC_WS	0	1	0	0	0	0	1	0	0	1	1	0	1	0
YM_MS	0	1	0	0	0	0	1	0	?	?	1	0	1	0
F_Al	0	0	0	0	1	1	0	0	?	?	0	1	0	1
F_S	0	0	0	0	1	1	0	0	?	?	0	1	0	0
OC_F	1	0	0	0	0	1	0	0	0	1	0	0	0	0
HG_HG	0	0	0	1	0	0	0	0	1	0	1	0	1	0
HG_AB	1	0	1	0	0	0	1	0	1	0	1	0	1	0
Cp_E	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Cs_HG	0	0	0	1	0	0	0	0	1	0	0	1	0	0
Hn_AC	0	0	0	0	1	1	0	0	1	0	0	1	0	1
Hn_S	1	0	0	0	1	1	0	0	0	1	0	1	1	0
Hn_E	1	0	0	0	0	1	0	0	0	0	0	0	0	0

Table 4: Blade Data Set

Taxa	Blade	LenticularCS	SubdiamondCS	IrregularPattern	Incomplete Horizontal	Random Flakes	Wide Flakes
PC_OG	0	1	0	1	0	1	0
BB_WS	0	1	0	0	1	1	0
LC_WS	0	1	0	0	1	1	0
CF_W	0	1	0	1	0	1	0
W_W	0	1	0	1	0	1	0
RA_H	0	0	1	1	0	1	0
ORB_H	1	0	1	1	0	1	0
SG_H	1	1	0	0	0	0	1
Hw_W	0	1	0	1	0	1	0
CWH_MS	0	1	0	1	0	1	0
FRC_WS	0	0	1	1	0	1	0
YM_MS	0	?	?	1	0	1	0
F_Al	0	?	?	0	1	0	1
F_S	0	?	?	0	1	0	0
OC_F	1	0	1	0	0	0	0
HG_HG	0	1	0	1	0	1	0
HG_AB	1	1	0	1	0	1	0
Cp_E	1	0	0	0	0	0	0
Cs_HG	0	1	0	0	1	0	0
Hn_AC	0	1	0	0	1	0	1
Hn_S	1	0	1	0	1	1	0
Hn_E	1	0	0	0	0	0	0

Table 5: Haft Data Set

Taxa	Angular Shoulder	NoShouldering	ConvexShoulder	SquareShoulder	Stem	ConvexBase	ConcaveBase
PC_OG	1	0	0	0	0	1	0
BB_WS	0	0	0	1	0	1	0
LC_WS	1	0	0	0	0	1	0
CF_W	1	0	0	0	0	1	0
W_W	0	1	0	0	0	0	1
RA_H	0	1	0	0	0	1	0
ORB_H	0	1	0	0	0	1	0
SG_H	0	1	0	0	0	1	0
Hw_W	0	0	0	1	1	0	1
CWH_MS	0	0	1	0	0	1	0
FRC_WS	1	0	0	0	0	1	0
YM_MS	1	0	0	0	0	1	0
F_Al	0	0	0	1	1	0	0
F_S	0	0	0	1	1	0	0
OC_F	0	0	0	0	1	0	0
HG_HG	0	0	1	0	0	0	0
HG_AB	0	1	0	0	0	1	0
Cp_E	0	0	0	0	1	0	0
Cs_HG	0	0	1	0	0	0	0
Hn_AC	0	0	0	1	1	0	0
Hn_S	0	0	0	1	1	0	0
Hn_E	0	0	0	0	1	0	0

Through the use of PAST (v. 2.17c) (Hammer et al, 2001), a Parsimony analysis was run on the data set to examine for descent with modification relationships. A Parsimony analysis constructs a hierarchical cladogram of the most parsimonious trees that represent the extent of branchiness or descent with modification (Lycett, 2009; Prentiss et al, 2014). This is done through establishing the most parsimonious tree(s), the trees that are found to require the shortest sequence of evolutionary events, and supporting them with calculations of the Consistency (CI) and Retention Index (RI) (Collard et al, 2006). The CI calculates for potential homoplasy (convergence or reversals) in the data and the RI calculates the amount of synapomorphies (shared, derived traits) (Collard et al, 2006; Prentiss et al, 2014). A CI of 0 would be complete homoplasy whereas a CI of 1 indicates that no homoplasy is present. In contrast, an RI of 0 would mean no synapomorphy is present and an RI of 1 would be perfect synapomorphy (Prentiss et al, 2011). If a CI and RI of .50 or higher is generated for the parsimony analysis, this would be a strong result suggesting that branching played a more important role than blending in cultural evolution (Collard et al, 2006; Lycett, 2009). Multiple most parsimonious trees were generated for each analysis of the modal data, haft data, and blade data, therefore a majority consensus tree was produced for each data set based on those parsimonious trees wherein only clades that are present in all trees were applied to the consensus tree (Baum and Smith, 2012). Bootstrapping was conducted to test for the strength of the branches that have been created by randomly re-sampling characters 1000 times and assuming a 50% significant rule (Anderson, 2001; Jordan and Shennan, 2009; Lycett, 2007, 2009).

Another calculation using PAST consisted of running a distance–based analysis using Neighbor-Joining analysis. This method is utilized to calculate the shortest possible distances between taxa which assume that the less similar two groups are the greater the distance between them (Baum and Smith, 2012). Calculating the similarity between two taxa is difficult to determine therefore distance is considered to reflect difference. Neighbor-joining is not a true cladistic approach because traits do not have to be shared or derived, nor does this analysis assume a constant, symmetrical rate of change like the parsimony analysis (Baum and Smith, 2012). This statistical technique is a valuable approach to calculating the shortest tree with the fewest evolutionary events. The neighbor-joining analysis was completed using Euclidean distance and bootstrapped by 10,000 replicates on the three data sets to simulate least distance between points.

The final analysis used Splitstree4 to run a neighbor-net networking analysis (Huson and Bryant, 2006). This method examines both branching and tokogenetic signals between taxa by creating a splitsgraphs that illustrates the patterns of borrowing and reticulations between taxa (Prentiss et al, 2011). The Q-residuals and Delta scores were calculated to measure for the strength of homoplastic reticulations through distance measurements of the branches (Gray et al, 2010; Wichmann et al, 2011). These measures look at how tree-like a splitsgraphs is whereas a value of 0 indicates that graph is completely tree-like (Gray et al, 2010; Holland et al, 2002). A neighbor-net plot was generated to demonstrate if evolution was more tree-like (descent with modification) indicating phylogenetic evolution, or more boxy (more blending between groups) indicating a higher role of borrowing and blending between groups (Collard et al, 2006; Gray et al, 2010; Prentiss et al, 2011; Wichmann et al, 2011).

Chapter 4: Results

4.1 Introduction

This chapter provides a detailed account of the results obtained by the use of the methods discussed in the previous chapter. These results include in order, parsimony, neighbor-joining, and neighbor-networking splitsgraph results for the modal, haft and blade data sets.

4.2 Parsimony Analyses

Parsimony cladograms for each group were generated using Heuristic (NNI), Fitch optimization, and bootstrapped by 1,000 replicates and are shown below in the following figures. The modal parsimony analysis produced 31 trees with a length of 36 and had a calculated RI of .725 and CI of .3889. A majority consensus cladogram of the modal data is shown in Figure 6. The polytomies in the consensus cladogram radiating from the second node from the base indicates that there is no clear distinguishable descent between these points. Instead, there is a significant amount of homoplasy related to the borrowing process occuring, and the low CI score does support this. However, the large number of taxa can also cause lower CI scores and with the co-occurrence of a high RI score implying a high degree of shared, derived traits, this is likely the case. Therefore, in an effort to provide understanding for the presence of these tokogenetic signals, the haft data and blade data were run separately and compared. Clades are discussed from right to left.

The haft parsimony analysis produced 158 trees with a length of 11 and a calculated RI of .8788 and CI of .6364. Cladogram #18 is shown in Figure 7 and the majority consensus cladogram in Figure 8. Removing the blade characteristics made a large impact to the parsimony analyses and resulted in four clades oriented by shoulder shape characteristics. I chose tree #18 due to its close similarity to the majority consensus cladogram displaying the same four clades, with the only difference being BB_WS.

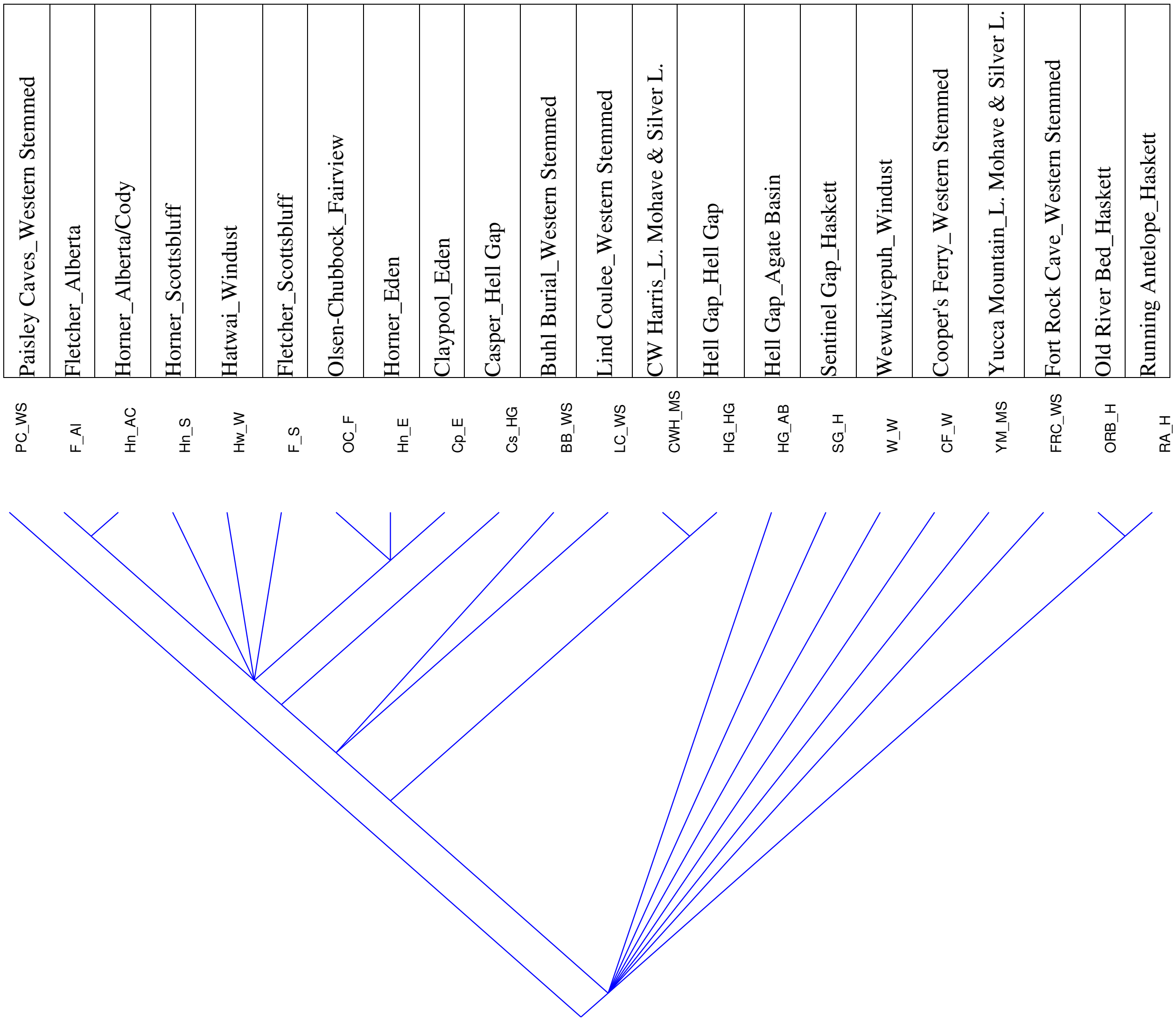


Figure 6: Modal parsimony analysis majority consensus cladogram

.

Some of the initial striking features of tree #18 show clade 1 (YM_MS, LC_WS, and CF_W points) branching off with moderate bootstrap scores indicating they are the least derived from the out-group. However, a polytomy is present in the consensus cladogram for the same points implies that the blending between them makes it un-interpretable which points are derived from which. All other points appear to be derived from a common ancestor identified at node five with a bootstrap score of 67 in Figure 7 and at node two in Figure 8. The second clade in tree #18 is composed of W_W, ORB_H, HG_AB, RA_H, and SG_H. What is most interesting about this clade is the inclusion of W_W, previously described as a Windust style, with other Haskett varieties. In the consensus cladogram, the fourth clade again shows W_W as the most primitive in that clade but with the other points as polytomies from the next node reflecting those tokogenetic, blending signals between them that make it harder to distinguish how descent with modification might have occurred. This close relationship could be indicative of a transition between Windust and Haskett styles which would account for W_W being the least derived point in this clade. This clade also includes the Agate Basin point from Hell Gap (HG_AB) which is suggestive of a close ancestor-descendent relationship between Haskett and Agate Basin but also of the inclusion of Agate Basin into the greater Western Stemmed Tradition. The sixth node shows a split from Cody Complex, Hw_W, and BB_WS points and HG_HG, Cs_HG, and CWH_MS points. The third clade shows clear descent with modification in the chronological sequence many archaeologists believe to be the sequence of the Cody Complex Tradition with the exception of Hw_W, and BB_WS points. In the third clade of the consensus cladogram (Figure 8), the points are represented by polytomies stemming from the same node, reflecting the higher level of blending between them. The final clade in Figure 7 is composed of Hell Gap and Lake Mohave points. I had previously expected Hell Gap to be more closely related to Agate Basin, however this particular tree, as well as the majority consensus tree, hypothesizes that these points are derived from a common ancestor rather than Hell Gap evolving from Agate Basin technology. This tree would instead suggest that Agate Basin is descended from the Haskett tradition while Hell Gap and other Great Basin points share a closer ancestor-descendent relationship. The high RI and CI scores for the haft data analysis lends support to hafting characteristics likely having evolved through vertical descent with modification.

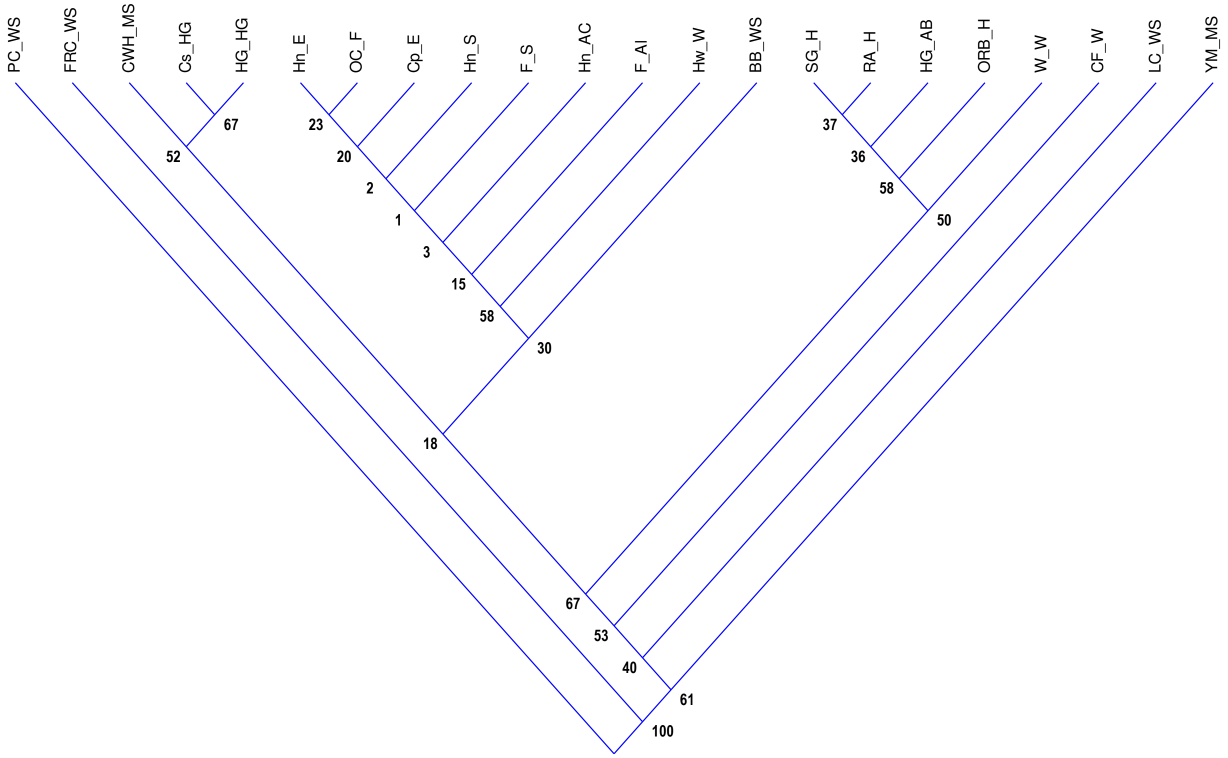


Figure 7: Haft parsimony analysis cladogram #18.

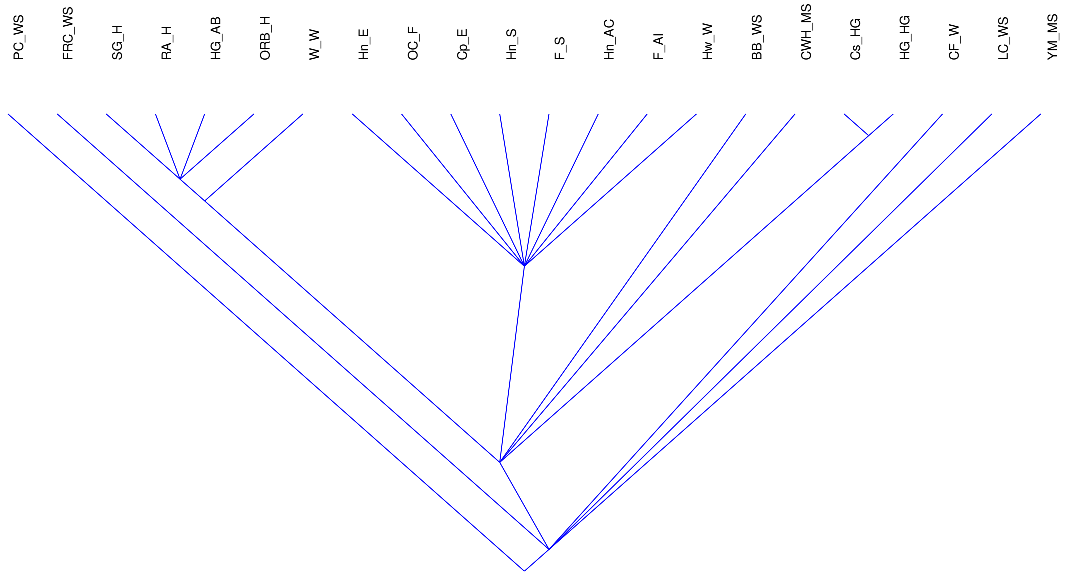


Figure 8: Haft parsimony analysis majority consensus cladogram.

The blade parsimony analysis produced 21 trees with a length of 14 and had a calculated RI of .8511 and CI of .5. Cladogram #1 is shown in Figure 9 very closely resembles the strict consensus cladogram in Figure 10. At first glance this tree essentially makes no sense; all bootstrap scores are under 50 with the exception of node 1 with a score of 100 which makes the high RI and moderate CI score all the more surprising. On closer inspection though, the descent pattern loosely follows with dates of these points, with older points branching off earlier and more derived points having a younger date. The only obvious points that don't align with this theory are the location of Horner points Hn_E and Hn_S that should be swapped with F_Al and F_S, as well as the BB_WS which dates to 10.6 k BP but is reflected on this cladogram as the most derived point. When ignoring these two discrepancies, the pattern through time seems to be reflecting the increased ability of the knapper to make narrower, collateral, bifacial pressure

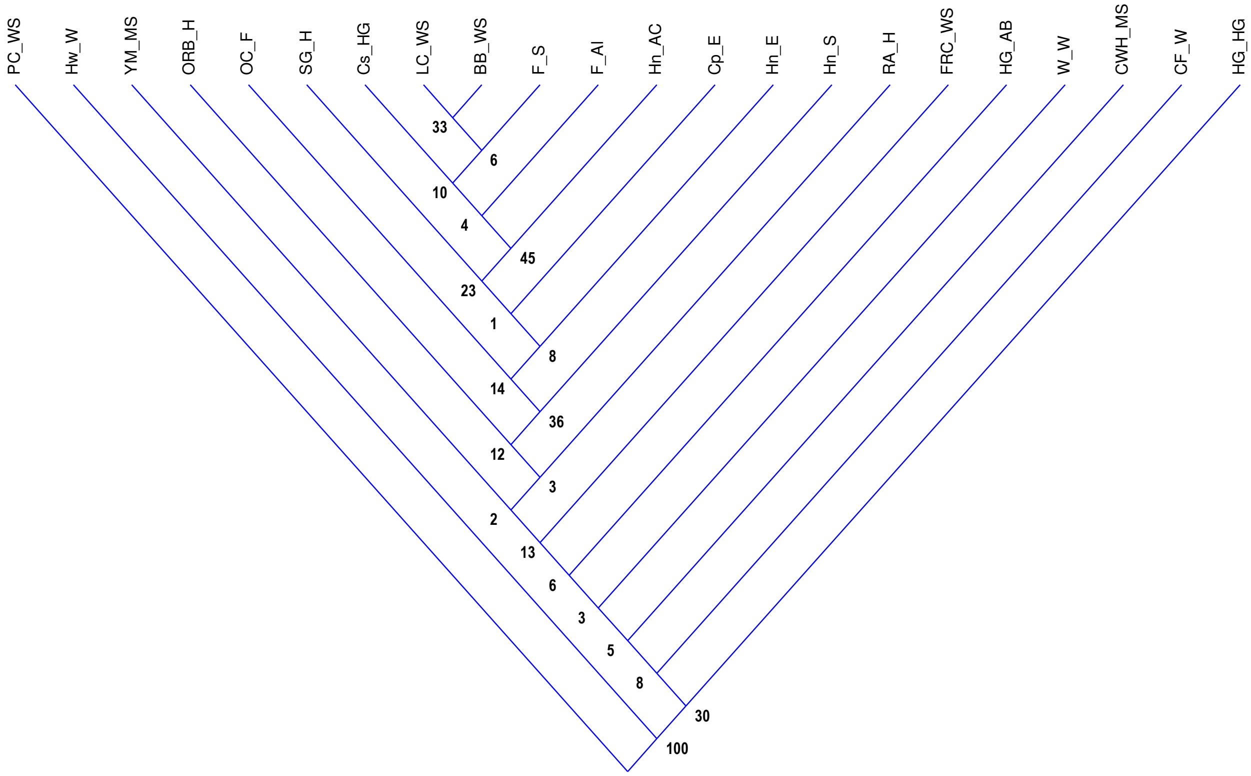


Figure 9: Blade parsimony analysis cladogram #1.

flaking. The high RI of .8511 and moderate CI of .5 strongly suggest that homoplasy and blending are present, but there is still descent with modification.

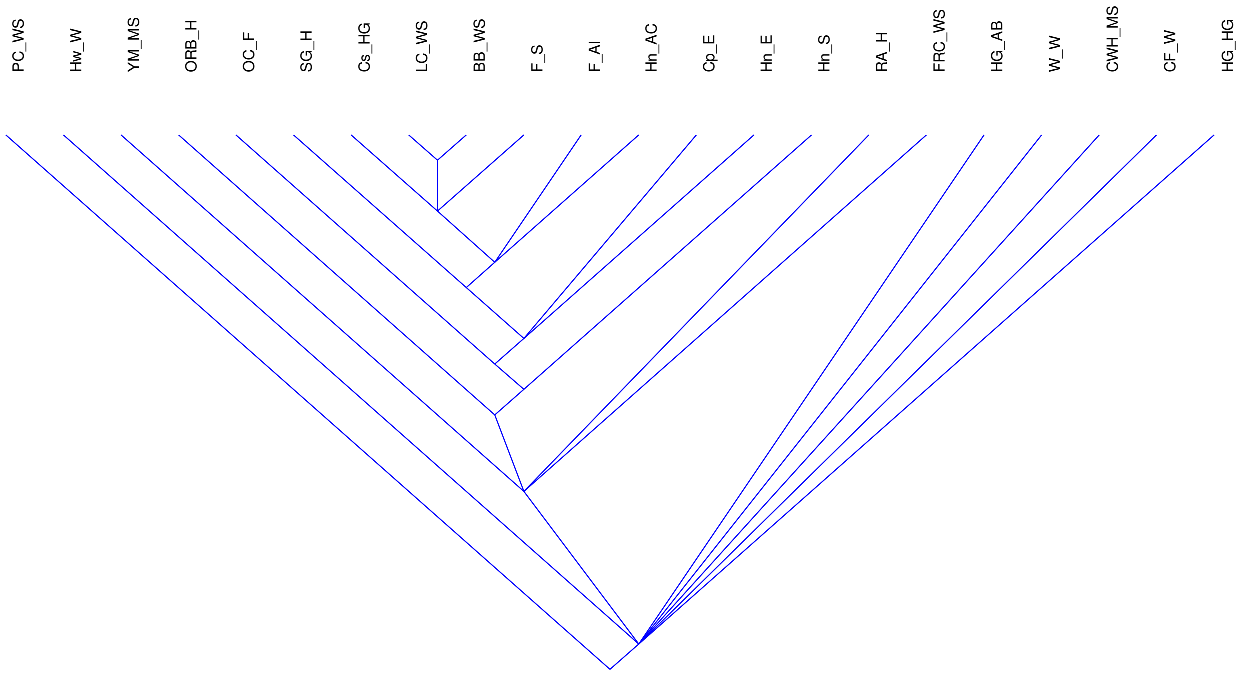


Figure 10: Blade parsimony analysis strict consensus cladogram.

When comparing the three majority consensus cladograms it's apparent the reasoning for the tokogenetic signals and lack of clear descent with modification in Figure 6 was due to combining these two types of characteristics, blade and haft. Instead, these traits appear to have evolved in a mosaic fashion that created two distinct lines of descent, one that is spatial and one that is temporal. The hafting cladograms produced results that closely favor stylistic typologies across the landscape with some potential ancestor-descendent relationships from Windust to Haskett to Agate Basin, from Windust to Cody, and between Hell Gap and Great Basin points. In contrast, the blade cladogram has no typological, spatial trend but instead the branching pattern from primitive to derived correlates to a certain extent with age.

4.3 Neighbor-Joining Analyses

The Neighbor-Joining analyses were generated using Euclidean distance, and bootstrapped by 10,000 replicates. The modal data is shown in Figure 11, the haft data in Figure 12, and the blade data in Figure 13. The neighbor-joining analysis calculated the distances between projectile point characteristics to simulate similarity between points. All analyses were rooted at the out-group to represent the distance and difference from the oldest and therefore most primitive point. A cursory look at these analyses illustrates that the haft data created clades based more similar on stylistic typologies while the blade data did not pattern along these typologies, suggesting that the most important characteristics for determining those typologies is contingent on traits that determine hafting functionality. Some notable insights from these cladograms include the distances of LC_WS from the out-group and CF_W, the W_W point, and FRC_WS to YM_MS.

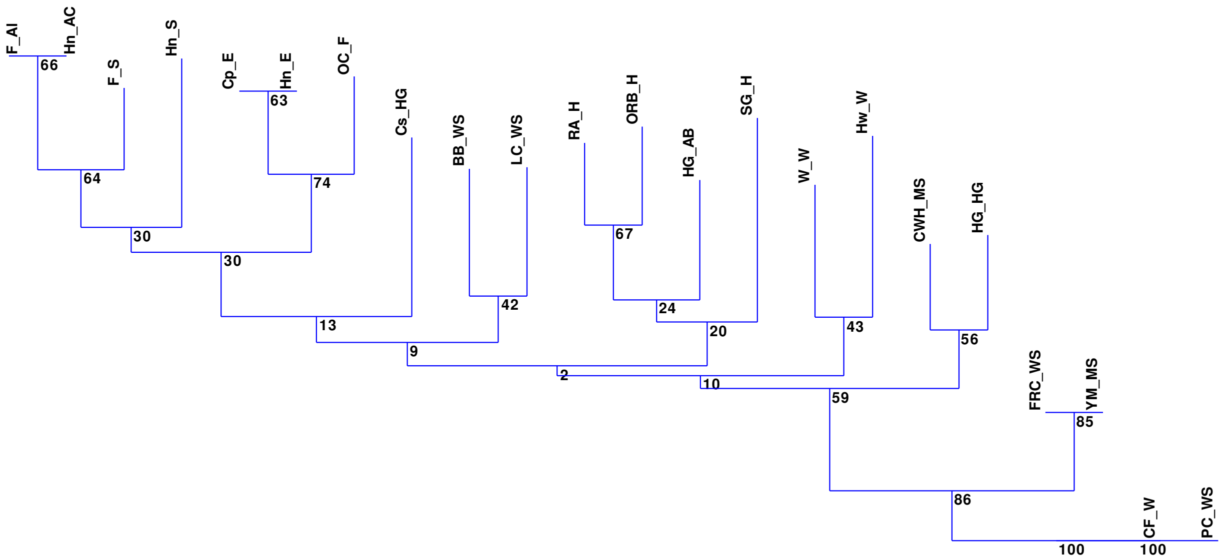


Figure 11: Neighbor-Joining modal data analysis.

Cooper's Ferry points have long been typologically defined as Lind Coulee points due to the close resemblances they share; however the overall modal point for LC_WS shares a closer resemblance to BB_WS. When compared to the haft and blade cladograms the reasons for this come to light. When only haft characteristics are analyzed CF_W and LC_WS have a smaller calculated distance as seen in Figure 12, whereas in Figure 13, LC_WS has a much larger distance from CF_W because the flaking patterns are more irregular on CF_W. In the modal and blade analyses the W_W point shared a closer similarity to Hw_W, the typical Windust point, lending support to W_W's inclusion in the Windust typology because it is not based solely on the shared concave bases between them but rather on the point as a whole. The close distance calculated between FRC_WS and YM_MS in all three cladograms was interesting. Though FRC_WS is technically in the Great Basin, it was a surprise to see close similarity between FRC_WS and other Great Basin Lake Mohave point types. Because of its location on the periphery of the Columbia Plateau, close proximity to PC_OG, and initial observations of the

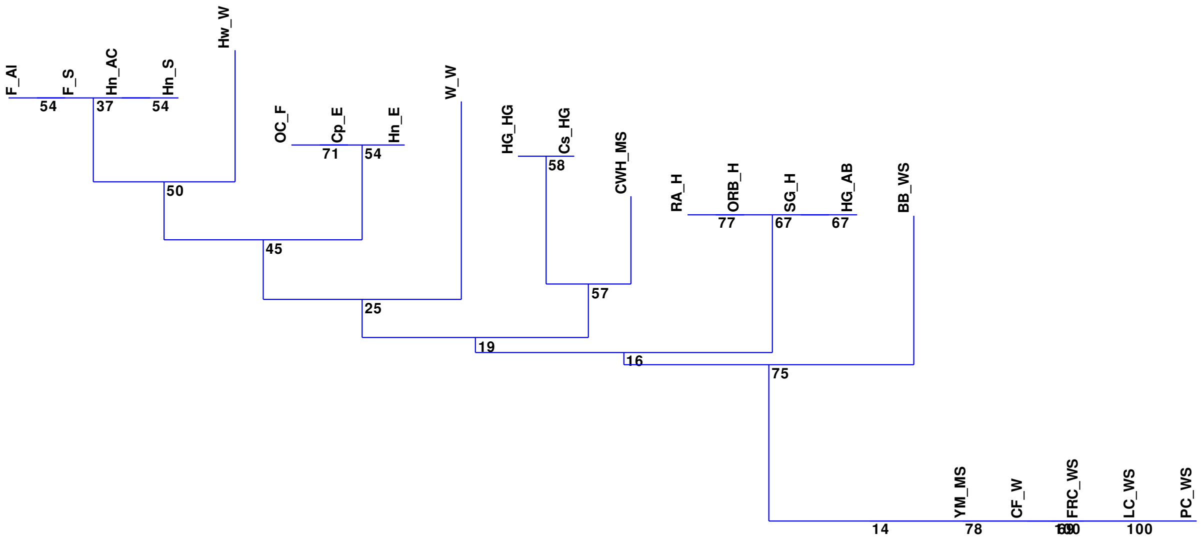


Figure 12: Neighbor-Joining haft data analysis.

projectile points suggested it would be closer related to Lind Coulee. This lends support to the very close similarities between projectile points on the Columbia Plateau and the Great Basin.

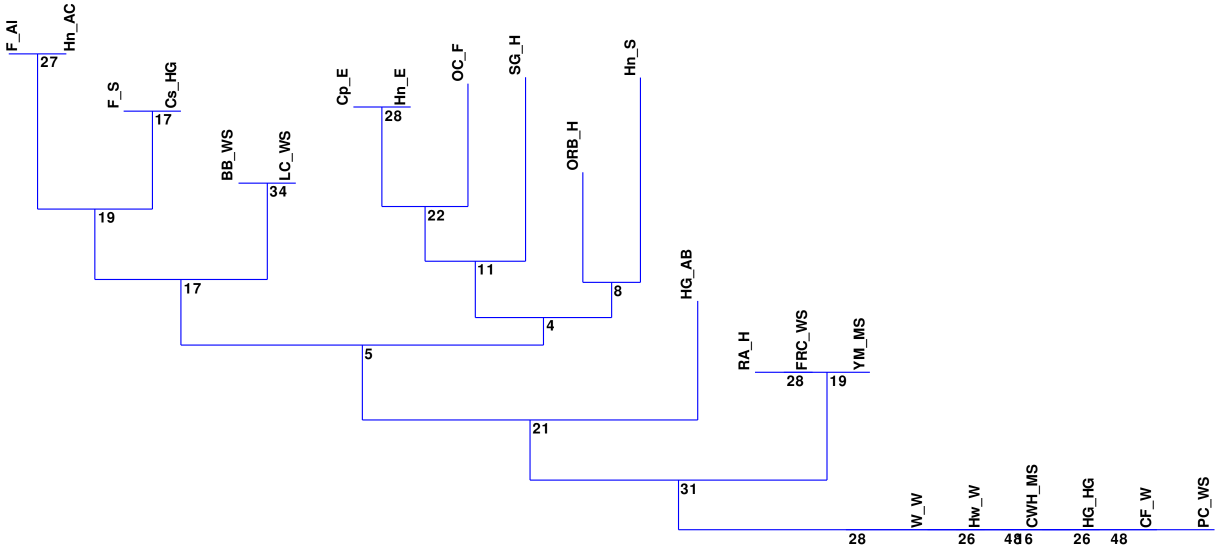


Figure 13: Neighbor-Joining blade data analysis.

4.4 Neighbor-Networking Analyses

The Neighbor-Networking Splitsgraphs are shown below for the three data sets. Clades are described beginning from the out-group (PC_WS) and moving clockwise around the graph. The modal data had a delta score of .3369 and Q-residual of .1312 and is shown in Figure 14. The modal splitsgraphs shows abundant blending and borrowing signals represented by boxiness and branches, split into five clades. This graph and the low bootstrap scores correlate with the parsimony results from the modal data that infers there is a high level of tokogenetic signals. On clade 3 W_W is on a branch with Hw_W, which has multiple lines connecting them to clade 5, between HG_AB, ORB_H, SG_H and to RA_H. This indicates that there is some blending between them. The location of FRC_WS on clade 1 places it in close association to PC_WS and CF_W but it has multiple lines connecting it to CWH_MS and HG_HG. The largest clade (4) is very boxy signifying a lot of blending and borrowing with clade 5 between Cody Complex points (Hn_AC, Hn_S, Cp_E, Hn_E, and OC_F), and Hell Gap (Cs_HG) with Lind Coulee points (LC_WS and BB_WS).

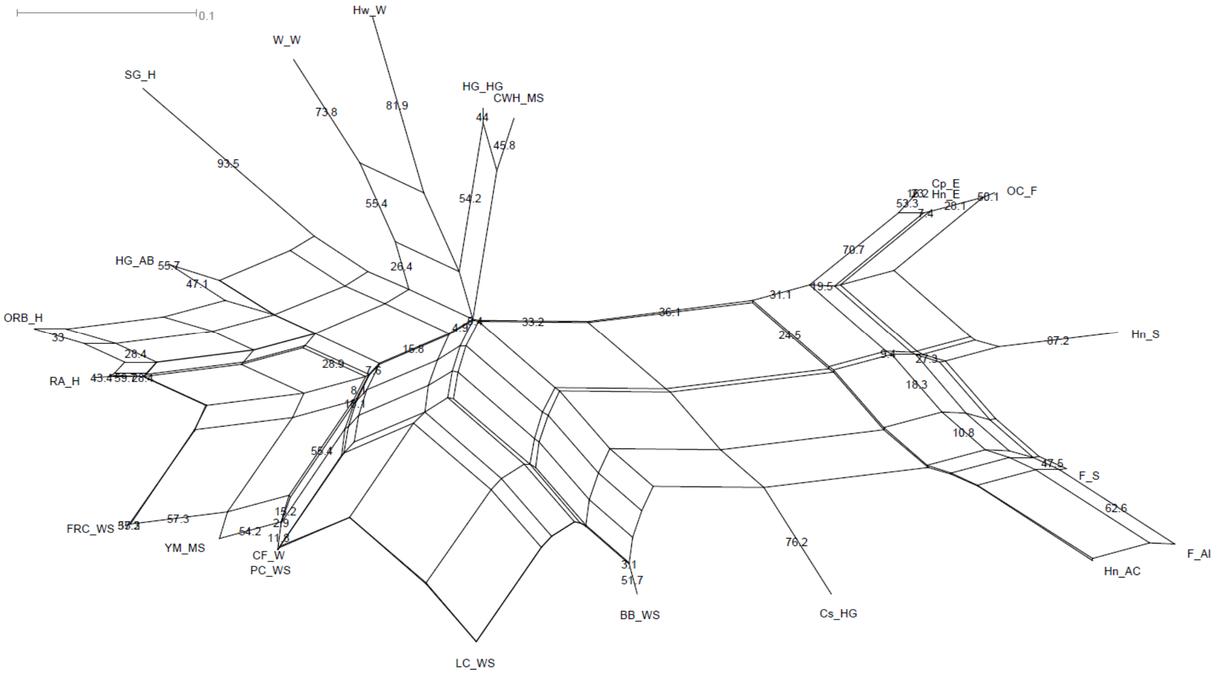


Figure 14: Neighbor-Networking splitsgraph modal data.

The haft splitsgraph had a delta score of .1042 and Q-residual of .07278 and is shown in Figure 15. The haft splitsgraph has some boxiness but is not dominated by tokogenetic signals and has a significantly lower delta and Q-residual score than the modal splitsgraph. The first clade contains the Lind Coulee, WSPt other, and Great Basin points with some limited blending to clade 2, Haskett and Agate Basin points, and to clade 5, Lake Mohave and Hell Gap points. There is a limited blending signal between clades 2 and 3 to clade 4 and significant blending between clades 5 and 4. The high bootstrap scores, low delta and q-residual scores support that the Haskett type points and Hell Gap type points evolved along two separate lines with limited borrowing of traits. This is followed by more significant borrowing between Hell Gap and Eden points.

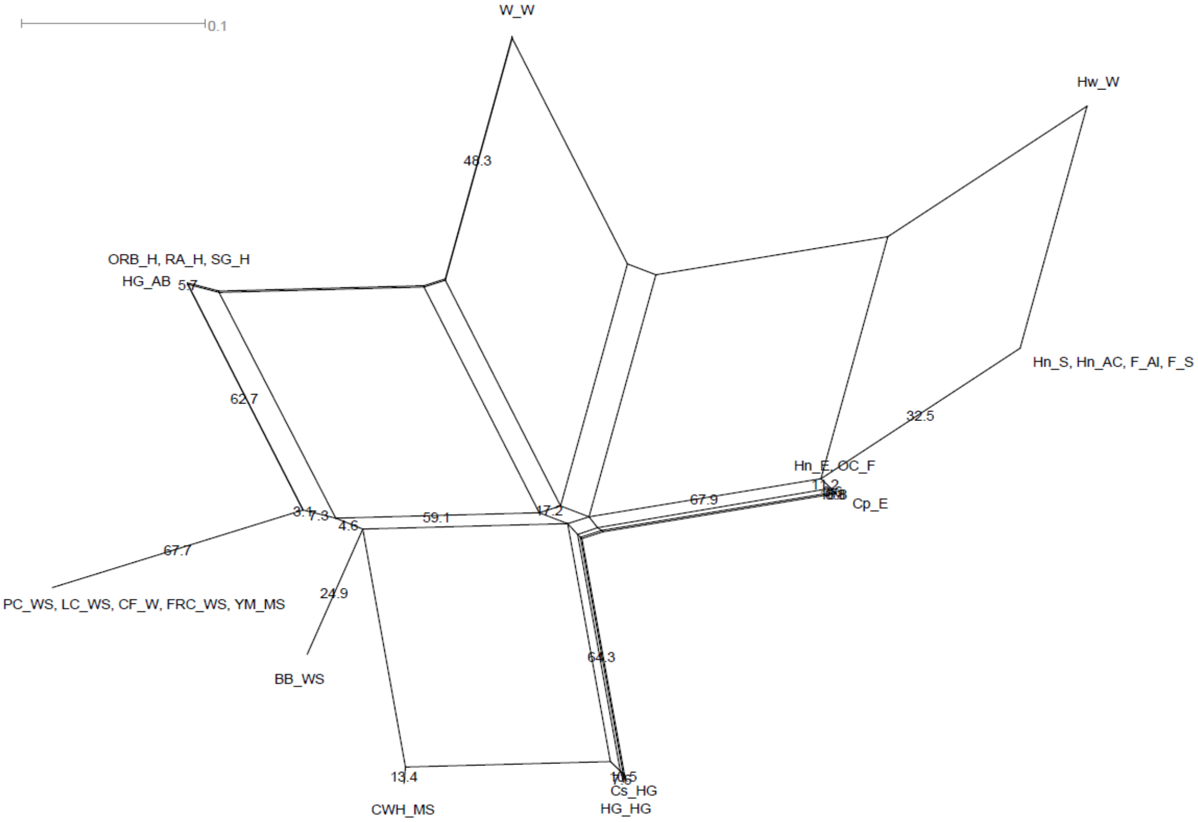


Figure 15: Neighbor-Networking splitsgraph haft data.

The blade data splitsgraph had a delta score of .3024 and Q-residual of .1995 and is shown in Figure 16. The blade splitsgraph has two main clades: the first clade consists of all points on the right hand side beginning with Hn_E clockwise to PC_OG through HG_AB, and the second clade on the left includes the points from BB_WS clockwise through SG_H. This splitsgraph is very boxy with low bootstrap scores suggesting there was frequent borrowing and diffusion of blade characteristics between traditions. The delta scores are slightly lower for this splitsgraph than the modal splitsgraph however they are higher than the haft splitsgraph. This supports the possibility that there is a degree of branching for the blade characteristics nonetheless is dominated by tokogenetic signals.

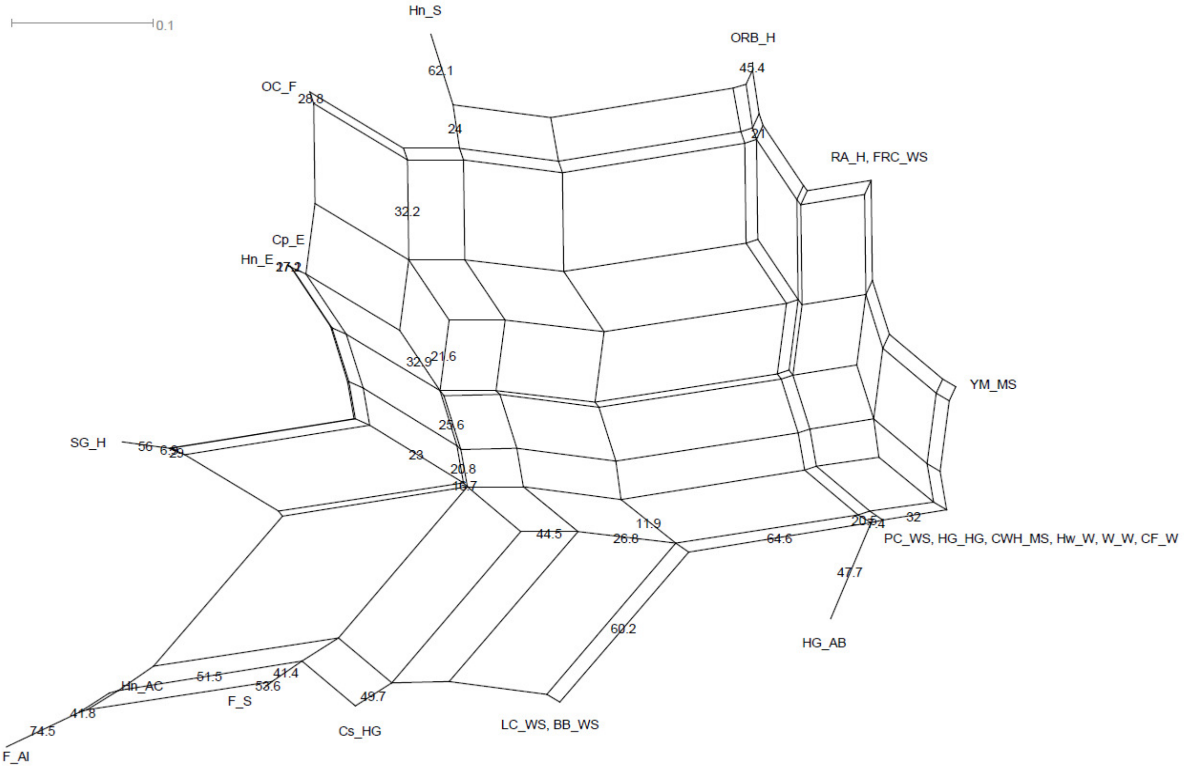


Figure 16: Neighbor-Networking splitsgraph blade data.

When comparing the three NeighborNet splitsgraph it is clear there has been some blending and borrowing of both haft and blade characteristics, although the extent of blending is more significant for the blade data across all point types. These results show there is a stronger tree-like pattern for the haft data but not for the blade data, advocating for the possibility that these traits evolved in a mosaic fashion that created two distinct lines of inheritance. The haft splitsgraph produced results that closely favor cross-regional typologies with some potential ancestor-descendent relationships from Windust to Haskett and Agate Basin, from Windust to Great Basin and Hell Gap points and blending between Hell Gap and Eden points. In contrast, the blade cladogram has no typological, spatial trend and suggests blade characteristics were more flexible and inclined to blending between traditions.

Chapter 5: Summary

5.1 Introduction

This chapter will summarize the results and discussion of the analyses while formally answering the hypotheses. Additionally, suggested further research will be provided.

5.2 Conclusion

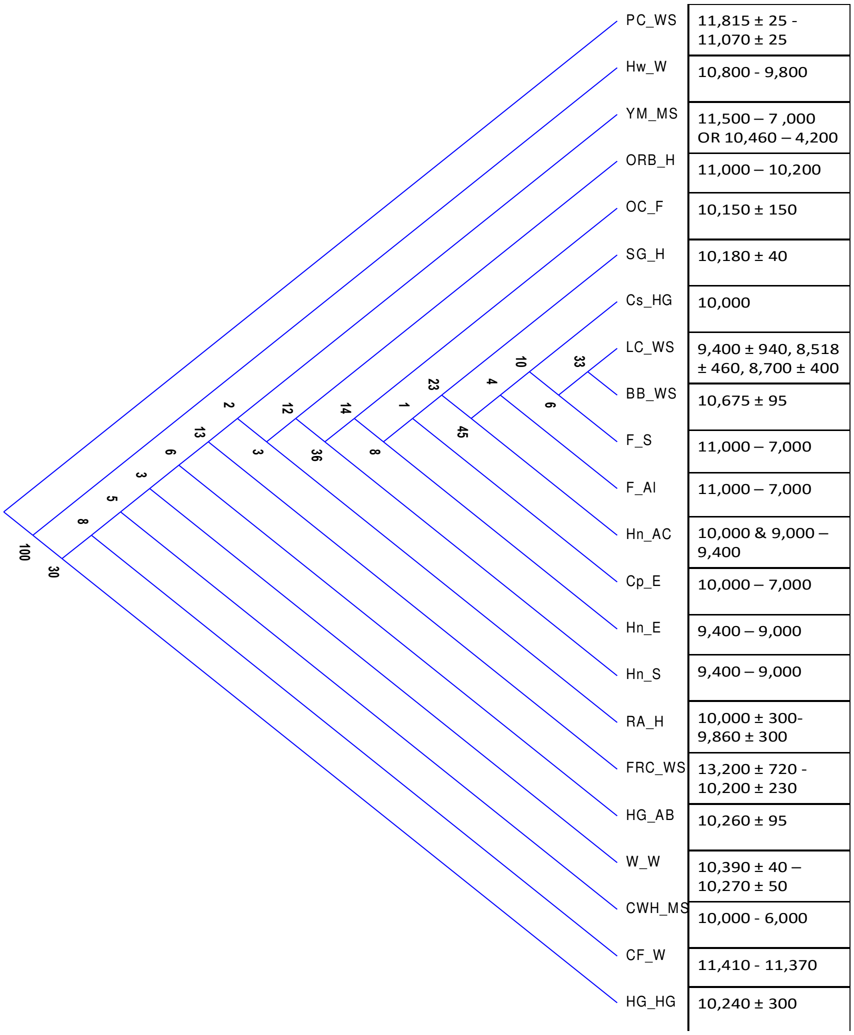


Figure 17: Blade data and dates.

The blade parsimony analysis produced a cladogram that loosely follows a vertical pattern of descent with modification through time. These dates are provided in Figure 17 for each modal point from the cladogram in Figure 9. In Figure 17, the dates corresponding to the points can be separated into three groups. The oldest group dates between 13,200-10,200 years ago and includes the most derived points, PC_WS through ORB_H and FRC_WS through HG_HG. The second group includes OC_F, SG_H and RA_H and date from 10,100-9,800 years ago. The youngest group includes Cs_HG, LC_WS and Hn_AC through Hn_S and date from

10,000-9,400 years ago. The outliers include BB_WS, which may be accounted for due to this point likely being made for the purpose of a burial (Green et al, 1998), and F_S and F_Al which have a broad ranging, unreliable date of 11,000-7,000 years ago. Unfortunately, the vertical transmission (branching pattern) following a temporal signal is not similarly reflected in the blade splitsgraph in Figure 16 and the moderately high delta score reflects it is dominated by reticulations. These points do not follow any perceived evolutionary change between point typologies however blade characteristics such as flake patterns do become more refined and narrow in the parsimony analysis. While blade characteristics appear to be more subjected to horizontal transmission there is slight directional change of variability of derived blade characteristics through time, therefore I conclude that the first hypothesis is only weakly supported.

In the haft parsimony (Figure 7), the third clade shows clear descent with modification in the sequential order many archaeologists believe to be the sequence of the Cody Complex tradition with the exception of Hw_W, and BB_WS points (Bamforth, 1991; Bradley and Frison, 1987; Bonnichsen and Keyser, 1982; Pitblado, 2003; Wheat et al, 1972). The Alberta and Alberta/Cody points were less derived than the Scottsbluff, Eden and Fairview points, however the polytomies in the consensus cladogram in Figure 8 does suggest that the reticulation between them does make descent difficult to determine. I had previously expected Hell Gap to be more closely related to Agate Basin, however in Figure 7 and 8, the haft and majority consensus tree, hypothesizes that these points are derived from a common ancestor rather than Hell Gap evolving from Agate Basin technology (Bradley, 2009; Pitblado, 2003). This tree would instead suggest that Agate Basin is descended from the Haskett tradition while Hell Gap and other Great Basin points share a closer ancestor-descendent relationship. There are a few potential explanations for the surprisingly low blending between Hell Gap and Agate Basin. It is possible the two branching signals could be indicative of Hell Gap replacing Agate Basin or even the co-occurrence of two separate technologies on the High Plains after they evolved from different lines. Another possible source for these reticulations could be from independent innovation. There are close similarities between Hell Gap and C.W. Harris Great Basin points (HG_HG and CWH_MS) and between Agate Basin and Haskett points (HG_AB, SG_H, RA_H, and ORB_ H) are visible in the haft parsimony and splitsgraph.

The occurrence of Windust, Lind Coulee and Lake Mohave Great Basin points on the same branch in Figure 15 and these same points creating a polytomy in Figure 8 support the theory that there is a long history of exchange between people on the Columbia Plateau and Great Basin regions (Amick, 2004; Beck and Jones, 2010; Daugherty, 1956; Rice, 1972). When these figures are taken together it seems reasonable that early Western Stemmed points resulted in three central lines of descent. One line of descent resulted in the Lake Mohave and Hell Gap styles with some blending between them, Haskett, and Eden points. A second line of descent resulted in the Haskett and Agate Basin styles with some blending with Windust, Great Basin and Hell Gap styles. The third line of descent consists of the Cody Complex points with possible descent and borrowing from Windust and Hell Gap points. These results point to likely patterns of transmission that produced cross-regional styles suggestive of migration patterns and trade networks. Consequently, I believe the second hypothesis is supported and that stemmed projectile points hafting characteristics do in fact follow a vertical pattern of transmission across space. This result established that descent with modification served a stronger role in the evolution of projectile point traits related to hafting functions. In Figure 18, the clades from Figure 7 are displayed on a map to visualize the spatial pattern that was created.

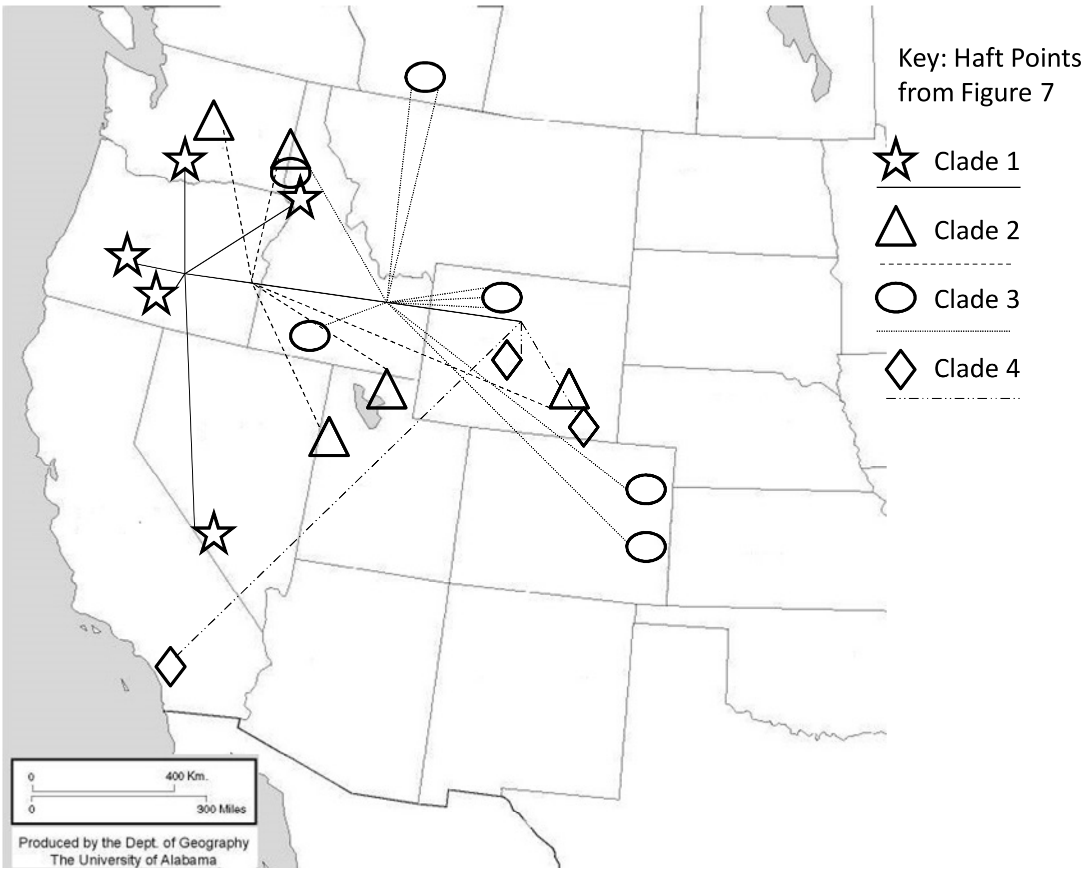


Figure 18: Spatial pattern of transmission for haft data.

The spatial pattern produced by the haft data in Figure 18 created some interesting results about the movement of the haft traits and ultimately the projectile point traditions. The first clade included Western Stemmed other (Fort Rock Cave, Paisley Caves and Lind Coulee), Windust (Cooper's Ferry) and Great Basin (Yucca Mountain) styles. Cooper's Ferry showed closer affinity to Western Stemmed other in radiocarbon date, and in hafting function and style as opposed to the Windust style. Clade two includes Haskett (Sentinel Gap, Running Antelope, and Old River Bed delta) and Windust (Wewukiyepuh) styles creating some spatial overlap with clade one on the Columbia Plateau but then moves onto the Great Basin. It is possible Wewukiyepuh is not a true Windust point or this point type could represent an ancestral transition between Windust and Haskett varieties. This clade also includes the Agate Basin (Hell

Gap) style from the High Plains. The lack of close similarity and limited blending between Agate Baisn and other High Plains points lends strong support for Agate Basin representing a cultural continuum of Haskett type points. The third clade shows a more north-south movement along the High Plains. However, the cultural similarities between Western Stemmed other (Buhl Burial) and Windust (Hatwai) styles along the Snake River in Idaho combined with previous research signifying migration routes through the Idaho – Wyoming region (Metcalf and McDonald, 2012) adds more support to this theory. The consequences of this west-east movement resulted in cultural continuity of hafting traits between Western Stemmed and Cody Complex technology. The fourth clade consists of Hell Gap (Casper and Hell Gap) and Great Basin – Lake Mohave/Silver Lake styles. The third and fourth clade likely evolved from a common ancestor, rather than Hell Gap and Great Basin evolving from Cody, Agate Basin, or Haskett points. With the exception of the inclusion of Great Basin in the fourth clade, there is a clear west to east movement of points across western North America.

Though I believe I can reject the blending hypothesis because neither the haft nor blade data were completely governed by tokogenetic signals, these cultural traditions were not isolated and blade characteristics were strongly influenced by blending and borrowing effects while haft related characteristics were only marginally affected. Additionally, further evidence for haft and blade traits evolving as separate units is supported in the neighbor-joining analysis. In the blade cladogram (Figure 13) Cs_HG clustered as most similar to F_S instead of CWH_MS and HG_HG which both clustered near early Western Stemmed points like CF_WS. In the haft cladogram (Figure 12) however, Cs_HG, CWH_MS, and HG_HG all clustered together. While the Agate Basin point clustered with Haskett points in the haft cladogram, it clustered closer to Hn_S and SG_H in the blade cladogram. Furthermore, the Hn_E, Cp_E, and OC_F points clustered together separate from other points in the haft cladogram, but clustered with SG_H, Hn_S and ORB_H in the blade cladogram. Finally, the haft data has F_Al, F_S, Hn_AC and Hn_S all clustered together as most similar, however in the blade cladogram they are split up onto different clades. These results provide further support for the occurrence of mosaic evolution of haft traits having evolved as separate units from the blade traits. This resulted in stronger vertical transmission of hafting traits with limited reticulations producing the stylistic typologies that we understand today. It is my conclusion that these stemmed projectile points do represent a continuum of an ever-evolving tradition that resulted in different artifact lineages with blending and borrowing between those lineages. However, the blade characteristics appear to have been much more fluid, allowing for significant borrowing of these cultural units between hafting traditions and producing differential persistence of blade traits through time.

5.3 Future Research

Though the result of mosaic evolution is very interesting, further work should be completed to test if the correlation between blade data and a change over time holds true. Additionally, there are still some unanswered questions about the history of possible distinct lineages on the Columbia Plateau. Since there was a fair amount of blending between Lind Coulee points, Hatwai and Wewukiyepuh Windust points, and the Buhl Burial point it was difficult to tell the relationship between them. In order to get a better sense of the correlations between them I believe an in-depth examination of the Columbia Plateau using more points and the phylogenetic methods described above would be useful. An further concern that should be addressed in future research is the association of Fairview points with Eden points. While this research shows a clear similarity between the two, a similar analysis should be completed with the Kersey, San Jon and Plainview points to determine if this is truly descent with modification or if blending processes were extensive enough that Eden-Fairview styles are a result of convergent evolution between separate artifact lineages.

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