A BEHAVIORAL ANALYSIS OF CLOVIS POINT MORPHOLOGY USING GEOMETRIC MORPHOMETRICS

A Thesis

by

HEATHER LYNN SMITH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

December 2010

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Ted Goebel
Committee Members,	David L. Carlson
	Thomas J. DeWitt
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ABSTRACT

A Behavioral Analysis of Clovis Point Morphology Using
Geometric Morphometrics. (December 2010)
Heather Lynn Smith, B.A., St. Edward's University
Chair of Advisory Committee: Dr. Ted Goebel

This thesis presents an investigation into Paleoindian projectile-point morphology. A goal of this research is to determine if evidence of a normative cultural manufacturing protocol can be identified on Clovis projectile points which can then be used to address research questions concerning Clovis point variability, and ultimately, the spread of this tool-form across North America. This paper addresses obstacles to behavioral investigations of stone tool morphology such as the effects of resharpening and raw material type on tool shape. I argue that a culturally normative process of manufacture was maintained throughout the life-history of Clovis projectile points which translated into a specific shape maintained to the time of exhaustion and discard. As an analytical tool, this study utilizes the geometric morphometric method to retain the geometry of each artifact throughout analysis by focusing on spatial covariation among landmarks uniformly found on each tool. This thesis investigates variability in 123 fluted projectile points from 23 archaeological sites in North America which met criteria meant to control for security of context in the archaeological record. Principle components describing the shape-variability inherent in this data-set were generated using geometric morphometrics and multivariate statistical analyses were employed to identify major factors of variability.

This research concluded that Clovis projectile-point shape was determined by normative cultural behavior maintained throughout the life of the artifact and not the result of raw material type or resharpening processes. Therefore, the projectile-point variability found to be geographically patterned provided evidence of Paleoindian movement and the spread of tool form. Multivariate analysis of variance determined that a regional trend in variability was present. The distribution of within-site variance suggested that artifacts from sites in the West were very homogeneous while artifacts from Eastern sites were more variable. The multivariate cluster and discriminant function analyses also demonstrated a closer affinity between artifacts in the Southwest and Northwest than either has with the Northeast. The similarities in projectile point morphology between the Southwest and Northwest regions suggest movement beginning with a Southwest point of origin from which Pleistocene peoples may have carried their fluted point technology north and east.

DEDICATION

This thesis is dedicated to
my parents,
Quintin and Peggy Smith

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CHAPTER I
INTRODUCTION

Late Pleistocene peoples were the last of human-kind to live among the great megafaunal species of the last ice-age. They lived in a challenging world with a multitude of dangers, yet many opportunities for adaptive success. Their coexistence with extinct mammals was key to their livelihood and is key to our fascination with them. The study of Paleoindian culture, however, is limited by the varying degrees of preservation within the archaeological record. Significant time depth and variability in climate has resulted in such degradation of the material record that investigators are often limited to study of the inorganic remains of Pleistocene cultures: stone tools (Shott 1986).

The interpretation of Paleoindian behavior has presented a unique challenge that archaeologists have met by investigating patterns of variation in stone tool shape. Hypotheses of Pleistocene human lifeways derived from variability in stone tools have thus far involved two approaches, one which tracks adaptive behavior diachronically and synchronically, and one which tracks population evolutionary history (Foley and Lahr 2003). According to the tenets of the former approach, researchers such as Binford (1973) and Schick and Toth (1993), for example, have hypothesized that variability in Pleistocene stone stools reflects adaptations to changing environmental conditions and can be used to track adaptive behavior over a landscape (Foley and Lahr 2003). Reflecting the latter, researchers using a phylogenetic/historical approach have attempted to track Paleoindian cultures and behavior by associating variations in stone-tool morphology and technology with specific cultural groups (Bordes 1968; Foley and Lahr 2003). My study, presented here, applies the phylogenetic/historical approach in an effort to

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This thesis follows the style of *American Antiquity.*

determine if cultural traits are evident in Paleoindian stone tools.

The projectile point, the most diagnostic remnant of North American Pleistocene peoples, lies at the forefront of their material culture. As a hunting weapon, it is their cultural adaptation to one of nature's most basic metabolic necessities and therefore reflects a most fundamental human behavior. This paper presents an investigation into Paleoindian projectile point morphology. A goal of this research is to determine if evidence of a normative cultural manufacturing protocol can be identified on Clovis projectile points which can then be used to address research questions concerning Clovis point variability and, ultimately, the spread of this tool form across North America.

Theoretical Orientation

Clovis represents a widespread, characteristically uniform, technological complex of stone tools dating to approximately 13,000 calendar years ago (Goebel et al. 2008; Kelly and Todd 1988;Waters and Stafford 2007). This archaeological phenomenon is fundamentally a cultural signature of one or many groups of Pleistocene hunters and gatherers. The potential for inferring normative behavior from cultural material such as projectile points is based on the observation that a culture is inherently homeostatic (Schiffer 1995). As a self-regulating entity, fluctuations of cultural variables ultimately remain within specifiable values (Schiffer 1995). This characteristic self-regulation is present at both the societal and individual level. Therefore, the individual knapper, as s/he imposes a predetermined shape upon a raw material, is consciously or subconsciously maintaining the values of her/his culture's variables (Schiffer 1995). The variable in question in this study is projectile-point manufacture, and the particular value of observation is the normative shape that the specific culture has come to internalize as the correct or definitive form of a projectile point.

The predetermined, definitive shape of a projectile point has been referred to by a number of archaeologists as "style" (Close 1978; Sackett 1977; Weissner 1983). As a concept governing the correct form of a projectile point that is enculturated within a socio-cultural context (Close 1978), style has been described by these researchers as a manner of production specific to a time and place (Sackett 1977). Complimentary to the descriptions of a self-regulating entity provided by Schiffer (1995), Sackett (1977:370) suggests that style is regulated in the material culture because “any given society exploits only a few narrowly selected ranges of the enormously broad spectrum of formal possibilities that are potentially open to it”. These selected ranges, or specifiable limits to values and shape options represented by the projectile point, is, ultimately, social information that can be used to investigate the behavior that generated it (Weissner 1983).

The inference of cultural behavior from lithic remains has by criticized by many archaeologists (Flenniken and Raymond 1986; Holdaway et al. 1996; see Shott 1986 and references therein). The cultural and natural transformations that an artifact undergoes between the time of manufacture and archaeological recovery often result in spatial, morphological, and contextual changes that are detrimental to behavioral interpretation (Holdaway et al. 1996; Schiffer 1995). Another obstacle to behavioral investigation of morphology is the hypothesis that raw-material type may serve as a constraint to artifact shape.

A major concern with using stone tools and projectile points in particular is the potential obliteration of original morphological characteristics during rejuvenation (Bettinger and Eerkens 1997). The reductive nature of the projectile point use-life, consisting of repeated re-sharpening, use-damage, and rejuvenation, results in shrunken examples of what began as a significantly larger tool. The potential to obscure the original shape of the tool is highly significant and it has been shown that regional variation in point shape can be a result of such reductive factors (Rondeau 1996). However, if projectile point manufacture is a cultural aspect passed from one generation to the next, then the shape imposed on the tool during resharpening may be normative as well. As demonstrated by Bradley (Winkler 1989), a knapper does not blindly chip away at a stone until it happens to develop into some sort of sharp instrument. The knapper is keenly aware of the shape to be imposed on the created tool (Towner and Warburton 1990). Given the exceptionally large geographic but short diachronic distribution of the Clovis projectile-point form, the method of manufacture and resultant shapes may be culturally based.

I argue that a culturally normative process of manufacture was maintained throughout the life-history of Clovis projectile points and that this translated into a specific shape maintained to the time of exhaustion and discard. Identification of this "normative" Clovis shape can help explain the widespread presence of Clovis artifacts on the North American landscape. Does Clovis represent a migration of humans into a previously uninhabited territory or diffusion of a new technology through a pre-existing population? Further, where did Clovis points originate and in what direction did they spread? These questions have been difficult to answer because archaeologists have been unable to precisely date Clovis sites and to clearly and comprehensively analyze variability in the shape of diagnostic Clovis points.

Traditionally, investigations of stone-tool shape have consisted of assigning tools to typological classifications and standardized measurements of metric attributes (Dibble and Chase 1981). Bordes' (1961) approach to analysis, description, and comparison of stone-tool assemblages presented one of the first comprehensive protocols for a standardized typological classification of stone tools (Debenath and Dibble 1993). This method provided systemized terminology and techniques that enabled quantitative and comparative studies of lithic artifact variability to be conducted (Debenath and Dibble 1993). This method emphasized its ability to dismiss "the idiosyncratic perspectives of the individual investigator" from the analysis, allowing a more empirical investigation into paleoanthropological behavior to proceed (Debenath and Dibble 1993:vii).

"Bordian" and other typological methods, however, are reportedly limited by their use of a simple nominal scale for classifications which does not allow for multivariate analysis of stone tools (Shea 1995:766). The utilization of typological techniques are thus suggested to be inadequate in addressing contemporary questions of Paleoindian behavior for which refined scales of parametric measurements and multivariate approaches provide a more comprehensive method of analysis (Shea 1995).

A goal of metric analysis, however, is to acquire objective, quantifiable, and reproducible measurements of shape morphology which can be used for statistical and multivariate research between and within a single class of artifacts (Dibble and Chase 1981). Application of standardized measurements of metric attributes to analysis of chipped stone tools has frequently involved the measurement of artifacts by hand-held calipers. Measurements consist of distances between landmarks, angles, and ratios of these distances (Rohlf and Marcus 1993). These measurements are converted into numeric variables that can be expressed graphically and compared using statistical methods such as principal component analysis (Rohlf and Marcus 1993). A hazard of standard metric analysis is the loss of the original shape in its entirety, thus the "overall form is neither archived nor used in the analysis" (Rohlf and Marcus 1993:129).

Advances in the methodology of shape analysis during the last decade have brought geometric morphometrics to the attention of lithic-analysts utilizing metric techniques. This digital technique has the potential to provide a more objective method of assessing variation and affiliated morphological sequences through space and time. As a tool, geometric morphometrics is able to describe shape variation and generate variables for statistical analysis from a series of coordinates that "capture the geometry of the [whole] structure being studied" (Rohlf and Marcus 1993:129). The use of the coordinate system is superior to traditional measurements because it preserves the entire geometry of the artifact throughout analysis and provides visualization of shape differences among specimens (Ruehl and DeWitt 2007).

My investigation employs geometric morphometric analysis to analyze variability in 123 Clovis projectile points from 23 archaeological sites in North America. Research questions address whether this method of shape analysis can serve to identify the major factors of variability in Clovis point shape. If variability in Clovis point morphology can be identified, is it patterned, and can such patterns be mapped geographically? Central to this investigation is determining whether variability in Clovis point morphology is simply due to rejuvenation or to raw material utilized. My research also addresses whether previously observed latitudinal trends (Morrow and Morrow 1999) hold up under closer scrutiny.

Exploring Bifacial Point Variability Geographically

Over the past few decades, archaeologists have hypothesized variability in projectile point shape to be an affect of geographic variability in technological and, therefore, behavioral adaptation (Bettinger and Eerkens 1997; Morrow and Morrow 1999; O'Brien et al 2001). These patterns of adaptation observed over a landscape have been interpreted in several ways. Morrow and Morrow (1999), for example, proposed that fluted projectile-point variability ranging from Canada to South America represents the effect of stylistic drift as a migratory population dispersed across the American continents. The utility of the technology remained constant through generations and across landscapes where big-game hunting was a major activity, but was altered as groups' specific circumstances changed (Morrow and Morrow 1999:216). Morrow and Morrow (1999:227) interpreted style change as an "ongoing translation of cultural practices from one generation to another".

A similar concept was espoused by O'Brien et al. (2001) who emphasized that continuity of tool shape over a landscape is evidence of heritable, phylogenic relationships. In their analysis, O'Brien et al. (2001:1117) stressed that the genetic notion of descent with modification could be applied to shape variability in stone tools because they shared derived characteristics which could be applied to the identification of "tool lineages". Employing cladistic analysis, the authors were able to identify particular homologous characters, or "styles", comprising the traditional projectile-point classes in their investigation (O'Brien et al. 2001:1133).

An application of behavioral transmission analysis to stone tool variability was conducted by Bettinger and Eerkens (1997) with the use of Great Basin projectile points. Like Morrow and Morrow (1999) and O'Brien et al. (2001), this study identified degrees of alteration from a parent shape. To explain shape variation, the authors employed cultural transmission theory to account for similarity in shape characteristics by attributing them to a cultural norm, the deviation from which would not be cost effective (Bettinger and Eerkens 1997). In this study, Bettinger and Eerkens (1997:189) "established the basic character of metric variability in Great Basin projectile-points" and identified a socially-transmitted, two-dimensional template "salient in the minds of point-makers".

These investigations concluded three important factors of Paleoindian projectile-point variability which are integral to my hypothesis of a process of manufacture maintained throughout the use-life of Paleoindian projectile point: stone tool manufacturing is a cultural variant which transmits between generations, traditional stone-tool "classes" are metrically homogenous, and a normative template for manufacture was utilized by tool-makers. Ultimately, these studies demonstrate that cultural information could be approached by tool-shape analysis. The traditional methods of metric analysis utilized by these researchers set standards within lithic research from which future investigations embarked.

Measuring Variability: Standard Metric Analysis

Traditional methods include caliper measurements, taken by hand, of artifacts, casts, and two-dimensional representations such as drawings and photographs. These measurements were then used to create indexes of tool shape with which to compare specimens (Morrow and Morrow 1999). The application of digital technology began in the late 1980s, and techniques have been recently streamlined in a number of biological studies (Adams et al. 2004; Kennedy and Lin 1988). Within the past few years these techniques have been applied to projectile-point analysis and have also utilized actual artifacts, casts, and two-dimensional representations.

In their study of Paleoindian projectile-point variability across the American continents, Morrow and Morrow (1999:216) acquired photographs and line drawings of the specimens for use in their data set. They also utilized raw metric data provided in tables within publications (Morrow and Morrow 1999:216). Their research utilized traditional hand measurements and focused on dimensions of the outline of the artifact as indicating that the fluctuation of outline shape is ultimately demonstrative of morphological variation (Morrow and Morrow 1999:218). Bettinger and Eerkens (1997) also recognized that shape is represented primarily in the two-dimensional, plan-view of projectile-points and set the precedent for morphological analysis for years thereafter. Morrow and Morrow (1999:218) focused on metric attributes consisting of total length, maximum width, height, basal width, basal concavity depth, and maximum thickness. Two problems were encountered in their analysis. The first was the varying quality of the drawings and photographs that made up their data-set (Morrow and Morrow 1999:218), and the second was the realization that the metric attributes were size-dependent, affected by resharpening and repair, and therefore restricted in their ability to reflect pure shape and thus the behavior determining shape (Morrow and Morrow 1999:219). To resolve this dilemma, the researchers used ratios and indexes of the measured attributes to remove the element of size; for example, their “Basal Concavity Depth: Basal Width” ratio allowed them to assess basal indentation regardless of size (Morrow and Morrow 1999:219). The specific attributes calculated for each projectile point and their means were then plotted on a map of the Americas in terms of approximate latitude, regional trends, and available radiocarbon dates (Morrow and Morrow 1999:219, 227). They suggested that variability in point shape formed a pervasive pattern across the continent (Morrow and Morrow 1999:220). Patterns of change identified included the increase of lateral indentation from the American Midwest south into Central America, an increase in basal concavity from the American Mid-Atlantic coast north to southwest Canada, and a decrease in the use of fluting from North America to South America (Morrow and Morrow 1999:220-227). The authors concluded by determining that variability in Paleoindian projectile-point form was ultimately dependent upon the employment of fluting, and, when compared to radiocarbon dates, this technological behavior developed in the North American interior, and variability accrued as it underwent stylistic drift when radiating north, south, and east across the landscape (Morrow and Morrow 1999:225-227).

The approach taken by O'Brien et al. (2001:1116) stressed the phylogenic implications in traditional seriation chronologies. This study employed Paleoindian projectile points from the American Southeast (O'Brien et al. 2001:1124). Actual artifacts, published drawings, and photographs were used in data acquisition (O'Brien et al. 2001:1127). Shape characteristics measured for analysis included the height of maximum blade width, the ratio between the length of the basal indentation to the tip and total length, the ratio between minimum blade width and maximum blade width, outer tang angle, ratio of length to width, and qualitative information such as basal shape and fluting presence (O'Brien et al. 2001:1126). When taking direct measurements, the problem of resharpening perpetuating a size-bias in the data was also encountered and was thus circumvented with the use of ratios (O'Brien 2001:1126). O'Brien et al. (2001:1126) hypothesized that these measurements would represent the aspects of shape most likely to change over time and create a strong "phylogenic signal". The methods employed by O'Brien et al. in their analysis have been traditionally used in biology to trace genetic lineages of organisms based on character states (O'Brien et al. 2001:1119).

The specific tool borrowed from the biological sciences was “cladistics, used to construct phylogenic histories of anything that evolves over time, including material remains found at archaeological sites” (O’Brien et al. 2001:1117). Using this technique, they grouped tool-shape characteristics in terms of similarity to track “heritable continuity”, or those traits retained from antecedent specimens (O’Brien et al. 2001:1119). O’Brien et al. (2001:1134) were able to recognize trends in tool lineages and draw hypotheses as to the mechanism responsible for the evolutionary history of projectile point lineages.

The method utilized by Bettinger and Eerkens (1997) also incorporated caliper measurements taken by hand. To investigate differences in metric variation in projectile points from the Great Basin, these authors employed measurements gathered by D. H. Thomas in the early 1970s consisting of 5285 specimens from 37 collections of the Great Basin (Bettinger and Eerkens 1997:182). Their observations focused on maximum length, axial length, maximum width, basal width, neck width, thickness and the use of common statistics such as mean and standard deviation (Bettinger and Eerkens 1997:169, 182). One goal of their analysis was to establish whether the accepted classification of Great Basin projectile points reflects an accurate index of the various morphological dimensions present in the data-set (Bettinger and Eerkens 1997: 169). As a result of their investigation, the authors were able to characterize the material variability of Great Basin projectile points and conclude that the differences in variability are quantitative and situational (Bettinger and Eerkens 1997:184). As in Morrow and Morrow (1999) and O’Brien et al. (2001), the issue of resharpening posed a significant effect on the appearance of variability throughout the life-time of the artifact. Bettinger and Eerkens (1997) found that metric variability decreased throughout the life-span of the artifact as resharpening obliterated specific characteristics, resulting in a more uniform morphological signature of exhausted and discarded projectile points. Despite this observation, in considering the rest of the artifacts, they suggested that attributes of an established standard that remain constant in the data-set are a result of the transference of a specific behavior, the departure from which would require costly experimentation and would, therefore, result only from necessity induced by varying situations such as material availability (Bettinger and Eerkens 1997:170). In concluding, they attributed the morphological pattern apparent in the Great Basin to cultural transmission theory to account for the conservative departure from an original standard (Bettinger and Eerkens 1997:181).

These and other investigations (Flenniken and Raymond 1986; Kuhn 1990; Shott 1997) demonstrate that traditional hand measurements have remained a standard method in artifact morphological analysis and have provided archaeologists with quantitative data from which to assess patterns of variation, conduct statistical analysis and draw behavioral hypotheses. As mentioned above, a significant drawback of this traditional technique is that the resulting data matrix of these measurements does not preserve the original shape or overall form of the object (Rohlf and Marcus 1993). The geographic form is, therefore, not actually utilized in the analysis so that the results are less powerful (Rohlf and Marcus 1993).

Measuring Variability: Exploratory Applications of Geometric Morphometrics to Archaeology

In what has been referred to as the "revolution in morphometrics" of the late 1980s, the application of digital technology provided a new, more comprehensive technique for quantifying morphological structures and data analysis in the field of Biology (Adams et al. 2004). This technique, known as "geometric morphometrics", is defined as the study of shape variation and its covariation with other variables (Bookstein 1991; Rohlf and Marcus 1993). The new method enabled researchers to quantify the geometry of the morphological structure and utilize this information throughout analysis (Adams et al. 2004). As methods of data-capture advanced, so too did statistical theory for shape analysis. During the time of the morphometric revolution, statisticians were developing theories to combine methods of multivariate statistics with digital visualizations of biological forms (Adams et al. 2004). In the late 1980s and early 1990s, the new method involving the digital outline and landmark-based techniques, used thus far by biologists to study variability in the outline of organisms, began to be experimentally applied to archaeological research (Adams et al. 2004). Two important early studies are Kennedy and Lin (1988) and Brande and Saragusti (1999). Each is presented below in some detail.

Kennedy and Lin (1988) presented the results of an endeavor to establish whether a geometric morphometric technique could adequately measure projectile point shape and be used to extract information contained in stone tool variability (Kennedy and Lin 1988:297). They used a video-digitizing system to acquire digitized representations of an assemblage of projectile points (Kennedy and Lin 1988:297). They then assigned Cartesian coordinates, or semi-landmarks, to the perimeter of each artifact (Kennedy and Lin 1988:297). During this research they noted that a greater number of landmarks making up the outline of the artifact resulted in less space between each landmark (Kennedy and Lin 1988:297). They referred to this space as “step length” (Kennedy and Lin 1988:297), and in this space “irregularities” would be overlooked. A greater number of landmarks circumventing the periphery resulted in a more and more precise measurement of shape (Kennedy and Lin 1988:297). The authors then performed a simple fractal analysis of shape space and determined that the use of this digital method could accurately provide an “unbiased quantitative classification and description of the points” (Kennedy and Lin 1998:299-301).

Brande and Saragusti (1999) applied a landmark-based approach to a collection of Acheulian handaxes from Gesher Benot Ya’aqov, Israel. These researchers addressed whether this method could provide a solution to problems encountered when dealing with large sample sizes, and whether the digital-landmark technique provided data adequate for summaries of shape variation and statistical measurement (Brande and Saragusti 1999:242). They assigned landmarks to various locations on the tools and determined the Cartesian coordinates for each (Brande and Saragusti 1999:242). Then, a series of lines were used to connect each landmark, and shape variability was modeled by comparing the vectors connecting the landmarks (Brande and Saragusti 1999:242). As a result of this analysis, the authors found that it was imperative that each specimen contain a "corner and intersection" that is uniform in the data-set to serve as primary landmarks from which to measure variation (Brande and Saragusti 1999:242). They concluded that the use of digital techniques has "wide applicability in archaeological studies of artifact form" (Brande and Saragusti 1999:244).

Geometric Morphometrics: Application to Fluted Point Morphology

Initial studies involving the application of geometric morphometrics to archaeological analysis were quite promising. In a variety of recent publications, the utility of the method has been demonstrated in its application to research endeavors such as testing the validity of some projectile point typologies, the effects of resharpening on Folsom projectile point form, and its application to cladistic analyses to assess New World colonization models (Buchanan 2006; Buchanan et al. 2007; Buchanan and Collard 2007; Buchanan and Collard 2010).

An application of geometric morphometrics to Paleoindian projectile-point variability and adaptation is demonstrated by Buchanan and Collard (2007) who, however, utilized the technique to compute typical distance measurements from the coordinates. To investigate the origins of Clovis peoples, the authors conducted a morphometric analysis of 216 complete to near-complete projectile points from the early Paleoindian period (Buchanan and Collard 2007:371). To collect morphological data from inter-landmark distances, they employed the central geometric morphometric protocol for the landmark-based approach and derived a euclidean distance matrix (Buchanan and Collard 2007:371). They then extracted eleven inter-landmark distances which accounted for tool width, length and basal dimensions (Buchanan and Collard 2007:371). As in aforementioned morphological studies of projectile points, they found that size produced confounding effects on their data and had to be adjusted (Buchanan and Collard 2007:371). The shape dimensions were then averaged and mean character states were derived for each site assemblage (Buchanan and Collard 2007:373-374). The morphometric data were then analyzed using cladistics in a fashion similar to O'Brien et al. (2001) (Buchanan and Collard 2007:370). By reconstructing historical relationships among assemblages of Paleoindian projectile points, Buchanan and Collard (2007:387) reached the conclusion that a rapidly migrating population entering North America from the ice-free corridor or the Northwest coast is responsible for the Paleoindian signature present in the archaeological record.

Over the past twenty years geometric morphometrics have undergone many advances. A central protocol for conducting morphometric analysis has been developed and a richer description of shape has been made possible by combining outline and landmark data into one analysis (Adams et al. 2004). Since the surge of morphometric developments in the 1990s, the technique has become a standard tool of biological research and has been applied to morphological analyses in many fields, in particular archaeology (Adams et al. 2004). Beyond the collection of usual distance measurements, its application to stone tool analysis allows researchers to preserve entire artifact shapes throughout analysis in a fashion far superior to traditional metric investigations.

As demonstrated in studies by Buchanan (2006), Buchanan et al. (2007), Buchanan and Collard (2007), and Buchanan and Collard (2010), geometric morphometrics and multivariate statistics have been successfully applied to the exploratory analysis of shape variation in projectile points. Its potential for dependable quantitative analysis of artifact morphology continues to grow as do the opportunities for its application. At present, there is a need for a more comprehensive study of Paleoindian projectile point variability based on individual specimens using geographic morphometrics in which the entire geometry of the artifact is preserved throughout analysis. My research represents an opportunity to apply geometric morphometrics to 123 individual projectile points representing 23 archaeological sites that were discovered in a secure buried, or datable context, found in a cache with diagnostic Clovis points, or are the earliest examples of fluted points in a region and represent the first humans to populate the area. Additionally, the need persists to control for the effect of resharpening. This may allow us to recognize if behavioral and technological norms that were used during a tool's first creation were still employed by tool makers in their attempt to refurbish their tools, which would result in a tool that retained its cultural signature. Geometric morphometrics is utilized in this investigation as a way to identify patterns of shape variability and behavioral signatures contained in Clovis point forms.

CHAPTER II
MATERIALS AND METHODS

Materials

The projectile points utilized in this investigation met three criteria to be included in the analysis. First, they were complete, avoiding the danger of false information resulting from interpolation. Second, they were discovered in a secure buried, or datable context corresponding to the late Pleistocene, from a cache with diagnostic Clovis-type artifacts, or are the earliest fluted points in a region representing the first human inhabitants. Third, they had to be available for analysis.

Actual artifacts and casts were used in this analysis. A pilot study was conducted to compare an assemblage of actual artifacts to their corresponding casts. Results confirmed the accuracy of the casts and their ability to serve in place of the actual artifacts. The resulting sample includes 123 projectile points from 23 North American archaeological sites (Table 2.1; Figure 2.1). Each of these is discussed briefly below. The data-set described here consists of actual artifacts unless otherwise indicated.

The Anzick site is located on Flathead Creek in Park County, Montana (Wilke et al. 1991:244). Excavations occurred in 1969 under the direction of D. Taylor, and the site was further tested by L. Lahren and R. Bonnichsen (Jones and Bonnichsen 1994:42). Two radiocarbon (^{14}C yr B.P.) samples extracted from collagen of bone foreshafts found associated with the Clovis points provided an average date of 11,040 ± 35 ^{14}C yr B.P. (Waters and Stafford 2007). Additionally, two radiocarbon samples were extracted from the bone foreshafts by Morrow and Fiedel (2006) which provided complementary dates of 11,040 ± 40 and 11,040 ± 60 ^{14}C yr B.P. Eight Clovis points were recovered at the Anzick site; of these five were complete (Wilke et al. 1991:251) and are included in this study.

Table 2.1 Assemblages of fluted points included in the analysis by archaeological site, location, and number of complete points analyzed.

Site name	Location	Number of Complete Points
Anzick	Park County, Montana	5
BWD	Blackwater Draw, New Mexico	9
Cactus Hill	Sussex County, Virginia	4
Colby	Bighorn Basin, northern Wyoming	3
Debert	Colchester County, central Nova Scotia	5
Dent	Millikin, Colorado	2
Domebo	Stecker, Oklahoma	2
Drake	Northcentral Colorado	13
Fenn	"Three-corners" area of Utah, Wyoming, and Idaho	19
Gault	Salado, Texas	8
Indian Creek	MacHaffie, Montana	1
Jake Bluff	Northwest Oklahoma	3
Kimmswick	St. Louis, Missouri	3
Lange-Ferguson	Shannon County, South Dakota	2
Lehner	Cochise County, Arizona	8
Murray Springs	San Pedro Valley, Arizona	4
Naco	Cochise County, Arizona	7
Paleo Crossing	Medina County, Ohio	1
Richey Roberts	County, Washington	5
Shawnee-Minisink	Upper Delaware Valley	2
Sheridan Cave	Wyandot County, Ohio	1
Simon	Fairfield, Idaho	5
Vail	Aziscohos Lake, Maine	11

The Clovis site at Blackwater Draw (BWD), New Mexico, was discovered in 1932. Since that time there have been several excavations of the site including those sponsored by the Philadelphia Academy of Natural Sciences and University of Pennsylvania Museum from 1932-1937, California Institute of Technology in 1933, Texas Memorial Museum from 1949-1950 and 1953-1957, Museum of New Mexico in 1956 and 1961-1963, University of Chicago from 1956-1957, Fort Burgwin Research Center from 1961-1963, Texas Technical College in 1958, 1962, and 1963, and Eastern New Mexico University in 1961 (Hester 1972:1). The site was revisited in 1962 and 1963 by the El Llano Archaeological Society of Portales, New Mexico. The society's field studies recovered eight Clovis points (Warnica 1966:345-349). A total of 25 Clovis points were found during excavations between 1932 and 1964 (Warnica 1966:352). Casts of nine of the complete Clovis points were available for analysis at the National Museum of Natural History and have been included in this study. Radiocarbon dates from the Clovis horizon on carbonized plants provided dates of 11,040 ± 500 ^{14}C yr B.P. and 11,630 ± 400 ^{14}C yr B.P. (Hester 1972:174-176).

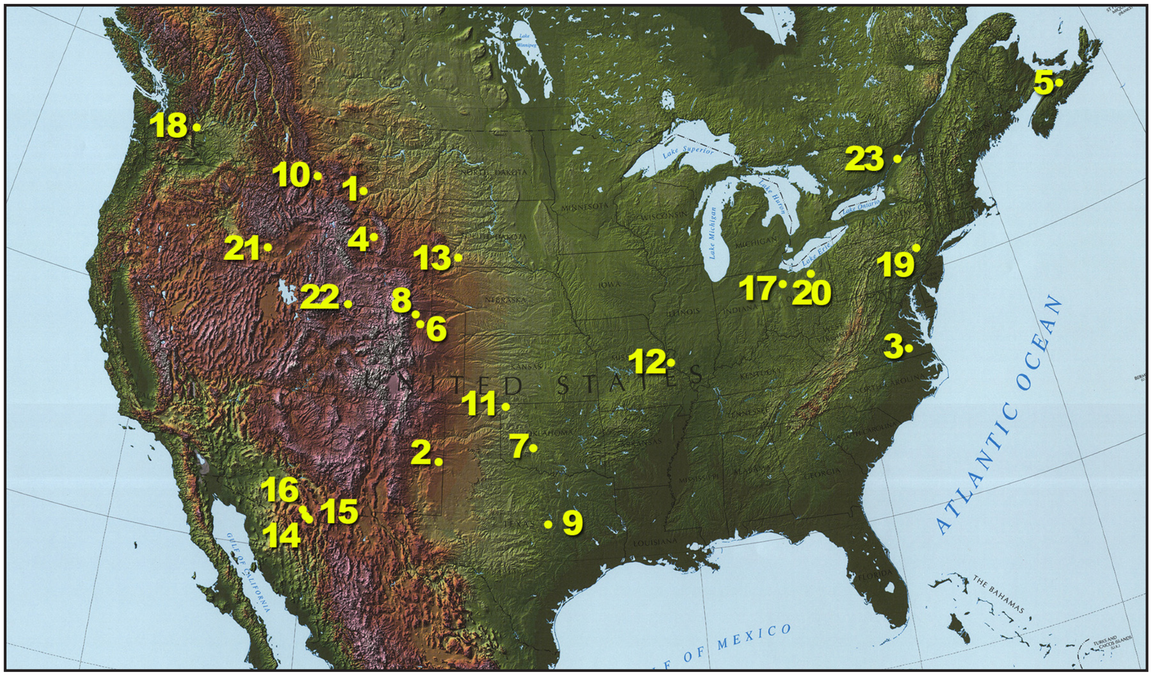


Figure 2.1. Early North American archaeological sites represented by the fluted points used in the analysis. 1) Anzick; 2) BWD; 3) Cactus Hill; 4) Colby; 5) Debert; 6) Dent; 7) Domebo; 8) Drake; 9) Gault; 10) Indian Creek; 11) Jake Bluff; 12) Kimmswick; 13) Lange-Ferguson; 14) Lehner; 15) Murray Springs; 16) Naco; 17) Paleo-crossing; 18) Richey Roberts; 19) Shawnee Minisink; 20) Sheridan Cave; 21) Simon; 22) Fenn Cache; 23) Vail.

Cactus Hill, 44SX202, is located along the Nottaway River in Sussex County, Virginia (McAvoy and McAvoy 1997:1). Excavations under the direction of J. M. McAvoy and M. F. Johnson were conducted intermittently from 1993-1996 (McAvoy and McAvoy 1997:1). Radiocarbon analysis conducted on hearth charcoal provided a date of 10,920 ± 250 ^{14}C yr B.P. (McAvoy and McAvoy 1997:180). Four complete Clovis points were found at Cactus Hill and have been included in this study. Their casts were available at Texas A&M University (McAvoy and McAvoy 1997:181).

The Colby site is located just east of the Bighorn River in the Bighorn Basin of northern Wyoming (Frison and Todd 1986:3-4). Excavations began under the supervision of G. Frison in 1973 and continued intermittently until 1978 (Frison and Todd 1986:12-21). Radiocarbon analysis from mammoth-bone collagen produced a date of 11,200 ± 220 ^{14}C yr B.P. (Frison and Todd 1986:22). Another piece of long bone produced an apatite date of 10,864 ± 141 ^{14}C yr B.P. (Frison and Todd 1986:22). A third piece of bone produced a collagen date of 8,719 ± 392 ^{14}C yr B.P., however this date was interpreted as too young and attributed the recurrence of inadequately young dates encountered in the general area (Frison and Todd 1986:22). Four Clovis points were recovered from the site, of which three are complete and included in this study (Frison and Todd 1986:91-92). Casts of these points were available at Texas A&M University.

The Debert site is located in Colchester County, central Nova Scotia (MacDonald 1985:1). Extensive excavations of the site were conducted in 1963 and 1964 under the direction of D. S. Byers and R. S. MacNeish (MacDonald 1985:3). Twelve hearth samples provided an average radiocarbon date of 10,604 ± 45 ^{14}C yr B.P. (MacDonald 1985:53). Debert excavations yielded 140 fluted projectile points (MacDonald 1985:70). Ten of these are complete specimens, and the casts of five of them were available for analysis as at the National Museum of Natural History (MacDonald 1985:70).

The Dent site is located west of the South Platte River floodplain near Millikin, Colorado (Brunswig 2007:87). Excavations began in 1932 by geologist C. Bilgery of Regis College (Brunswig 2007:87), and in 1933 excavations were conducted by the Colorado Museum of Natural History under the direction of F. Howarter (Brunswig 2007:87-88). Radiocarbon testing on purified mammoth-bone collagen provided a date of 10,990 ± 25 ^{14}C yr B.P. for the Dent site Clovis assemblage (Brunswig 2007:90-91; Waters and Stafford 2007). Two complete Clovis points were recovered during the 1932-1933 excavations; casts of both were available at the National Museum of Natural History and were included in this study (Brunswig 2007:91).

The Domebo site is located approximately three miles east of the village of Stecker in Caddo County, Oklahoma (Retallick 1966:3). Excavations began in 1962 under the supervision of A. Anderson (Leonhardy 1966:1). Radiocarbon analysis conducted on mammoth bone associated with the Clovis artifacts provided a date of 10,960 ± 30 ^{14}C yr B.P. (Waters and Stafford 2007:1124,4). Two complete Clovis points were recovered at Domebo and have been included in this study (Leonhardy and Anderson 1966:16). Casts of these points were available at Texas A&M University.

The Drake Cache was found in northcentral Colorado between Pawnee Buttes and the South Platte River (Stanford and Jodry 1988:21). After discovery of the site in 1978, it was tested by B. Lutz and visited thereafter by D. Stanford of the National Museum of Natural History (Stanford and Jodry 1988:21). No datable material was found associated with the artifacts. Thirteen complete Clovis points were recovered from the Drake cache. All of these were available at the National Museum of Natural History and have been included in this study (Stanford and Jodry 1988:21).

The Fenn Cache was first brought to the attention of professional archaeologists in 1988 when F. Fenn bought the collection in Santa Fe, New Mexico (Frison and Bradley 1999:22). Research has suggested that the collection came from the “three-corners” area of Utah, Wyoming, and Idaho (Frison and Bradley 1999:22). While no radiocarbon date was attainable, red ochre and hafting material was found adhered to some of the Clovis points and hydration testing conducted on obsidian points confirm the antiquity of the tools (Frison and Bradley 1999:80). Of 31 fluted points from this cache, 19 are complete. All of these were available for analysis at Texas A&M University and have been included in this study (Frison and Brandley 1999:8-35).

The Gault site is located west of Salado, Texas, in the ecotone of the Balcones Escarpment (Collins 2007:61). Intense excavations of the site were conducted in 1991 and 1998 under the direction of M. B. Collins and T. R. Hester and from 1999-2002 under the direction of Collins, Hester, H. J. Shafer, and M. R. Waters (Collins 2007:61). No radiocarbon date has been published at this time. Thirteen Clovis points have been recovered from the Gault Site (Collins 2007:76). Eight of these are complete, were available for analysis at the Texas Archaeological Research Lab and have been included in this study.

The Indian Creek site (24BW626) is located 30 km south of MacHaffie, Montana (Davis 1993:268). Excavations took place in 1982 and 1983 under the direction of L. B. Davis (Davis 1984:9). Radiocarbon analysis conducted on charcoal recovered from the Clovis deposit yielded a date of 10,980 ± 110 ^{14}C yr B.P. (Waters and Stafford 2007:1124,5). This date is associated with one heavily reworked Clovis point, "Clovis-like artifacts" and debitage assemblage (Davis et al. 1985:45; Waters and Stafford 2007:5). A cast of this point was available for analysis at the National Museum of Natural History.

The Jake Bluff site is located in northwest Oklahoma approximately 25 km south of the Kansas border (Bement and Carter 2003). L. Bement oversaw excavations that took place during the 2001, 2002, and 2004 field seasons (Bement and Carter 2003). Three radiocarbon analysis conducted on XAD-purified bison-bone collagen produced an average date of 10,765 years ± 25 ^{14}C yr B.P. (Waters and Stafford 2007:4). Three

Clovis projectile points were recovered in association with the bison bone piles (Bement and Carter 2003). Casts of these artifacts were available at Texas A&M University and have been included in the data-set.

The Kimmswick site is located approximately 32 km south of St. Louis, Missouri (Graham et al. 1981:1115). Although no datable material was found at this site, the Clovis artifacts were found in association with mastodon bones and other extinct fauna, all of which were encased in a clay matrix (Graham et al. 1981:1115-1116). There was no evidence of vertical transport or displacement of artifact or bone at this locality (Graham et al. 1981:1116). Three complete Clovis points were recovered from the deposit, the casts of which were photographed at Texas A&M University and included in this study (Graham et al 1981:1115).

The Lange-Ferguson site (39SH33) is located in the White River Badlands on the Pine Ridge Indian Reservation in Shannon County, South Dakota (Hannus 1990:86). Excavations were conducted between 1980 and 1984 by L. Adrian Hannus (Hannus 1990:86). The Clovis horizon provided charcoal suitable for radiocarbon analysis and when combined with analyses of purified mammoth collagen, rendered an average date of 11,080 ± 40 ^{14}C yr B.P. (Waters and Stafford 2007:1124,3). Two complete reworked Clovis points were recovered and included in this analysis (Hannus 1990:91). Casts of these points were available at Texas A&M University.

The Lehner site is located in Cochise County, Arizona. Excavation was conducted by E. Haury in 1955 and 1956 (Haury et al. 1959:2). The presence of mammoth (Mammuthus columbi) remains in association with Clovis projectile points and charcoal radiocarbon dates between 12,000 and 11,000 ^{14}C yr B.P. securely place this site within the Clovis era (Haury et al. 1959:6, 24). Thirteen Clovis points were recovered during Haury's excavation, eleven of which are complete (Haury et al. 1959:6). Broken tips on several of the points have been hypothesized to be the result of impact (Haury et al.

1959:9). Nine casts of the complete specimens are curated at the National Museum of Natural History and were available to be included in this study.

The Murray Springs site is located in the San Pedro Valley, Arizona. Excavations were conducted from 1966-1971 under the direction of C. V. Haynes and E. T. Hemmings (Haynes 2007:6-8). The last two field seasons held in 1970-1971 were conducted by L. D. Agenbroad (Haynes 2007:13). Eight radiocarbon samples derived from charcoal associated with the Clovis occupation provided an average date of 10,885 ± 50 ^{14}C yr B.P. (Waters and Stafford 2007). Nineteen complete or fragmentary Clovis points were recovered from Murray Springs (Huckell 2007:194-195). Of these, casts of the only four complete points were available to be photographed at the National Museum of Natural History and were included in this study.

The Naco site is located approximately 2 km northwest of the town of Naco, Arizona, in an arroyo eroded by Greenbush Creek (Haury et al. 1953:1). Excavations initially began in 1951 by amateur archaeologists F. and M. Navarrete (Haury et al. 1953:1). Further excavations were conducted by E. Antevs, J. Lance, E. B. Sayles, H. Russell and E. Haury in 1952 (Haury 1953:1). An average radiocarbon date of 9,250 ± 300 ^{14}C yr B.P. was obtained from two charcoal fragments associated with mammoth remains and Clovis points (Wise and Shutler 1958:73). However, Antevs (Haury et al. 1953:17) was able to accurately correlate the position of the mammoth and artifact bed with the end of the Estancia Pluvial and the Younger Dryas which provides a date for the Naco site of approximately 11,000 years B. P. (Haynes 1990:66). Eight Clovis points were recovered at the Naco site (Haury et al. 1953:5). Five were found in situ associated with mammoth remains, and three additional points are confidently associated with the same kill event (Haury et al. 1953:5). Casts of all eight were available for analysis at the National Museum of Natural History and have been included in this study. One additional Clovis point was found by rancher M. Navarrete in the arroyo bed of Greenbush

Creek approximately 0.5 km from the mammoth remains and was determined to "agree with the projectiles recovered among the bones of the elephant and may also be labeled as of the Clovis Fluted type" (Haury et al. 1953:11). Therefore, this point was included in the data-set and analysis while the original specimen was on loan at Texas A&M University.

The Paleo Crossing site is located in Sharon Township, Medina County, Ohio. Excavations of the site were conducted from 1990-1993 by the Cleveland Museum of Natural History under the direction of D. S. Brose and B. Barrish (Brose 1994:62). Charcoal from a posthole within the Clovis horizon provided three radiocarbon dates that presented an average date of 10,980 ± 75 ^{14}C yr B.P. (Waters and Stafford 2007:4). Of the 34 fluted points found, consisting of both complete and broken points, one complete Clovis point was available to be photographed at the National Museum of Natural History.

The Richey Roberts Clovis Cache is located in East Wenatchee, Douglas County, Washington, just west of the Columbia River (Gramly 1993:11). The first excavation of this site was directed in 1988 by P. Mehringer from Washington State University (Gramly 1993:5). Excavations were reopened in 1990 by R. Gramly of the Buffalo Museum of Science of Buffalo, New York, and the North Central Washington Museum of Wenatchee, Washington (Gramly 1993:5). Mehringer found Glacier Peak ash adhering to Clovis artifacts from the site; this tephra has been independently dated to 11,125 ± 130 ^{14}C yr B.P., providing a lower-limiting date for the cache (Mehringer and Foit 1990:496-497). The lower-limiting date was determined by adherence of the tephra only to the bottom-site of the in-situ artifacts (Mehringer and Foit 1990: 498). Fourteen Clovis points were recovered from the cache (Gramly 1993:6); of these, five casts are available to be photographed at Texas A&M University.

The Shawnee-Minisink site is located at the confluence of the Delaware River and Brodhead Creek in the Upper Delaware Valley area of Pennsylvania on the second terrace (McNett et al. 1985:4). Initial excavations began in 1974 by D. Kline (McNett et al. 1985:5). Subsequent excavations were conducted from 1975 to 1977 under the direction of C. McNett, Jr. (McNett et al.1985:4). Hearths associated with Clovis artifacts provided carbonized seeds which produced an average radiocarbon date of 10,935 ± 15 ^{14}C yr B.P. (Waters and Stafford 2007:4). Two complete Clovis points were recovered at Shawnee-Minisink, casts of which were available at the National Museum of Natural History and have been included in this study (McNett 1985:88).

Sheridan Cave is located in northwestern Wyandot County, Ohio (Tankersley 1997:713). Excavations began in 1990 by R. Hendricks (Tankersley 1997:714). H. G. McDonald of the Cincinnati Museum of Natural History conducted paleontological excavations of the site's Pleistocene faunal assemblage (Tankersley 1997:714). Archaeological excavations continued in 1993 under the direction of K. Ford and lasted for three years (Tankersley 1997:715). In 1996, K. Tankersley conducted a geoarchaeological survey of the deposits (Tankersley 1997:716). He obtained two radiocarbon dates from a charcoal lens associated with the artifacts that average 10,920 ± 50 ^{14}C yr B.P. (Waters and Stafford 2007:5). One fluted point was recovered during excavations, the cast of which was available at the National Museum of Natural History and has been included in this study (Redmond and Tankersley 2005:514).

The Simon Cache is located approximately 5 miles west of Fairfield in south-central Idaho (Butler 1963:23). Several seasons of excavation were conducted under the direction of B. R. Butler beginning in 1961 (Woods and Titmus 1985:3). An unpublished radiocarbon date assigns a date between 10,000 - 11,000 ^{14}C yr B.P. (Butler 1963:23). The casts of five complete Clovis points from the Simon site were available to be photographed at the National Museum of Natural History.

The Vail site is located on the shores of Aziscohos Lake in western Maine

(Gramly 1982:13). Excavations were conducted in 1980 under the direction of R. M. Gramly (Gramly 1982: 12-14). Charcoal from a hearth feature was radiocarbon dated to 10,300 ± 90 ^{14}C yr B.P. (Gramly 1982:59-61). Seventy-nine fluted projectile points were recovered from the Vail site and eleven of those that are complete were available to be photographed at the National Museum of Natural History and are included in this study (Gramly 1982:23).

Methods

An important consideration, implemented in my study, when conducting digital analysis of high-resolution photographic representations is consistency and reproducibility of a method used to obtain a uniform data-set.

My analytical process began by arranging the photographic stand to duplicate the parameters used for every specimen included in the analysis. The photographs were taken on a light table to increase the amount of contrast between the artifact and the background and to minimize shadows. A piece of graph paper was affixed to the light table to serve as a scale. A rectangular hole was cut into the graph paper so that it did not touch the specimen directly. This was accomplished on a copy stand, which allowed the camera to be mounted at a 90-degree angle above the specimen. A level was used to insure that the camera was aligned at a 90-degree angle on the camera stand. The specimen was positioned so that its face was at a 90-degree angle to the camera lens. This involved using putty to support a side of the artifact that may have had irregular bulges on one face causing it to lean to one side.

Due to variability in translucency/opacity of the material, multiple photographs were taken of each specimen. I found the best film speed to be 100 ISO. The result was a sharper, less grainy photograph. Initially, the camera was set to an F-stop of 5.6 with a shutter speed of 1/30 of a second utilizing a 50 mm lens. In addition to this setting, bracketed exposures utilizing shutter speeds of 1/25 and 1/40 of a second were taken.

An advantage of using a digital camera was that the exposure could be immediately observed and the setting could be adjusted to increase contrast as necessary (for example, increasing shutter speed at increments until photographs with desired contrast levels were obtained). It was also beneficial to use both F5.6 and F22 F-stops to adjust the depth of field on thicker points thereby placing the focal point at the tool edge. Manual settings and manual focus were preferred to insure that the focal point was controlled for. Obtaining multiple photographs of each specimen using a variety of lighting situations was most beneficial in providing options for selecting a suitable photograph for digitization.

Prior to digitizing the photographs in tpsDig software (v. 2.12; Rohlf 2008a), the photograph with the highest degree of contrast was chosen. This allowed the program to readily differentiate between the dark pixels representing the artifact and the light pixels of the light-table. This was especially challenging when digitizing specimens made from translucent materials such as quartz. The use of graphical software such as Adobe Photoshop (v. 9.0.2) was used to increase the contrast of the image as needed.

Shape Analysis

Shape analysis is the use of a geometric morphometric method which "retains the geometry of shape spatial covariation among landmarks throughout the analysis and facilitates visualization of shape differences between" specimens (Ruehl and DeWitt 2007).

Photographs were first converted into a .tps file with the use of the tps Utility program (v. 1.40; Rolf 2008c). This step allowed the digitizing program to compile all of the coordinates for each specimen into one file. This file was then uploaded into tpsDig software (v. 2.12; Rohlf 2008a). Four landmarks were placed on each photograph at uniform positions on the graph paper to regulate scale. The software's outline tool was then used to capture the outline of the artifact. This outline was formed by assigning adjacent semi-landmarks around the perimeter of the point. The number of semi-landmarks varied from approximately 1500 to over 5000 points depending on the size of the artifact. These were saved as Cartesian coordinates.

The Cartesian coordinates were then entered into an Excel spreadsheet designed to take the matrix through a series of algorithms to further regulate the data. The Cartesian coordinates for each semi-landmark surrounding each projectile point, referred to hereafter as projectile-point data, were centered and rotated to rest horizontally along the X-axis. The tip and basal corners were digitized as major landmarks that served as uniform points of reference for each projectile-point data. These major landmarks have also been referred to as homologous landmarks by Bookstein (1991) designating their utility as the fundamental reference points from which to align the artifacts, thereby dismissing size and only measuring variability of shape. A major landmark was assigned to the distal end by finding the greatest positive X-coordinate at the zero Y-coordinate of each centered projectile-point data. The two basal corners were digitized as major landmarks by first rotating the centered, horizontal projectile-point data 45-degrees clockwise and locating the highest positive y-value. The point data were returned to center and then rotated 45-degrees counter-clockwise to locate the lowest possible negative y-value. The semi-landmarks were then reordered to set the initial semi-landmark at the same location as the major landmark at the distal end of the projectile-point data. The coordinate-outline was then rotated back to its horizontal state and returned from its centered position to its original location in shape space so that it could be re-opened in the tpsDig program (v. 2.12; Rohlf 2008a). Scale was also regulated using the concatenate function and the four scale-landmarks originally digitized in tpsDig (v. 2.12; Rohlf 2008a) and added to the data corresponding to each specimen. The processed high-resolution outlines were then reduced to 100 semi-landmarks at equidistant intervals in tpsDig (v. 2.12; Rohlf 2008a) to reduce the data to a size that is within the RAM-capacity of most computer systems. The distal reference point was superimposed with the initial landmark, and the two basal reference points were then added to the landmark count. This resulted in a total count of 102 landmarks, or coordinates, representing the 2-dimensional shape of each artifact.

The projectile-point data for the entire data-set was then consolidated into a single TPS file and converted into an NTS file in the tps Utility program (tpsUtil) (v. 1.40; Rohlf 2008c). This file was then imported into the tps Relative warps program (tpsRelw) (v. 1.46; Rohlf 2008b), which was used to calculate the partial warp scores, relative warp scores and centroid size for each artifact. During this process, a variance-covariance matrix was computed from the original coordinates and the principal components were extracted from this matrix in the form of relative warps (Bookstein 1991). Variability in shape was represented by the deformation, or warping, of an original grid (Figure 2.2) (Adams et al. 2004:8). Partial warp scores represent parameters that describe the grid deformations caused by the varying shape of each artifact. The combined scores of the partial warps and the uniform components are represented by the relative warp scores which ultimately serve as principal components of the projectile point data in terms of the bending energy imposed on the original grid (Bookstein 1991; Querino et al. 2002). According to Bookstein (1991:178) "centroid size is the most powerful size variable to use for size comparisons on the null model for shape variation" and is therefore utilized as the size variable in this analysis. Using the tpsRelw program (v. 1.46; Rohlf 2008b), the centroid size is determined by the square root of the sum of squared distance of the series of measured landmarks to their common centroid (Bookstein 1991). This value can then be assigned as a dependent variable in order to analyze the entire form of an artifact which incorporates size and shape. When the value of centroid size is placed as an independent variable it is dismissed from the analysis and only shape is considered.

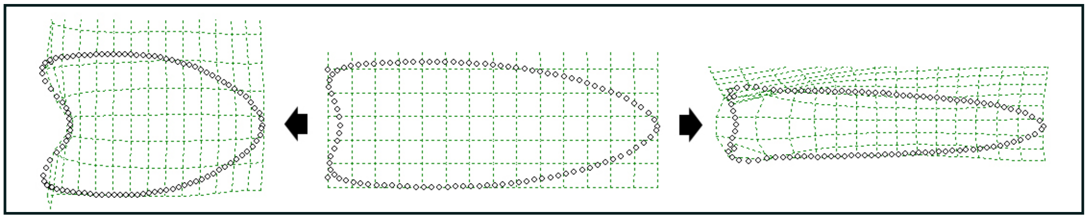


Figure 2.2. Variability in shape is represented by the deformation, or warping, of an original grid (center).

Statistical Methods

Multivariate analysis of variance (MANOVA) was carried out to test for variability in shape within the entire data-set. In addition, MANOVA was used to analyze a partial data-set from which the cache sites were removed. MANOVA analyses were conducted using JMP (ver. 8.0.1; SAS Inc.). Analyses of each data-set were conducted twice for both form and shape. It was determined that the presence of cached artifacts may have had an effect on the results of the analysis because of the pristine nature of many of the specimens included in the caches. The presence of a cache effect was statistically controlled for by setting it as an independent variable in all analyses. Artifact size was found to be correlated with the cache effect. Therefore, when analysis focused on shape, to dismiss the element of size, centroid size was also set as an independent variable. In analysis of tool form, centroid size was treated as a dependent variable. A series of null hypotheses was tested using MANOVA to determine if patterns of variability were present. Seven factors were used as grouping variables: mean radiocarbon age; latitude; longitude; archaeological site; five geographical regions consisting of the northwestern United States (NW), North American southwest (SW), southern High Plains (SHP), Lower Great Lakes vicinity (NE) and Atlantic Coastal region (ECoast); and site type, categorized as habitation sites, kill sites, and caches (Figure 2.3). The seventh grouping variable consisted of a consolidation of the five regions into three major regions to observe the extent of geographic variability: northwestern United States (NW), combined North American Southwest and southern High Plains (SW), and combined Great Lakes and Atlantic coastal regions (NE) (Figure 2.4).

The distribution of variance of the first two principal components was then calculated for each site, the five major regions, and the three consolidated regions using JMP (ver. 8.0.1; SAS Inc.). The distribution of variance for principal components 1 and 2 was also calculated for the three major-regional groups. Scatter-plots were used to provide a graphic display of the relationship between the variance of principal component 1 and principal component 2. These were used to compare variance within and between sites as well as regional variance.

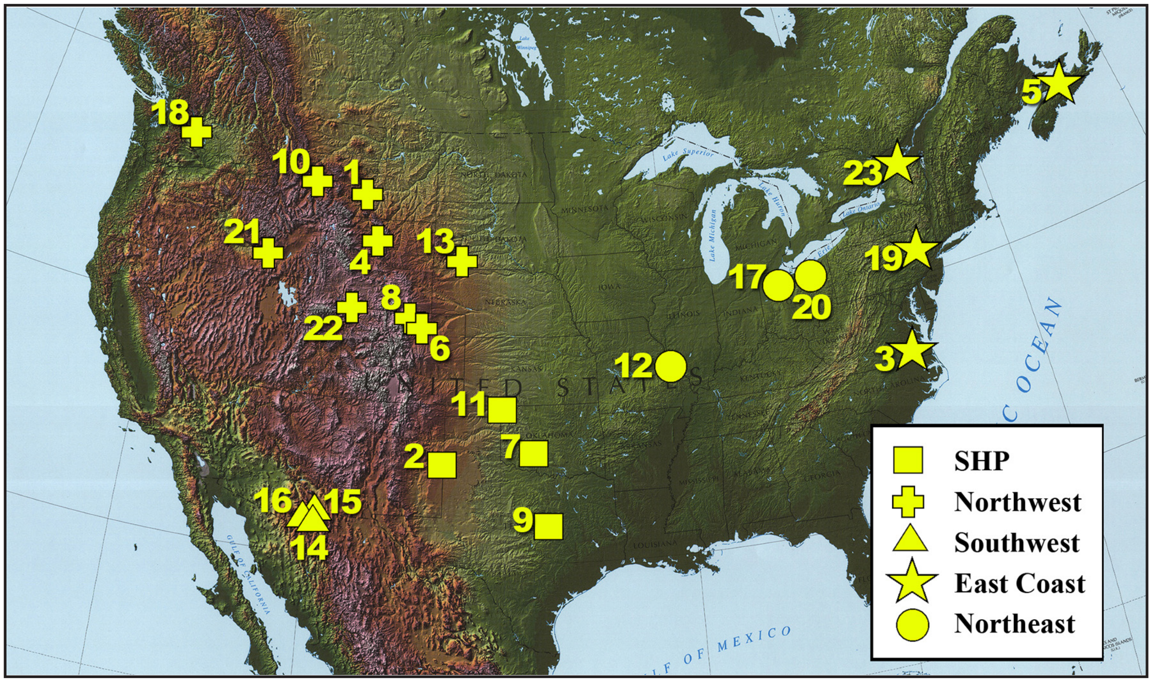


Figure 2.3. Five geographical regions consisting of the northwestern United States (NW), the North American southwest (SW), the Southern High Plains (SHP), the lower great lake vicinity (NE) and the Atlantic Coastal vicinity (ECoast).

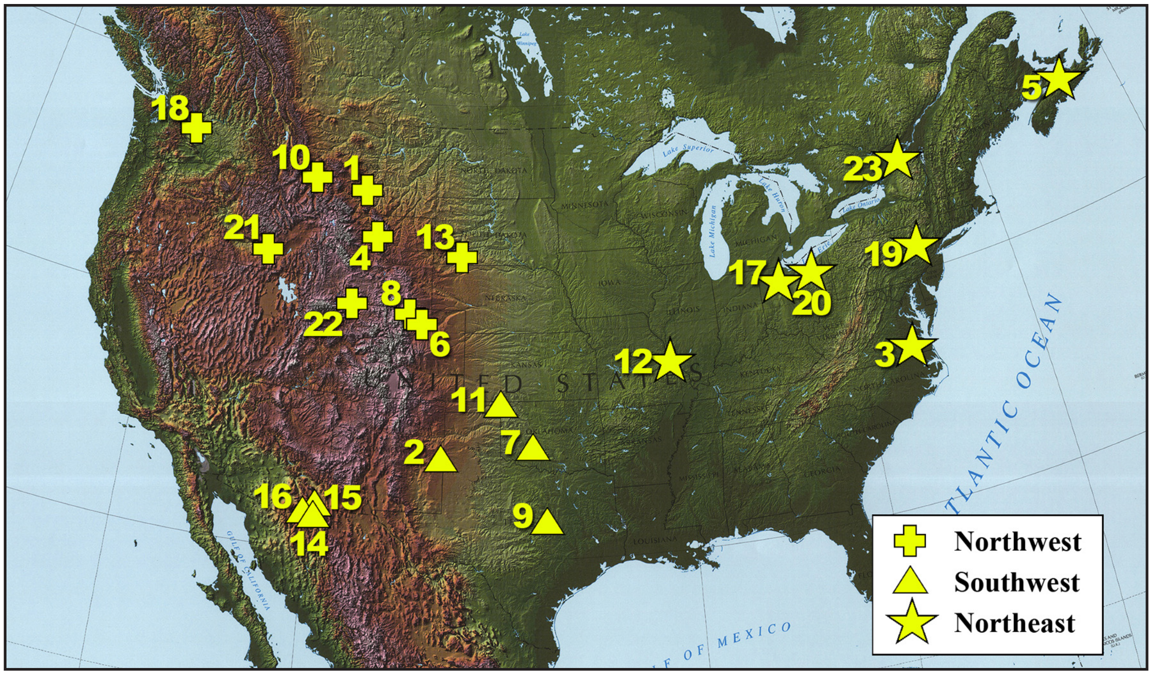


Figure 2.4. Three major regions consisting of the northwestern United States (NW), the combination of the North American Southwest and the Southern High Plains (SW), and the combination of the Great Lakes and Atlantic coastal vicinities (NE).

A hierarchal multivariate cluster analysis and Euclidean distance matrix was generated on a site-by-site scale using the least-squares means of the principal components. Dendrograms were developed for sites in both the entire data-set and the data-set from which the caches were removed to identify relationships in shape among individual sites. Euclidean distance matrices were arranged in order from those most closely related to those least closely related and organized into an array. Cumulative-frequency graphs were created to model the range of Euclidean distances. A trend line was fitted to the portion of the curve that became level once the closest relationships were no longer affecting the slope. The most significant relationships were determined by all those above the trend line.

To expand the analysis to individual projectile points, the residuals of the principal components were employed in a discriminant function analysis (DFA). The three major regions were used as grouping variables to determine whether the three major regions could be defined in terms of projectile-point shape. Additionally DFA was utilized to identify which projectile points possessed the shape characteristics that had been assigned to another region which served to identify relationships between regions on a point-by-point basis.

To explore the major factors of point-shape variability, principal components were generated for each major region and the cache sites as a group (NW, SW, NE and Caches). The individual group's principal components demonstrated the major elements of variability characteristic to a region. The shape characteristics demonstrated by each region's principal components could then be compared to the principal components of the entire data-set to identify the major elements responsible for shape variability. To confirm which characteristic shape elements were utilized in each region, these regional shape-elements were then compared to the loadings of the original principal components generated for the entire data-set.

To address similarity in shape due to raw-material constraints, multivariate cluster analyses were conducted on the projectile points from the Fenn Cache, Drake Cache, and Lehner site for which I had raw-material information. Within the Fenn Cache, six different raw materials were used to manufacture the 19 projectile points included in this study: obsidian (1), Green River Formation chert (2), red jasper (2), quartz crystal (2), Utah agate (11), and another chert type (1) hypothesized to be from the Amsden Formation in Wyoming (Kilby 2008). Within the Drake Cache, all projectile points were made from Alibates dolomite except for two, one from Edwards chert and one from a yellowish-gray chalcedony (Kilby 2008). The Lehner site points were made from four raw materials: quartz (3), chalcedony (2), chert (2), and jasper (1) (Haury et al. 1959). Projectile points made from the same raw material were hypothesized to form the closest relationships represented by their Euclidean distances thereby suggesting that raw material was the determining factor of shape similarity.

The 123 projectile points analyzed in this analysis represent a pure sample of selected specimens that met specific criteria. The criteria were meant to control for security of context in the archaeological record. Once principal components describing the shape-variability inherent in this data-set were generated using the geometric morphometric method, multivariate statistical analyses could be employed to identify major factors of variability across North America. The analytical methods of MANOVA, distribution of variance, cluster analysis, and DFA served to identify shape characteristics imposed on each projectile point, as well as morphological patterns and relationships amongst artifacts in the sample. Research questions concerning the influence of resharpening and raw material on point shape were also addressed. The incorporation of geometric morphometrics and these statistical methods facilitated a comprehensive analysis of Paleoindian projectile point morphology.

CHAPTER III

RESULTS

Introduction

A geometric morphometric analysis of fluted point variability was successful in generating principal components which describe the shape variability within the data-set. These components facilitate the MANOVA analysis and demonstrated patterns of shape characteristics present in the assemblage. The results of the MANOVA tests prompted further investigation into the distribution of variance within and between sites and a multivariate cluster analysis. The discriminant function analysis served as an effective indicator of the shape relationships inherent in the data-set. These analyses provided an interesting array of results which are discussed in detail below.

Principal Components

Figure 3.1 displays the average fluted point shape within the data-set of 123 projectile points from 23 archaeological sites. The first four principal components (PC) representing 94.75% of shape variability are illustrated in Figure 3.2. For each PC, the images to the left and right of the average point shape represent the aspects of shape that diverge from the average along an axis. The change in shape present at each end of the axis is also illustrated by the deformation of the original grid utilized by the average point shape. The projectile point shapes shown at each end of the PC-axes represent only the possible extremity of that variant in shape and is not an image of any particular point in the data-set. The true shape of each artifact is characterized by four axes of variability working in concert. The isolation of each axis allows us to identify which specific factors of shape weigh more heavily upon an artifact's morphology. The body of the projectile point, consisting of the portion beyond the base, will be referred to as the "blade" of the artifact in the following text.

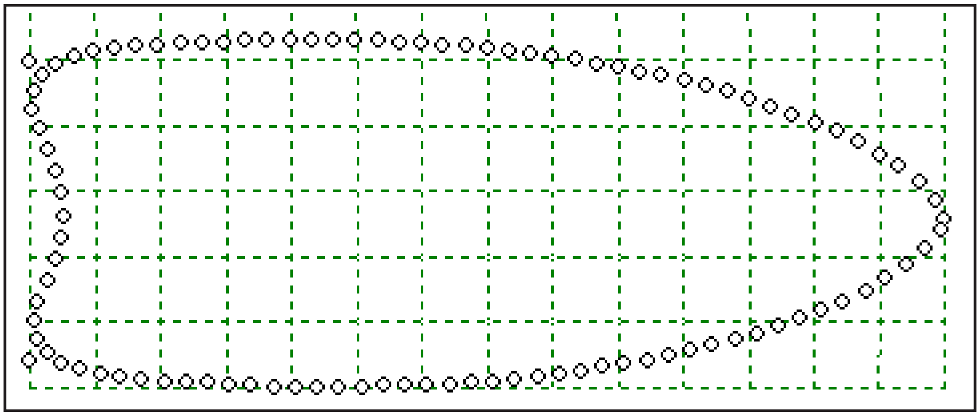


Figure 3.1. Average fluted projectile point shape.

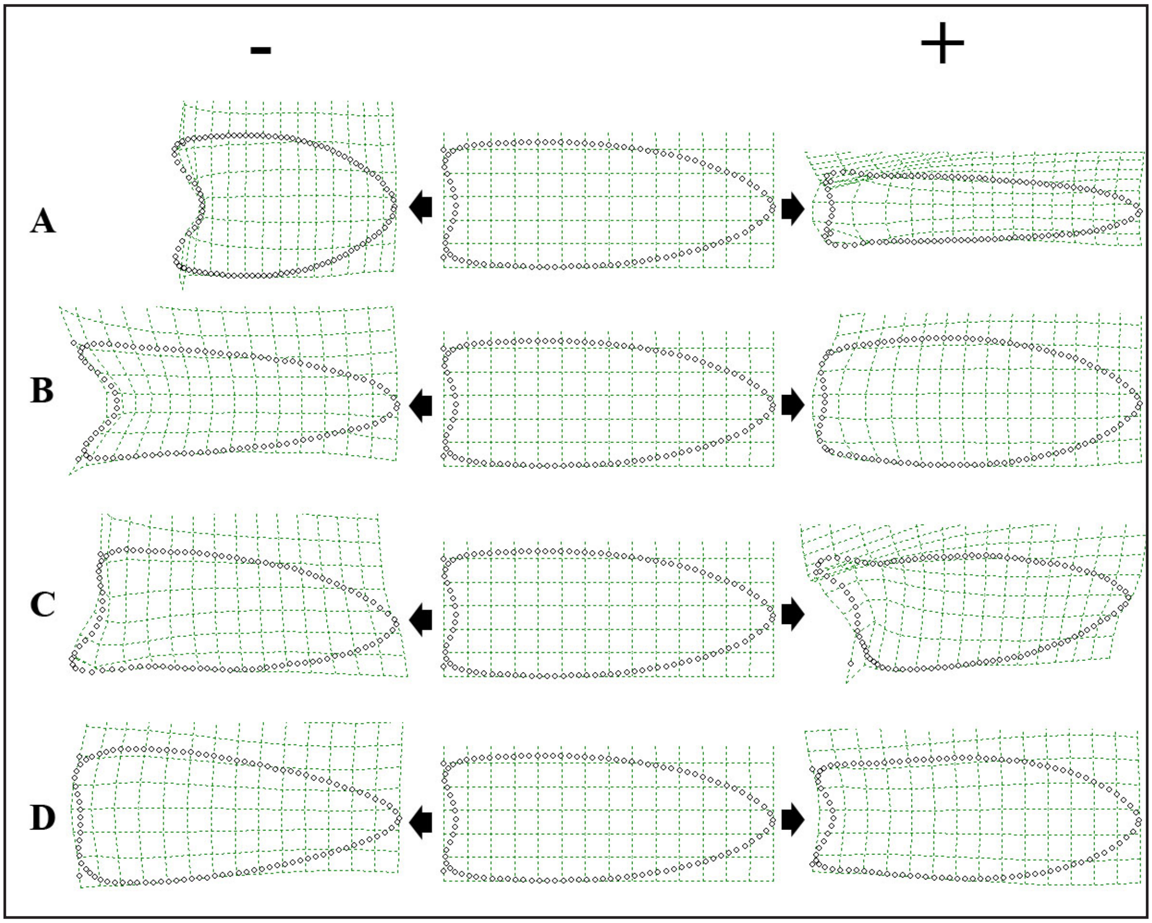


Figure 3.2. Principal components 1-4. A) PC-1; B) PC-2; C) PC-3; D) PC-4.

The first principal component (PC1) demonstrates variation along the first relative warp and suggests a gradient upon which shorter points are wider than longer points (Figure 3.2A). This relationship between length and width is evident in both the blade and base. At the negative end of the axis (left) the tool is short and wide. The point of maximum tool width is beyond the basal area. The blade edge begins just beyond the position of greatest width, and due to the high width-to-length ratio, the blade edges must angle towards the tip at a steep gradient. There is no lateral indentation between the basal area and point of maximum width, and the basal indentation is deeper than that demonstrated at the positive end of the axis. The projectile point represented by this end of the PC1 axis is long and thin. The base is wider than the overall blade width and there is lateral indentation immediately beyond the basal area. At this position, the blade edge begins to angle toward the tip at a low degree. The basal indentation is less extreme than that of the negative end of the axis. The shape of the basal ears and symmetry of the tool are preserved at both ends of the PC1 shape gradient.

The second principal component (PC2) represents variation along the axis of relative warp two and emphasizes the point of maximum blade width relative to basal indentation (Figure 3.2B). Length is not an aspect of variability on this axis. At the negative end of the axis the position of maximum tool width is located at the base. Basal indentation is extreme, and the blade angle begins to grade towards the tip at the basal ears. At the positive end of the axis, there is lateral waisting at the base with very little basal indentation or flaring of the basal corners. From the lateral indentation of basal area the blade's edge angle increases outwards to a maximum blade width located at the approximate half-way point of the long axis. At the point of maximum width, the blade angle changes direction and forms an arc toward the tip. This causes the blade to assume a rather swollen appearance and almost a leaf-shape as opposed to the lanceolate-like images demonstrated by negative PC1 and negative PC2.

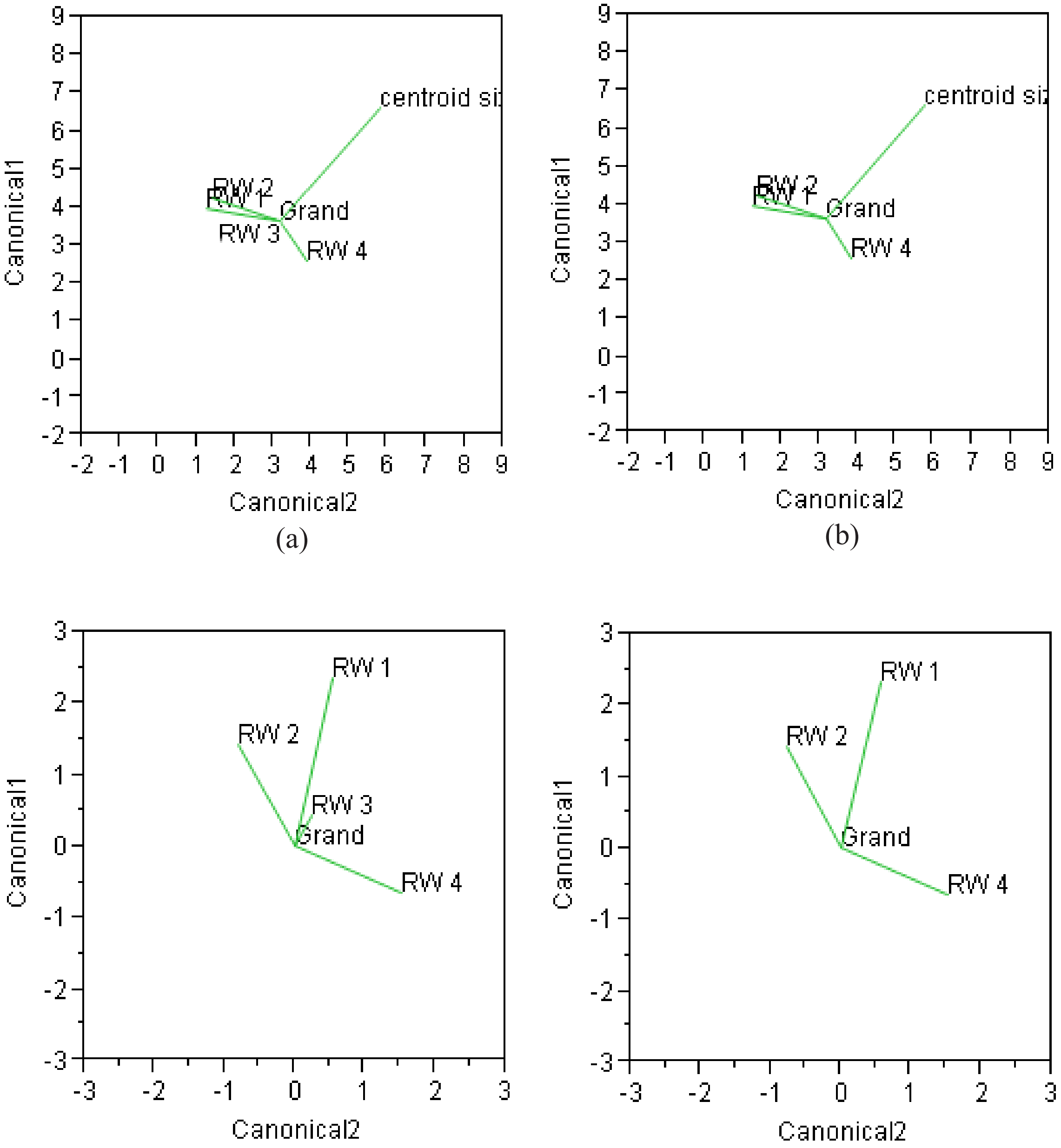
The third principal component (PC3) demonstrates shape variability represented by relative warp three (Figure 3.2C). The variability represented along the axis of this morphological gradient specifically concerns asymmetry. Each end of the axis displays mirror images of shape variability in which one basal ear is longer than a non-existent counterpart. The side of the tool with the long basal ear demonstrates a lateral indentation just beyond the basal area from which the blade angles outward to reach the point of maximum width located at the center of the long axis. The blade's edge angle then decreases towards the tip. The opposite side of the point is quite different. At the basal corner, the ear appears to be missing and the blade edge begins an immediate incline toward the tip. The different positions on the long axis at which the blade edges begin to angle toward the tip results in an asymmetrical blade shape. Tool length is not a factor on this axis of shape variability. The extreme asymmetry in the base is not characteristic of any artifact in the sample. As previously stated, the true shape of each artifact is characterized by the four axes of variability applied in concert. Therefore, the asymmetry inherent in each artifact is represented by a place along the PC3 axis.

The fourth principal component (PC4) demonstrates variability of shape represented by the fourth relative warp (Figure 3.2D). The critical factors of variability here are the position of maximum tool width and degree of basal indentation. At the negative end of the axis, the position of maximum tool width is just beyond the base. There is a small amount of waisting from the point of maximum width to the proximal end causing the basal corners to curve inward. This aspect of negative PC4 is almost leaf-shaped as there is very little basal indentation. From the point of maximum width, edge angle decreases at a rather steep gradient toward the tip promoting the overall teardrop appearance. The positive end of the PC4 axis has a greater degree of basal indentation. There is a lateral indentation in tool width immediately beyond the basal area causing the basal ears to flare outwards. From the indentation, the blade's edge angle increases toward the point of maximum tool width located beyond the mid-point of blade length. From this position, the edges begin to arc toward the tip. Ultimately PC4 describes the inverse of PC2 by reversing the relationship between maximum width and basal indentation.

Figures 3.3a and 3.3c show the centroid plots of the four principal components for the entire data set with regard to both form and shape. The first two principal components alone account for 89.56% of Clovis shape variability represented in the data set, and the significant length of their biplot rays attest to their influence in shape variability. The fourth principal component was found to be complementary to the second and its loading is highly comparable to that of PC1 and PC2. The third principal component, however, does not load heavily in regard to shape variability. It, therefore, explains a trivial amount of information. To lessen the amount of noise imposed by PC3, it was dismissed from the rest of the analysis. Figures 3.3b and 3.3d show the centroid plots in regard to both shape and form without the employment of PC3. The dismissal of PC3 does not affect the descriptive power of PCs 1, 2 and 4.

Multivariate Analysis of Variance

The results of the MANOVA tests are reported in Tables 3.1 and 3.2. These tests evaluated the significance of variability with regard to the grouping variables of archaeological site, mean radiocarbon (^{14}C) age, latitude, longitude, the interaction of latitude and longitude, geographic region, and site type. The results of the MANOVA tests considering tool form, which incorporates the element of size, are reported in Table 3.1. Overall, there is significant variability in all grouping variables; however, the degree of significance fluctuates. The test for variability between sites resulted in a significant F-statistic and p-value ($F=3.61$, $p=0.0000$), indicating that the between-group variability is large relative to the within-group variability, and the statistical likelihood of this being due to random chance is extremely small. Mean ^{14}C age was statistically significant but much less so in relation to other grouping variables ($F=2.56$, $p=0.0456$). Variability in



(a) (b)

(c) (d)

Figure 3.3. (a) Centroid plots of the four principal components for the entire data set with regard to form; (b) Centroid plots of principal components 1, 2 and 4 for the entire data set with regard to form; (c) Centroid plots of the four principal components for the entire data set with regard to shape; (d) Centroid plots of principal components 1, 2 and 4 for the entire data set with regard to shape.

relation to latitude and longitude showed extreme significance (latitude, F=15.89, p= 0.0000; longitude, F=15.34, p=0.0000). There was a significant result for the interaction between latitude and longitude suggesting that variation along the latitudinal axis is dependent upon the location along the longitudinal axis (F=4.11, p=0.0037). The significance of latitude and longitude is reproduced in the significant results in the test against the five geographic regions (F=6.02, p=0.0000). When the five regions were further consolidated into three major regions, the significance of variability increased (F=8.62, p=0.0000). Variability between site type is also significant (F=5.35, p=0.0005). This is an important result in that it supports previous observations of greater variability in tool types present at habitation and quarry sites, where points are being rejuvenated or replaced, relative to special-purpose sites types such as kill and cache sites.

Table 3.1. MANOVA results for form.

Variable	F-test	NumDF	DenDF	p-value
Archaeological Site	3.616084	84	385.59	0.000000
Mean RadioCarbon Age	2.567562	4	69	0.045600
Latitude	15.89071	4	117	0.000000
Longitude	15.34298	4	117	0.000000
Lat*Long (cross)	4.106979	4	115	0.003791
5 Geographic Regions	6.020329	16	348.9134	0.000000
3 Major Regions	8.619801	8	232	0.000000
Site Type	5.354848	4	117	0.000538

Table 3.2. MANOVA results for shape.

Variable	F-test	NumDF	DenDF	p-value
Archaeological Site	3.31112	63	290.3855	0.000000
Mean RadioCarbon Age	2.380647	3	69	0.077021
Latitude	20.21312	3	117	0.000000
Longitude	19.30031	3	117	0.000000
Lat*Long (cross)	5.27207	3	115	0.001920
5 Geographic Regions	7.95588	12	301.9072	0.000000
3 Major Regions	11.33914	6	232	0.000000
Site Type	7.139437	3	117	0.000191

The element of size incorporated into tool form can potentially bias results. The significance of longitude can be a result of the large size of the cached points in the West. The presence of large cached artifacts can likewise affect the significance of variability between archaeological sites themselves, the regional consolidation of sites, and site type. To confirm that the significance in variability reported in these MANOVA tests was not the result of a size differential, size was removed from the equation by making it an independent variable. This allowed shape to be analyzed independent of size.

The results of the MANOVA tests considering tool shape alone are reported in Table 3.2. With the exception of archaeological site groupings (F=3.31, p=0.0000) and mean ^{14}C age (F=2.38, p=0.0770), the variability in all grouping variables increased in significance. With regard to shape alone, variability increased in significance latitudinally (F=20.21, p=0.0000), longitudinally (F=19.30, p=0.0000), in the interaction of latitude and longitude (F=5.27, p=0.0019), in five regional groupings (F=7.95, p=0.0000), in three major regional groupings (F=11.34, p=0.0000), and in site type (F=7.14, p=0.0002). Therefore, major aspects of variability are present with regard to projectile-point shape regardless of artifact size. Furthermore, the significance of variability increases when size is removed from the equation suggesting that size is not a determining factor in variability across the continent.

Controlling for the Early Use-life of Cached Artifacts

While caches do contain projectile points that have some degree of use and resharpening, they contain many new and pristine projectile points (Kilby 2008). The nature of the caches can, therefore, potentially bias the significance in variability reported in the MANOVA testing. To investigate the effect of the cached artifacts on the analysis, the MANOVA tests were conducted again without the caches. Figure 3.4 shows the first four principal components that account for 92.89% of the shape varability

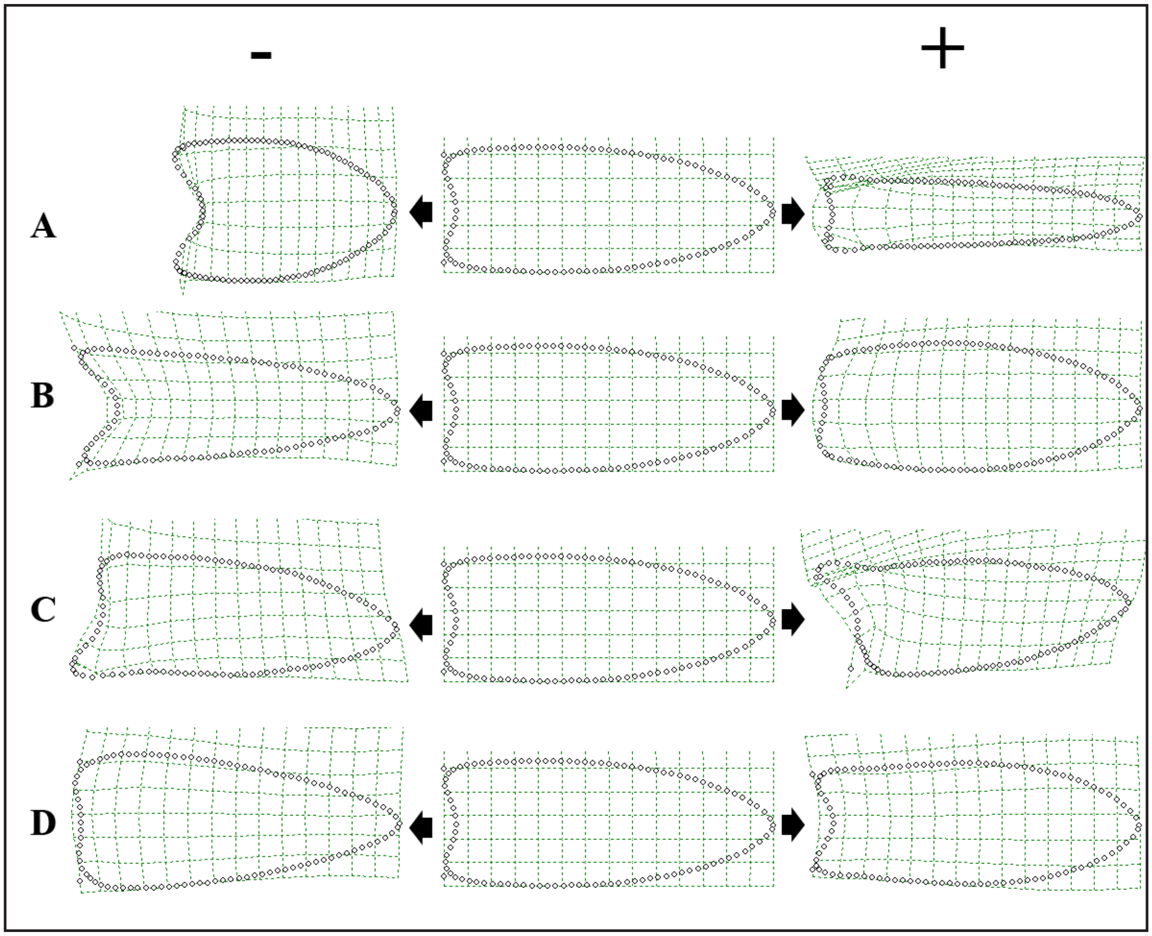


Figure 3.4. Principle components 1-4 of non-cache data-set. A) PC-1; B) PC-2; C) PC-3; D) PC-4.

in the data-set without the caches. Each principal component is identical to the original principal components developed for the entire data set (Figure 3.2). Figure 3.5 displays the centroid plots generated for the non-cache data set and demonstrates the continued small loading of PC3 and its dismissal from the analysis. Tables 3.3 and 3.4 show the results of the MANOVA tests. The removal of the caches caused the results to be less dramatic; however, the significance of variability in most of the grouping variables remained. MANOVA tests of both form (Table 3.3) and shape (Table 3.4) were also conducted with this new data set. When the element of size was removed, significance in variability increased in almost all groups as in the former analysis of the entire data set.

Without the influence of the cached artifacts, significant variability remained in the test against archaeological site (F=2.18, p=0.0001), latitude (F=14.52, p=0.0000), longitude (F=13.44, p=0.0000), the interaction between latitude and longitude (F=4.91, p=0.0037), five regional groupings (F=5.90, p=0.000), three major regional groupings (F=7.45, p=0.0000), and site type (F=4.74, p=0.0045).

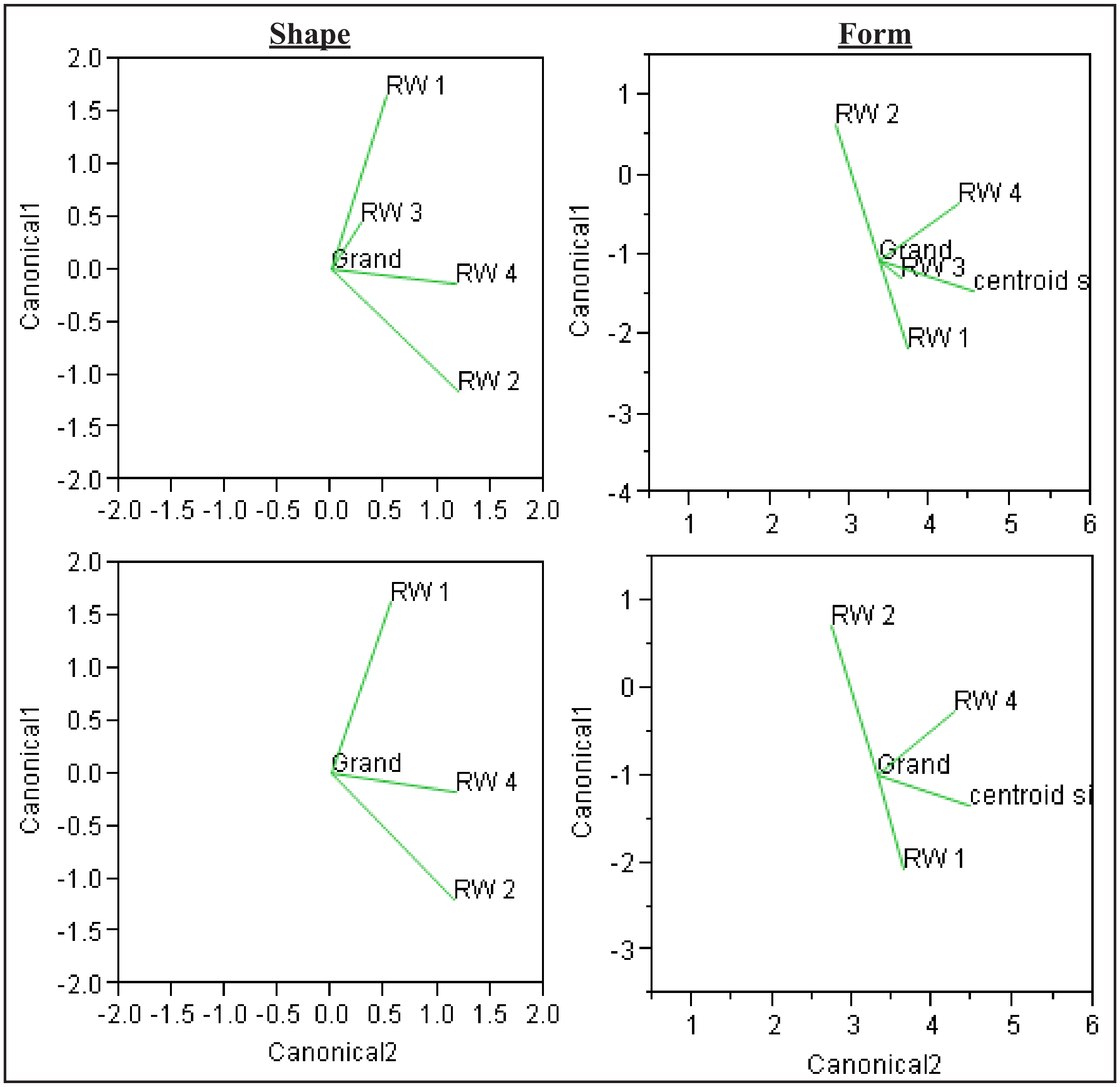


Figure 3.5. Centroid plots of the four principal components for data-set without cache sites with regard to both shape and form.

Table 3.3. MANOVA results for form (no caches).

Variable	F-test	NumDF	DenDF	p-value
Archaeological Site	2.026881	68	218.1541	0.000065
Mean RadioCarbon Age	3.124924	4	60	0.021130
Latitude	10.9055	4	71	0.000001
Longitude	10.1225	4	71	0.000002
Lat*Long (cross)	4.261176	4	69	0.003857
5 Geographic Regions	4.699145	16	208.3811	0.000000
3 Major Regions	5.843243	8	140	0.000002
Site Type	3.58371	4	71	0.010174

Table 3.4. MANOVA results for shape (no caches).

Variable	F-test	NumDF	DenDF	p-value
Archaeological Site	2.179785	51	164.5497	0.000116
Mean RadioCarbon Age	1.432128	3	60	0.242302
Latitude	14.52818	3	71	0.000000
Longitude	13.44391	3	71	0.000000
Lat*Long (cross)	4.915921	3	69	0.003740
5 Geographic Regions	5.903016	12	180.2026	0.000000
3 Major Regions	7.453958	6	140	0.000001
Site Type	4.744177	3	71	0.004506

Distribution of Variance

To further identify the nature of the variance apparent in the MANOVA tests, distribution of variance was calculated for sites and regions in relation to PC1 and PC2 (Figures 3.6-3.9). Sites with only one projectile point (Indian Creek, Paleo Crossing, and Sheridan Cave) could not be included in this analysis. When all remaining sites are plotted (Figure 3.6), it is apparent that caches and those sites in the American Southwest (SW), Southern High Plains (SHP) and Northwestern U.S. (NW) have the least amount of within-site variability. The sites in the Northeast (NE), such as Shawnee-Minisink, Kimmswick, Cactus Hill, Debert, and Vail, have the greatest amount of variability. The

Colby site also has a large amount of within-site variability similar to that of the NE sites. When caches are removed, differences in variance between those sites in the SW and NW, and those in the NE remain (Figure 3.7). When the sites are grouped into five regions there is a strong relationship in degree of shape variability present between the SW, NW, and SHP regions (Figure 3.8). Sites consolidated into the Great Lakes Region (NE) and Atlantic states regions (ECoast) are considerably more variable. When the caches are removed, SW and SHP sites retain their strong relationship of low variability; however, NW increases in variability suggesting that the influence of the caches played a significant role in the homogeneity of the NW region (Figure 3.9).

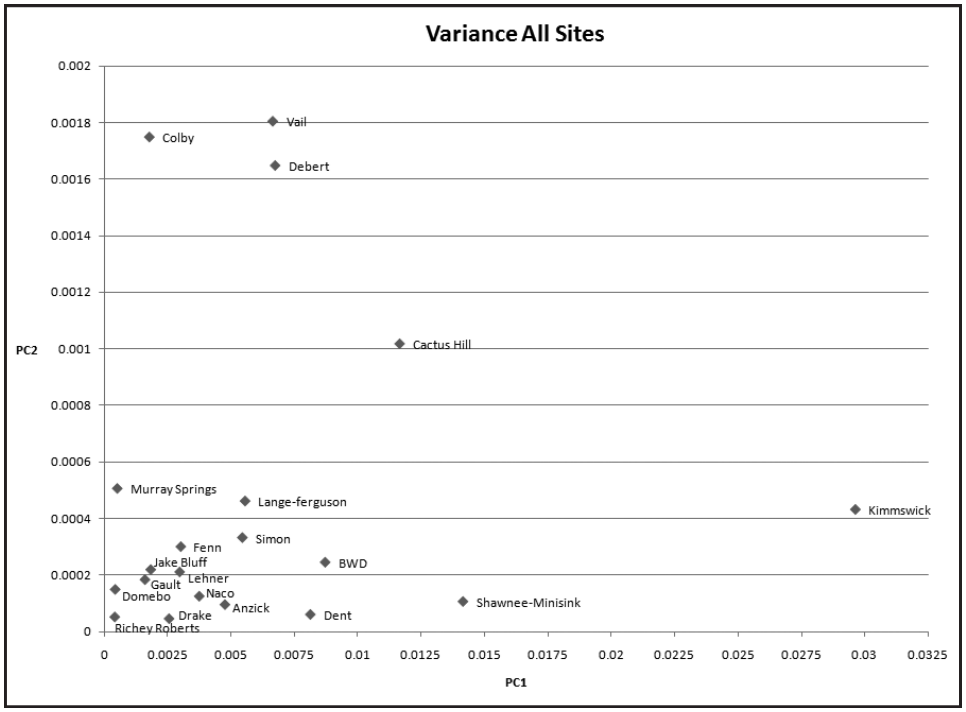


Figure 3.6. Variance between all sites.

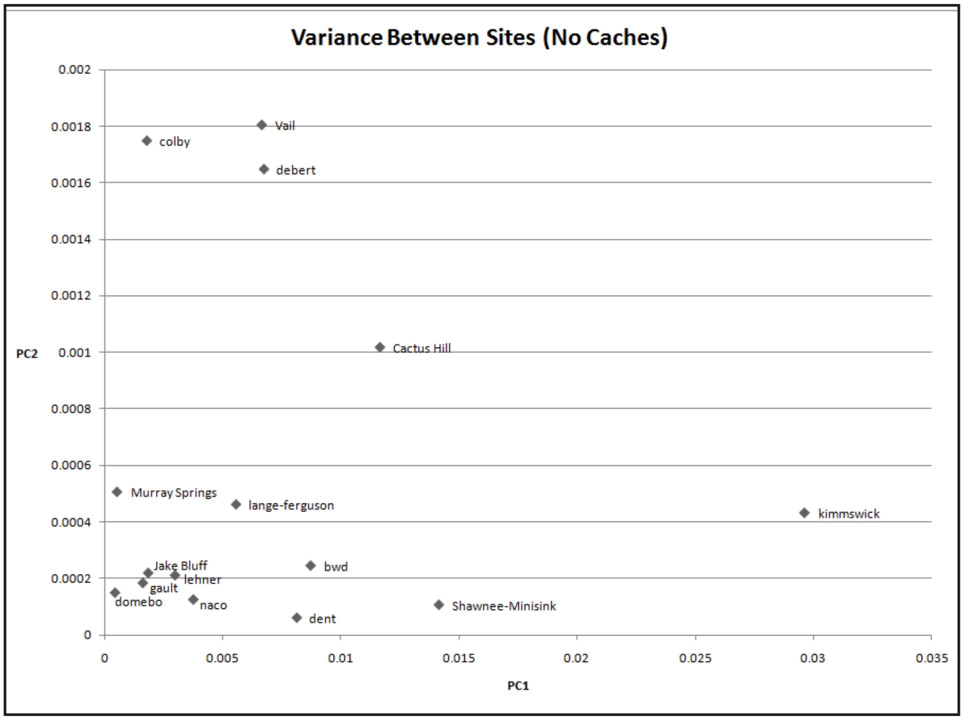


Figure 3.7. Variance between sites without caches.

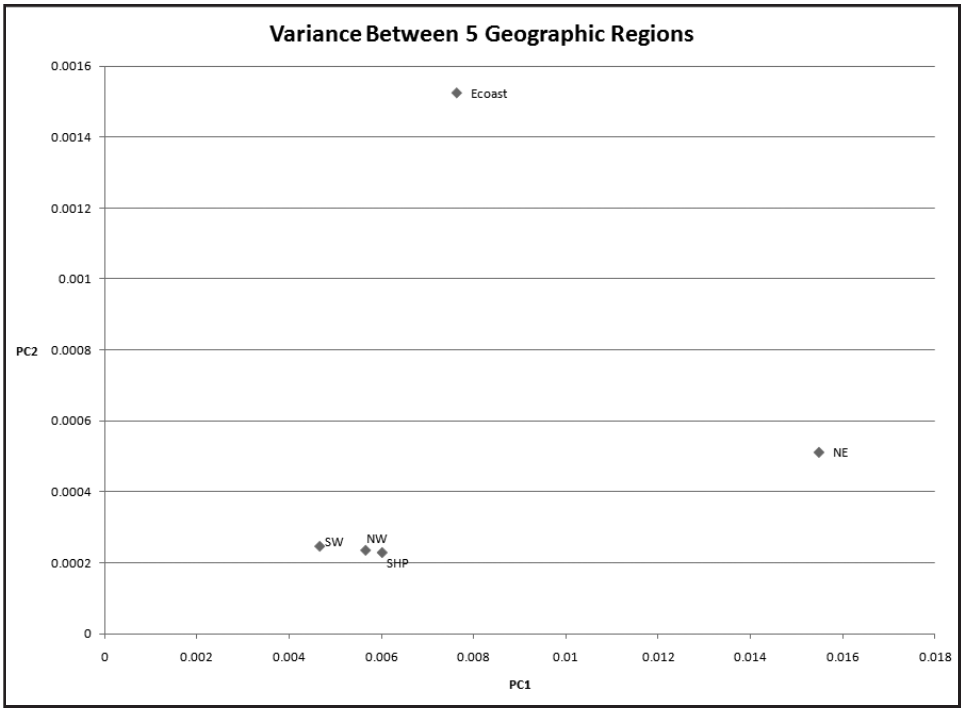


Figure 3.8. Variance between 5 geographic regions.

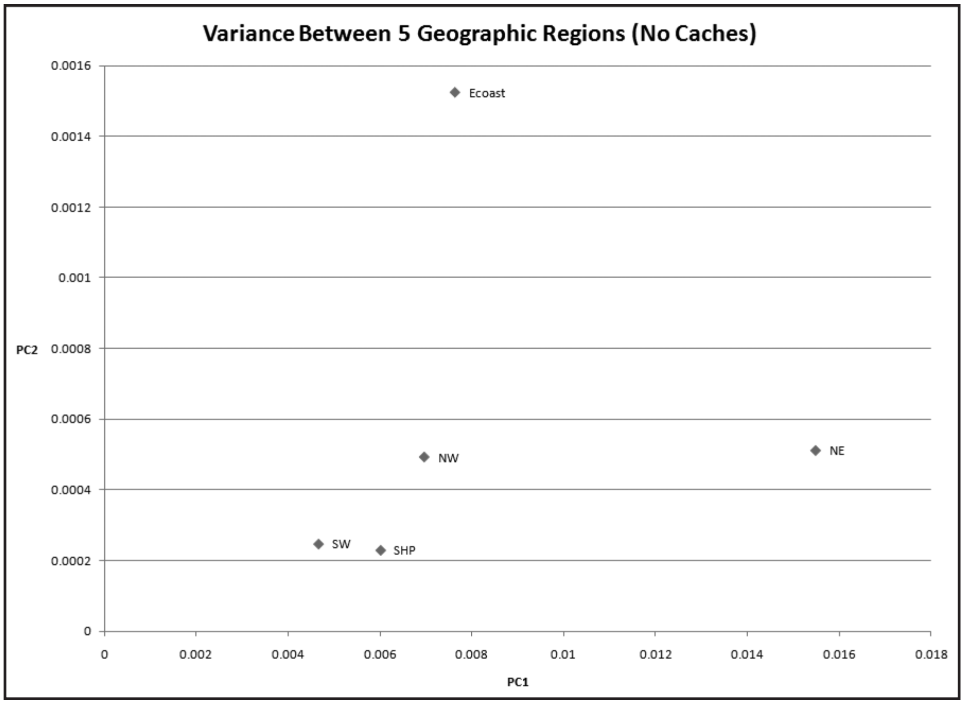


Figure 3.9. Variance between 5 geographic regions without caches.

The sites were further consolidated into three major regions. When all sites are considered and consolidated into three major regions, the SW (American Southwest combined with the Southern High Plains) and NW (Northwestern US) sites continue to show related degrees of low variance whereas sites in the NE (Great Lakes Region combined with the Atlantic states) group are highly variable (Figure 3.10). When caches are removed, variance increases in the NW grouping, which separates it from the SW group and further emphasizes the low variance among the cached artifacts (Figure 3.11).

To further investigate major relationships in shape variability between and within the three major regional groupings, three new groups were assembled containing (1) NW and SW points, (2) SW and NE points, and (3) NE and NW points. Figure 3.12 shows that when all sites were considered, the NW and SW sites continue to have the lowest variance. The relationship between the SW and NW sites was evident as the combination of these sites also had low intra-group variance. The SW and NE sites had more variance within them but less than the relationship between the NE and NW sites. The NE group remained in position as having the most inherent variance. Figure 3.13 displays the same results as with the caches having been removed. This reflects the same increase in variance within the NW group. However, the close relationship in variance between the SW and NW groups remained. The next-closest relationship is between the SW and NE groups. The relationship in variance between the NE and NW groups remains greater than the within-group variance of the NE groups alone.

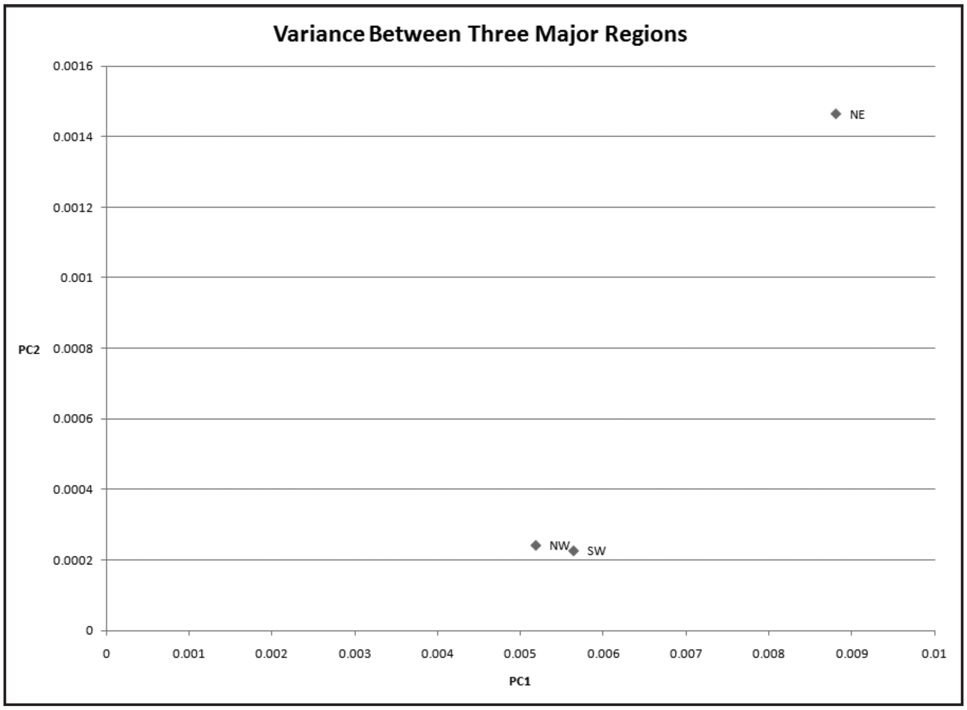


Figure 3.10. Variance between three major regions.

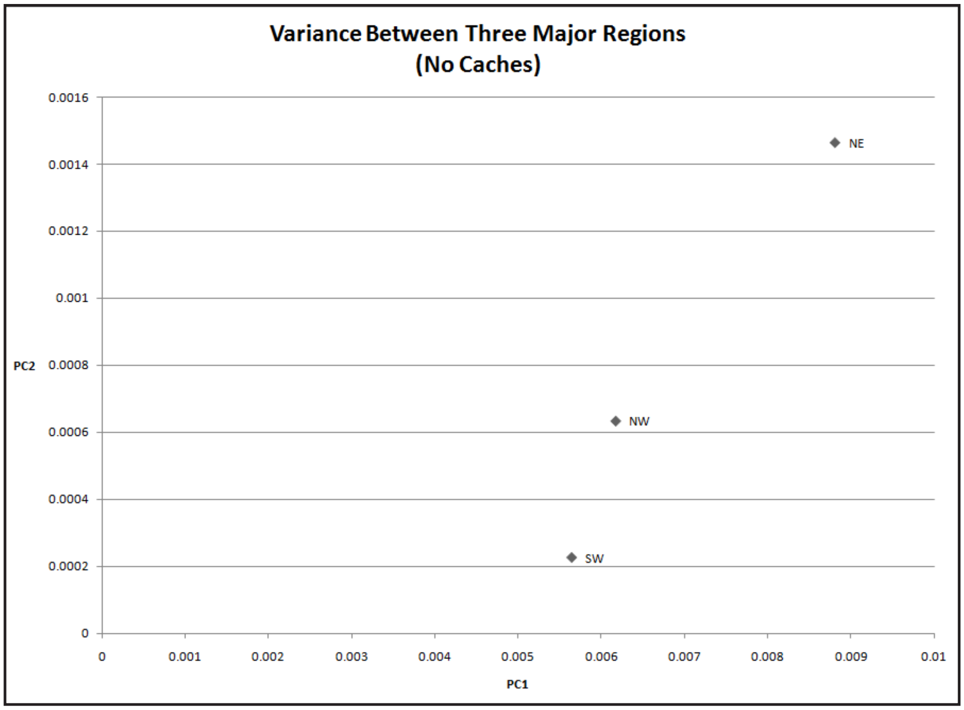


Figure 3.11. Variance between three major regions without caches.

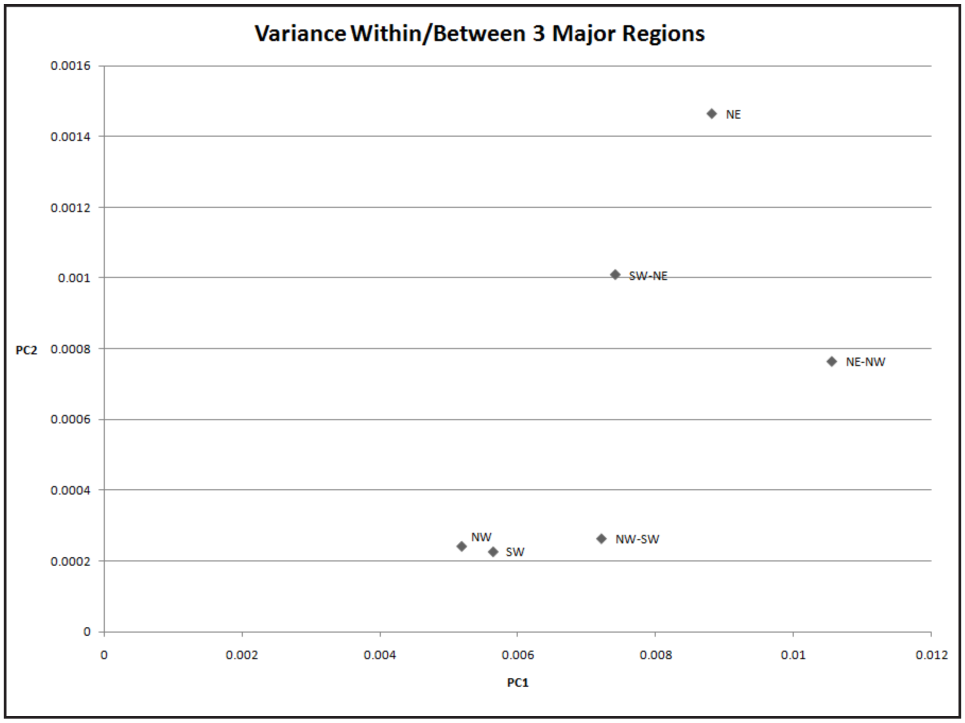


Figure 3.12. Variance within and between 3 major regions.

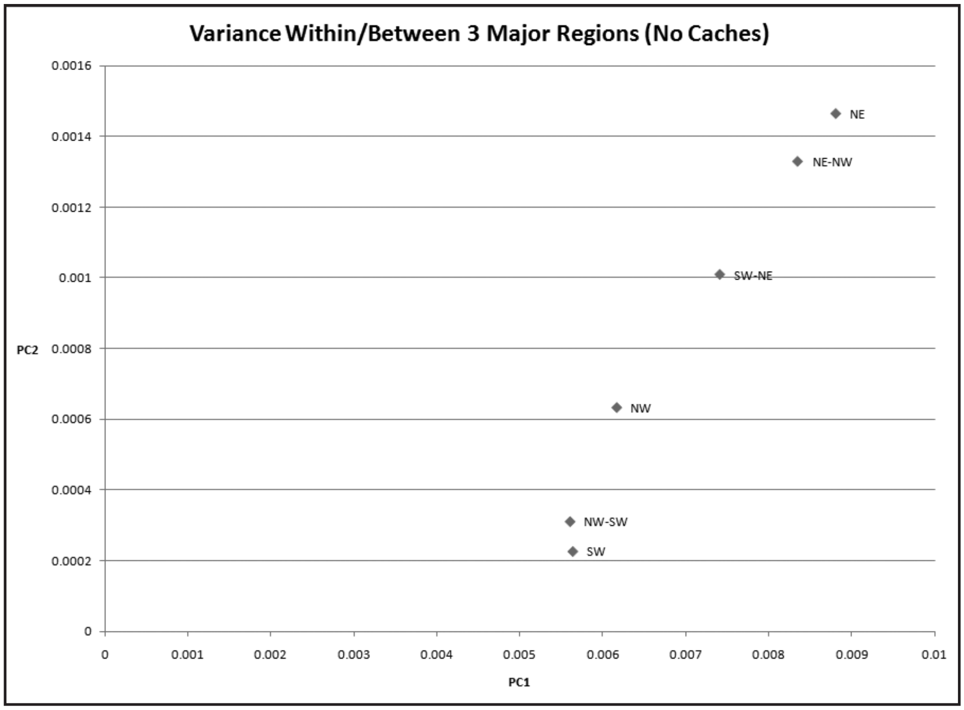


Figure 3.13. Variance within and between 3 major regions without caches.

Variance of PC 1 and 2 was also plotted against sample size (Figures 3.14 and 3.15). There was no relationship found between variance and sample size. Sample size is therefore not a factor affecting within-site variance.

These results suggest that projectile points in the SW group are the least variable and that they are highly related in variance to NW groups, whether or not caches were included in the analysis. The removal of caches though, does increase the variance of the NW group. Projectile points in the NE groups seem more closely related to points in the SW groups than to the NW groups. Projectile points in the NE group have the highest amount of variance. This analysis also confirmed that a larger degree of variance is not a result of a larger sample size.

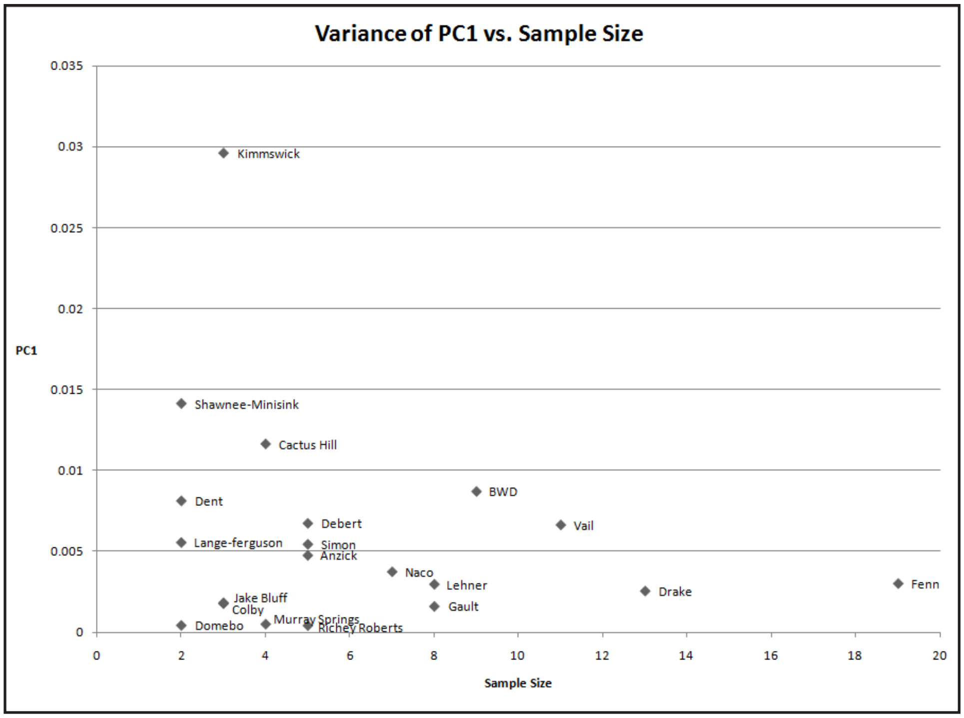


Figure 3.14 Variance of PC1 vs. sample size.

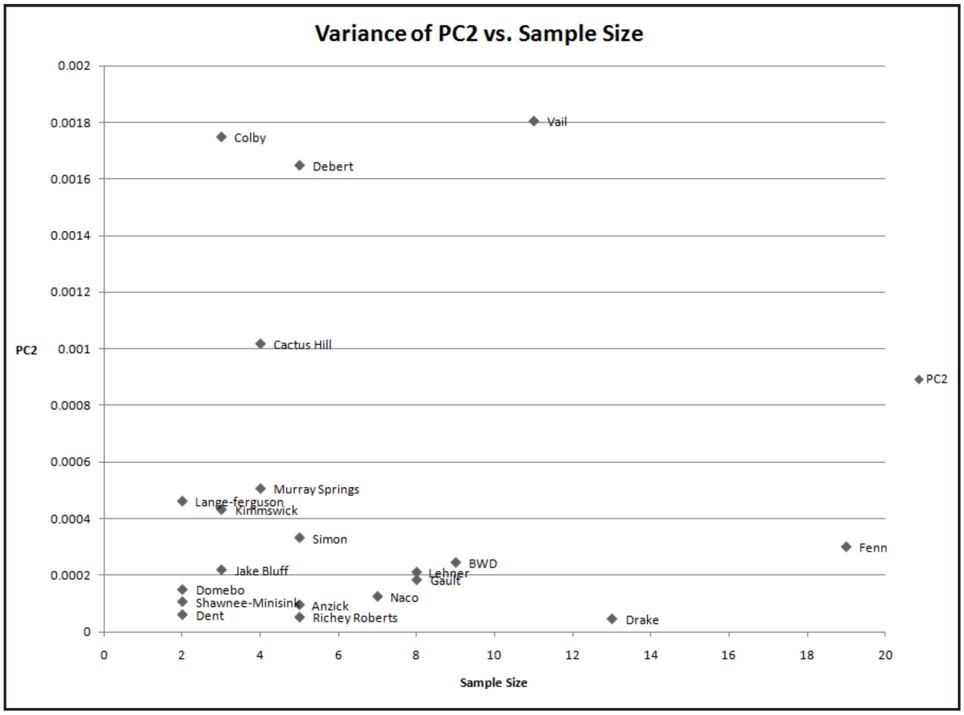
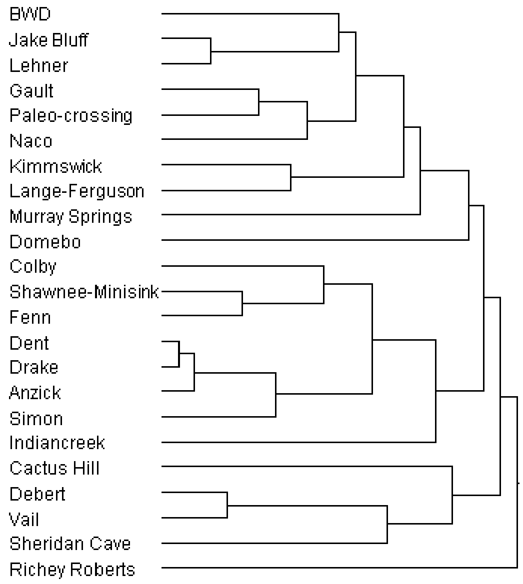


Figure 3.15. Variance of PC2 vs. sample size.

Multivariate Cluster Analysis

Multivariate cluster analysis was conducted to establish the closest relationships among individual sites (Figures 3.16-18). A dendrogram and Euclidean distance matrix was generated for the entire data-set, and Euclidean distances were organized from most to least related (Figure 3.16). According to the dendrogram, two major groups were partitioned: Cactus Hill, Debert, Vail, and Sheridan Cave points grouped together, while BWD, Jake Bluff, Lehner, Gault, Paleo-crossing, Naco, Kimmswick, Lange-Ferguson, Murray Springs, Domebo, Colby, Shawnee-Minisink, Fenn, Dent, Drake, Anzick, Simon, and Indian Creek grouped within the latter group. A division was further evident between sites in the SW and cache sites. Interestingly, Lange-Ferguson, Paleo Crossing, and Kimmswick were assigned to the SW group, while the kill-sites of Dent, Colby, Indian Creek, and Shawnee-Minisink were assigned to the cache group. Richey Roberts was considered to be an outlier in this analysis.



Drake	Dent
Anzick	Dent
Drake	Anzick
Lehner	Jake Bluff
Paleo-Crossing	Naco
Vail	Debert
Fenn	Shawnee-Minisink
Simon	Shawnee-Minisink
Jake Bluff	BWD
Shawnee-Minisink	BWD
Lehner	Lange-Ferguson
Lange-Ferguson	Jake Bluff
Shawnee-Minisink	Jake Bluff
Naco	Kimmswick
Paleo-Crossing	Gault
Lehner	BWD

Figure 3.16. Multivariate cluster and Euclidean distance matrix for entire data-set.

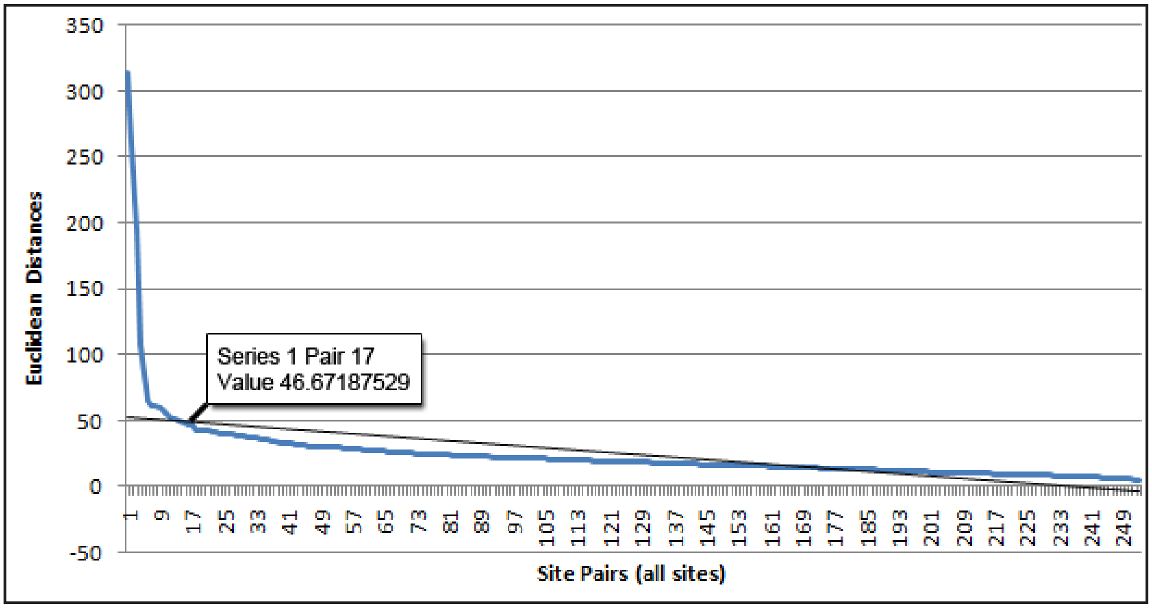
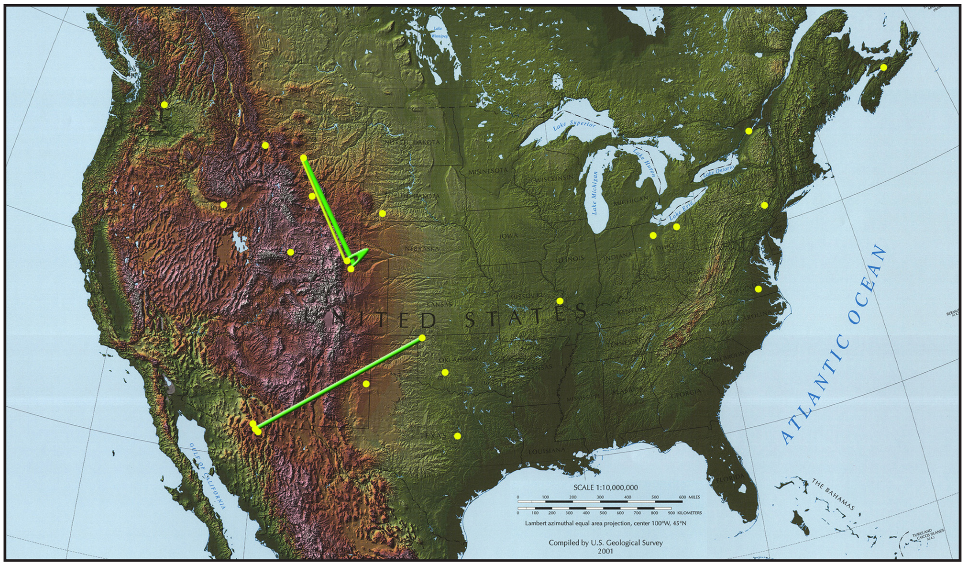


Figure 3.17. Cumulative frequency chart of Euclidean distances for entire data-set.

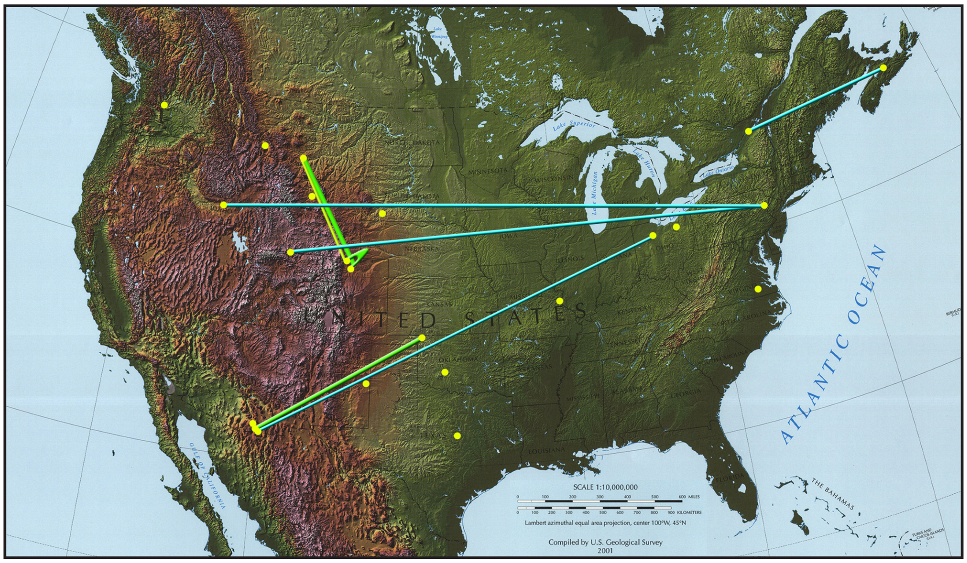
To determine at length past which Euclidean distances are too great to indicate a close relationship, a cumulative frequency chart was constructed to model the array of distances (Figure 3.17). A trend-line was fitted to the portion of the curve that became relatively level once the closest relationships were no longer affecting slope. The most significant relationships were determined to be those above the trend-line or "distance threshold". According to the dendrogram and Euclidean distances, the closest relationship regarding tool shape was between the Drake cache and Dent site. Next, the Anzick cache and Dent site were most similar. Lehner and Jake Bluff formed the next-closest relationship. Together, these demonstrate the low variance within the SW group. Within the distance threshold, the close relationship between Jake Bluff and Blackwater Draw was also obvious. After this, the next-closest relationship was between Naco and Paleo Crossing; however, the low sample size at Paleo Crossing (n=1) may have distorted this relationship. Still, the close similarity within and between the SW and NW sites was demonstrated by the relationship between Jake Bluff and Blackwater Draw and the presence of close Euclidean distances between Paleo Crossing and Gault, all of which occurr above the distance threshold. A close relationship between Vail and Debert was also demonstrated. Similar relationships were suggested between the Fenn and Simon caches and Lange-Ferguson, with the Shawnee-Minisink site displaying a connection between the NW and NE sites. Likewise, the relationship between Blackwater Draw and Jake Bluff with the Shawnee-Minisink site modeled the relationship between the SW and NE sites. There was also a relationship between Lange-Ferguson and Lehner and Jake Bluff. The connections between these sites are modeled in Figures 3.18a-d. Each map displays the cumulative 16 relationships that lie above the distance threshold.

When the caches were removed from the analysis, the Colby site joins the NE sites within the two major groupings (Figure 3.19). The Dent and Indian Creek sites

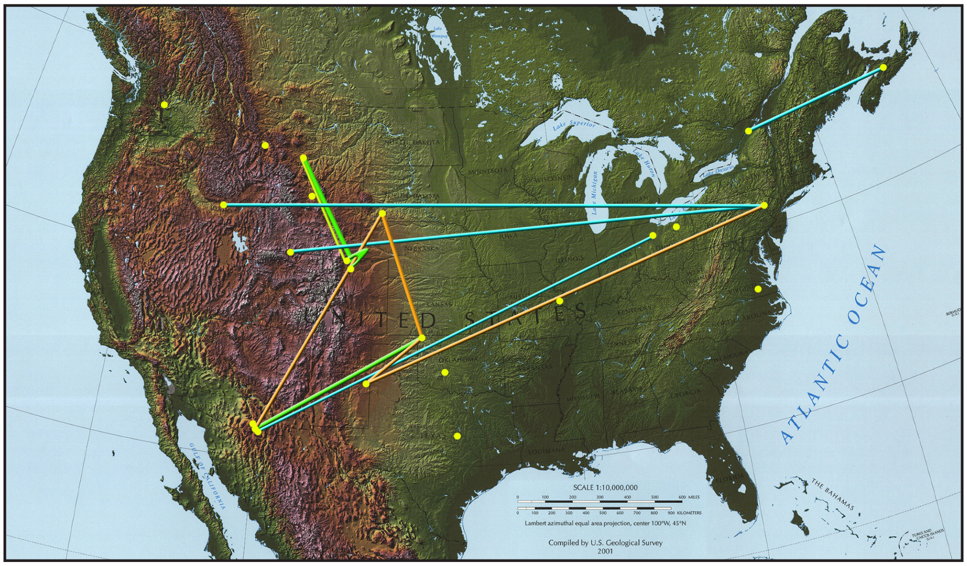


(a)

Figure 3.18. (a) First 4 Euclidean distances according to all archaeological sites in the data-set; (b) First 8 Euclidean distances according to all archaelogical sites in the data-set; (c) First 12 Euclidean distances according to all archaeological sites in the data-set; (d) First 16 Euclidean distances according to all archaeological sites in the data-set.

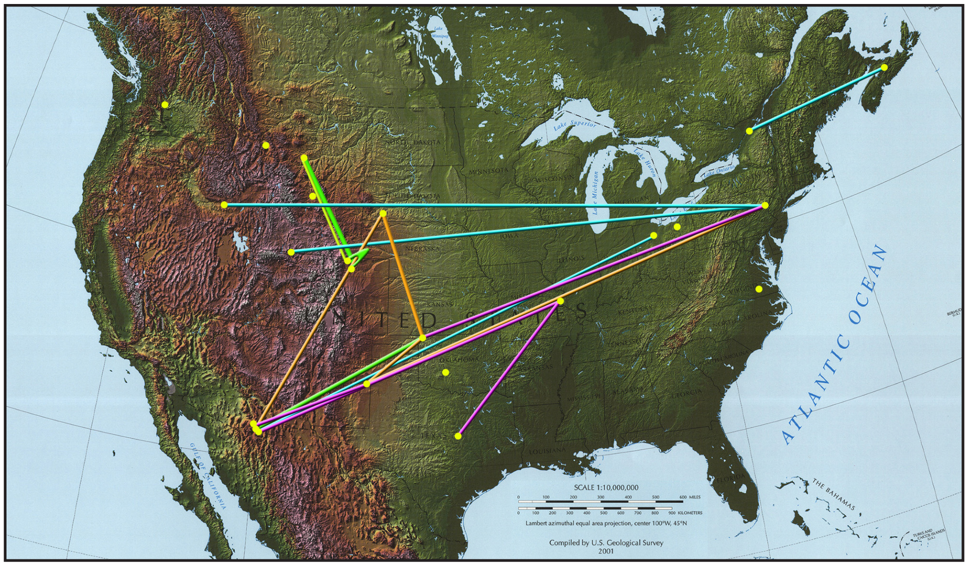


(b)



(c)

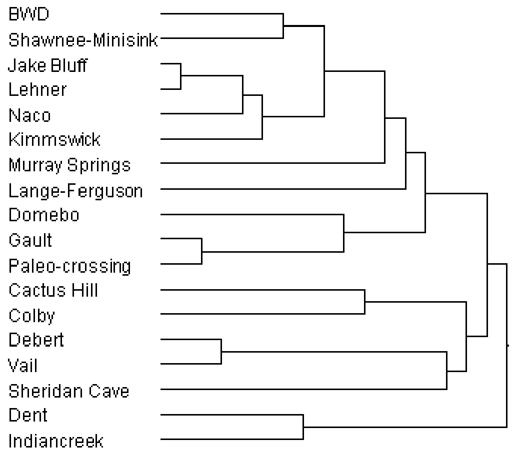
Figure 3.18 Continued.



(d)
Figure 3.18 Continued.

were assigned a close relationship yet were positioned as an outlier group suggesting their close ties with the cache sites that no longer influenced the results. The other group featured a close relationship between Jake Bluff, Lehner and Naco, and a close relationship between Gault and Paleo Crossing.

The list of closest Euclidean distances among sites when caches were removed also highlights the close relationship between Gault and Paleo Crossing, Lehner and Jake Bluff, and Naco and Kimmswick (Figure 3.19). All of these relationships were present before the caches were removed and their presence was emphasized when the low within-group variance of the caches did not dominate the Euclidean distance matrix. Shawnee-Minisink and Kimmswick represent the NE sites with the closest relationships to the NW and SW sites, specifically Naco, Blackwater Draw, Jake Bluff, and Lange-Ferguson. Colby and Cactus Hill also had a close relationship. Each map displays the cumulative 16 relationships that lie above the distance threshold (Figure 3.20). The relationships between these sites are modeled in Figures 3.21a-d.



Paleo-Crossng	Gault
Lahner	Jake Bluff
Naco	Kimmswick
Shawnee-Minisink	Dent
Naco	BWD
Shawnee-Minisink	Naco
Shawnee-Minisink	BWD
Lange-Ferguson	Kimmswick
Jake Bluff	BWD
Naco	Jake Bluff
Shawnee-Minisink	Jake Bluff
Vail	Debert
Kimmswick	Jake Bluff
Lange-Ferguson	Jake Bluff
Kimmswick	BWD
Colby	Cactus

Figure 3.19. Multivariate cluster and Euclidean distance matrix for data-set without caches.

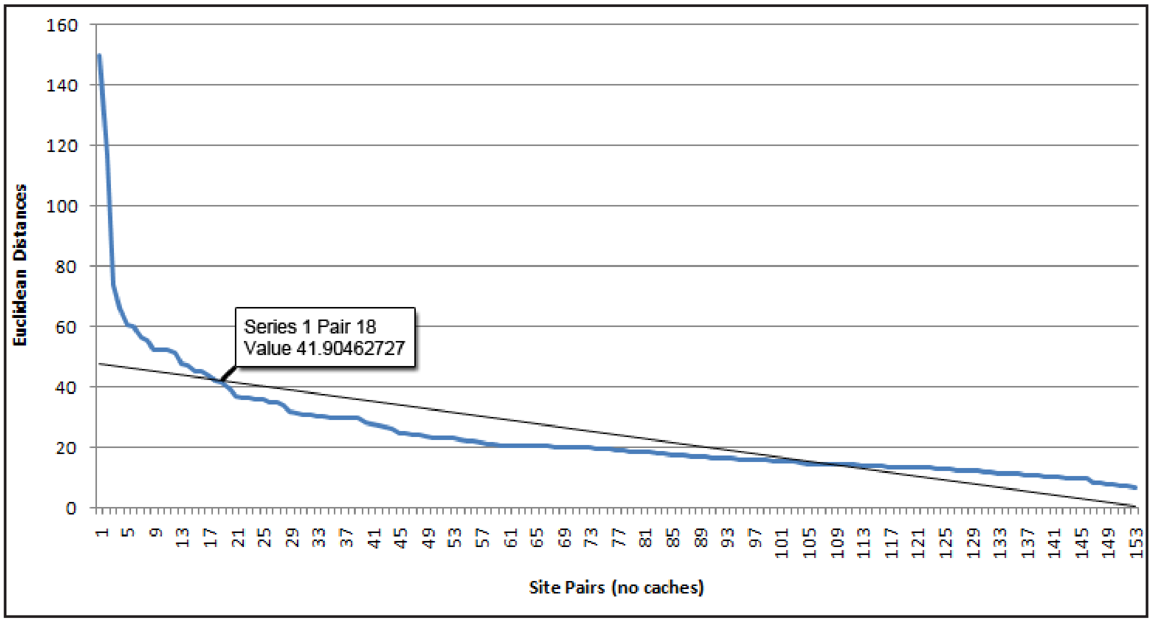
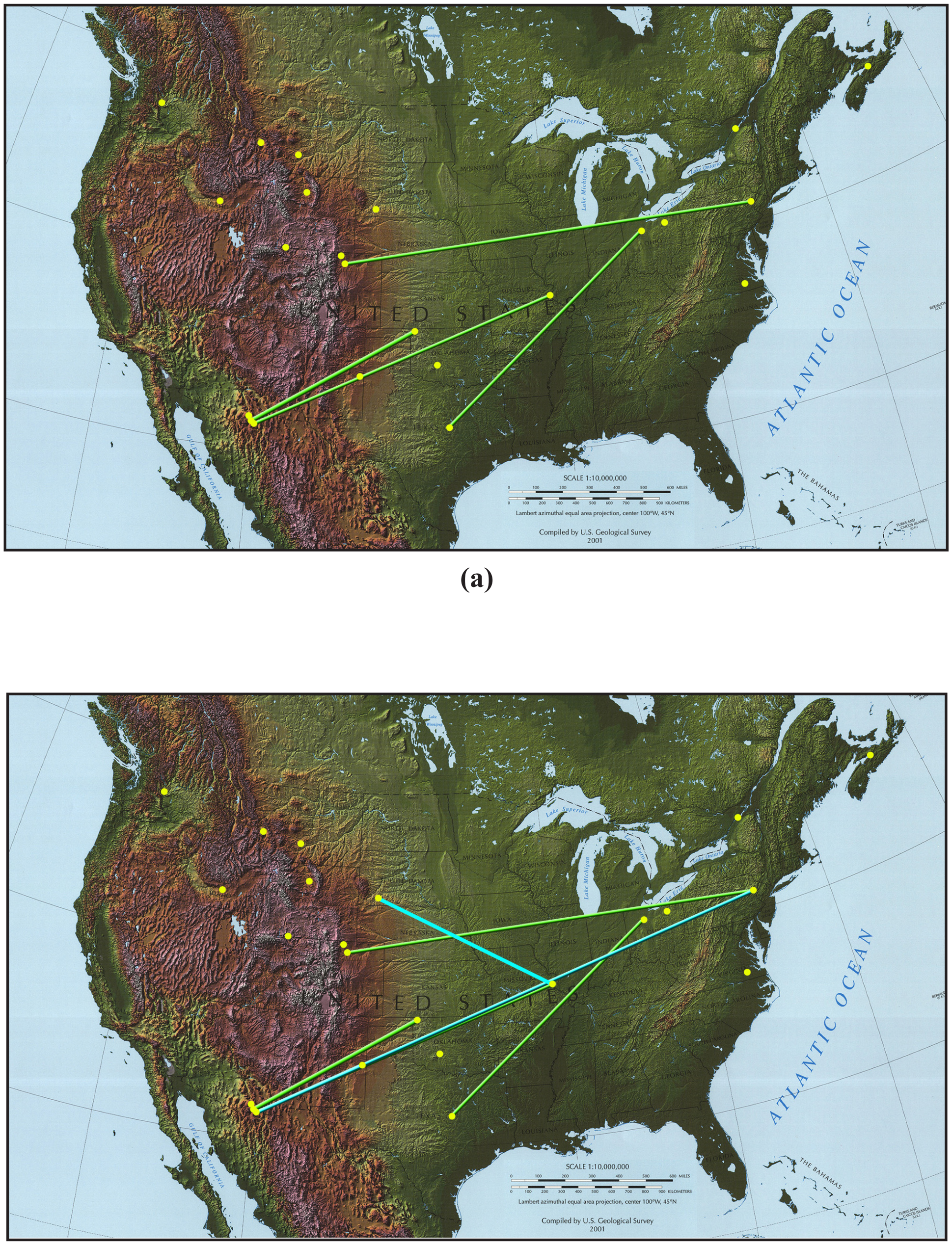


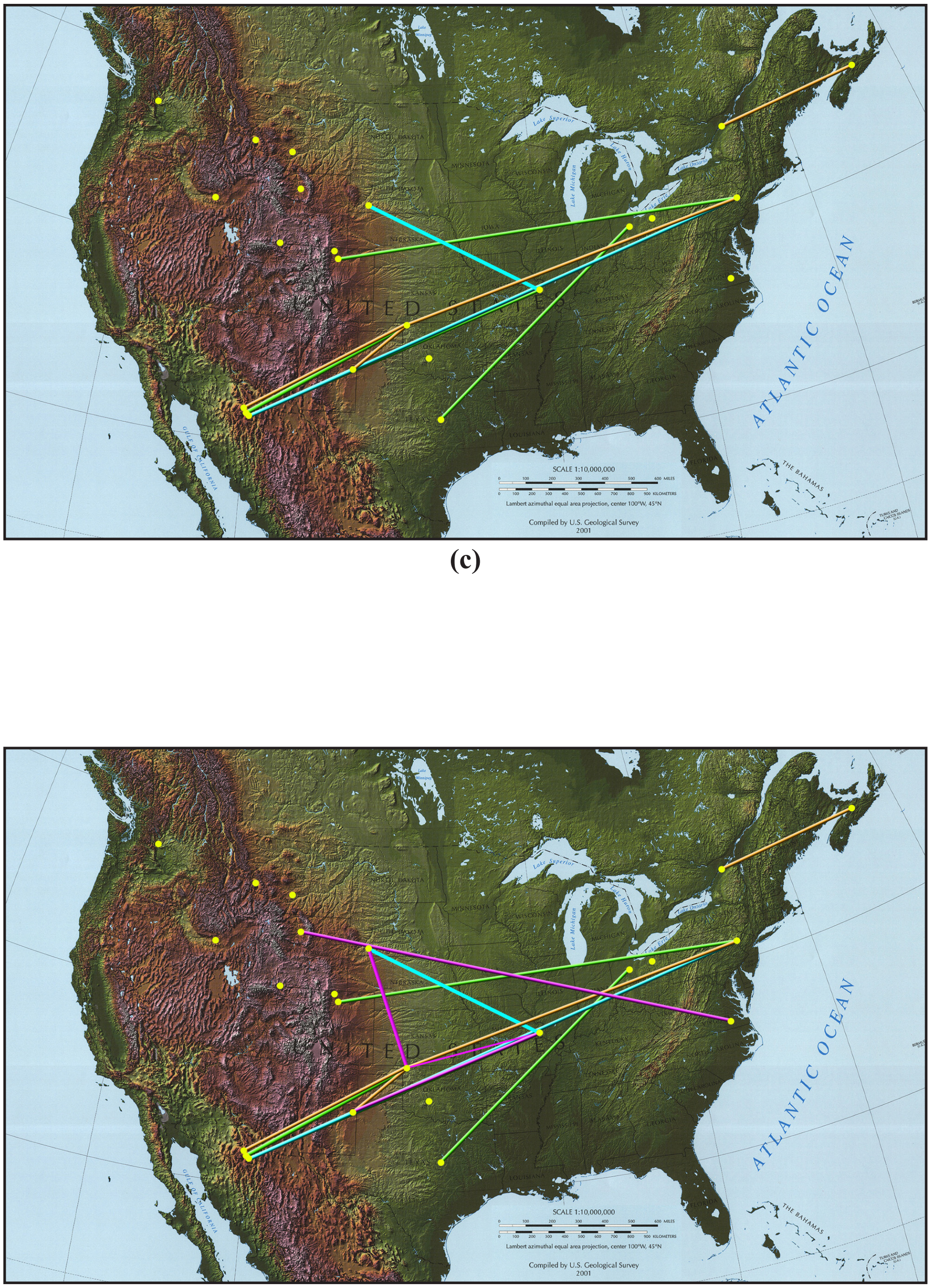
Figure 3.20. Cumulative frequency chart of Euclidean distances for data-set without cache sites.



(a)

(b)

Figure 3.21. (a) First 4 Euclidean distances according to data-set without caches; (b) First 8 Euclidean distances according to data-set without caches; (c) First 12 Euclidean distances according to data-set without caches; (d) First 16 Euclidean distances according to data-set without caches.



(c)

(d)

Figure 3.21 Continued.

When individual sites were considered, large regional variance may have proved to distort identification of the specific sites that were closely related in terms of tool shape. The close relationship between SW and NW projectile points was not as dramatic in this analysis. It must be acknowledged, however, that multivariate cluster analysis generates an average point shape for each site that is then utilized in the comparison. A significant draw-back to this is that the analysis does not consider the individual projectile points, and the "average point shape" may result in a shape that does not actually exist at the site. The differential in sample size per site may also serve to skew results, as the average point shape for a site with a lower sample size will be closer to reality than that of sites with a larger sample size, all of which contribute to the formulation of a mean point shape.

Discriminant Function Analysis

To investigate shape relationships among individual points, a discriminant function analysis was conducted. The results of this analysis are shown in Tables 3.5 and 3.6. When all of the projectile points in the data set were grouped into three major regions, 30.89% misclassified (Table 3.5). Almost 75% of the points from the NW classified correctly, suggesting an overall similarity in shape for that region. Eighteen-percent of the NW points misclassified as SW points and only 7% misclassified as NE points. Over 68% of the points from the SW classified together suggesting similarity in shape within that region. Twenty-seven percent of the SW points misclassified as NW points, while 5% misclassified as NE points. Within the NE projectile points, almost 60% of the points classified correctly implying a similarity in shape for that region. Twenty-five percent of the NE points misclassified as SW points and 15% misclassified as NW points. The large percentages of points that classified correctly within a region suggest that a homogenous shape is present within each region. The majority of the points from the NW that misclassified (18%) suggests that they are more similar in shape to those in the SW. Likewise, the majority of the SW points that misclassified (27%) are attributable to the NW region. This demonstrates a close affinity of the SW and NW points, and their consanguinity with the NE points. When considering the NE points, they have more shape similarity with the SW (25%) than the NW (15%). Finally, the relative degree of misclassification of the NE points supports their closer affinity to the SW points than to the NW points.

Table 3.5. DFA: All sites classified into 3 major regions.
30.89% of the projectile points were misclassified.

	1-NW	2-SW	3-NE
1-NW	74.54%	18.18%	7.27%
2-SW	26.83%	68.29%	4.89%
3-NE	14.81%	25.92%	58.26%

	1-NW	2-SW	3-NE
1-NW	41	10	4
2-SW	11	28	2
3-NE	4	7	16

Table 3.6. DFA: Sites without caches classified into 3 major regions.
32.89% of the projectile points were misclassified.

	1-NW	2-SW	3-NE
1-NW	62.50%	25%	12.50%
2-SW	21.95%	73.17%	4.89%
3-NE	11.11%	29.63%	59.26%

	1-NW	2-SW	3-NE
1-NW	5	2	1
2-SW	9	30	2
3-NE	3	8	16

When the caches were removed from analysis, 32.89% of the projectile points misclassified (Table 3.6). Despite the significant decrease in sample size, 25% (n=2) of the NW points continued to misclassify as SW points. Among the NW points, 12.5% (n=1) misclassified as NE points, while among SW points 21.95% misclassified as NW points and only 4.89% misclassified as NE points. Thus with caches removed, fewer of the SW points were assigned to the NW, suggesting similarity in shape between some of the SW points and the caches in particular. A slightly larger percentage of the NE points (29.63%) misclassified as SW points and 11.11% misclassified as NW points. This represents one artifact that changed in classification from NW to SW points. The close relationship between the SW and NW points remains apparent. Thus, the NE points continue to show a closer relationship with SW points than with NW points.

Factors of Variability per Region

To determine the major factors of variability per region that influenced the results of the discriminant function analysis, principal components were generated for each region and for the cached artifacts alone in the tps Relw program (Rohlf 2008b). PC1 and PC2 for each region are displayed in Figures 3.22 and 3.23. The original principal components for the entire data set are at the top for reference. Results for each region is discussed in detail below.

Northeast

According to the PC1 developed for the NE assemblage (Figures 3.22), the ratio of length to width continued to show a dramatic contrast from one end of the axis to the other. However, points with both negative and positive PC1 scores had a deep basal concavity. The positive end of PC1 displayed significant flaring of the basal corners. The shape variability represented by PC2 suggested that placement of maximum width fluctuated less and, as in PC1, both the negative and positive end of the PC2 axis incorporated a relatively deep basal concavity (Figure 3.23). The principal components of the NE group emphasized the deep basal concavity and a low width-to-length ratio.

In returning to the principal components generated for the entire data set, PC1 was highly negatively related to the majority of the NE group (Figure 3.24). The second highest factor loading attributed to the majority of the NE group was the negative end of PC2. The high negative correlation of PC1 and negative correlation of PC2 suggested that the NE group is characterized predominantly by shorter projectile points with deeply concave bases. Maximum blade width was between the base and midline of the long axis, and at this point the blade’s lateral margins slope at a sharp angle toward the tip.

Figure 3.25 displays the point-shape characteristic of the NE region (top) generated by the tpsRelw program (v. 1.46; Rohlf 2008b) and a selection of projectile points misclassified to the NE region by the discriminant function analysis (DFA). All of these projectile points seem to demonstrate relative degrees of the characteristics diagnostic of the NE region.

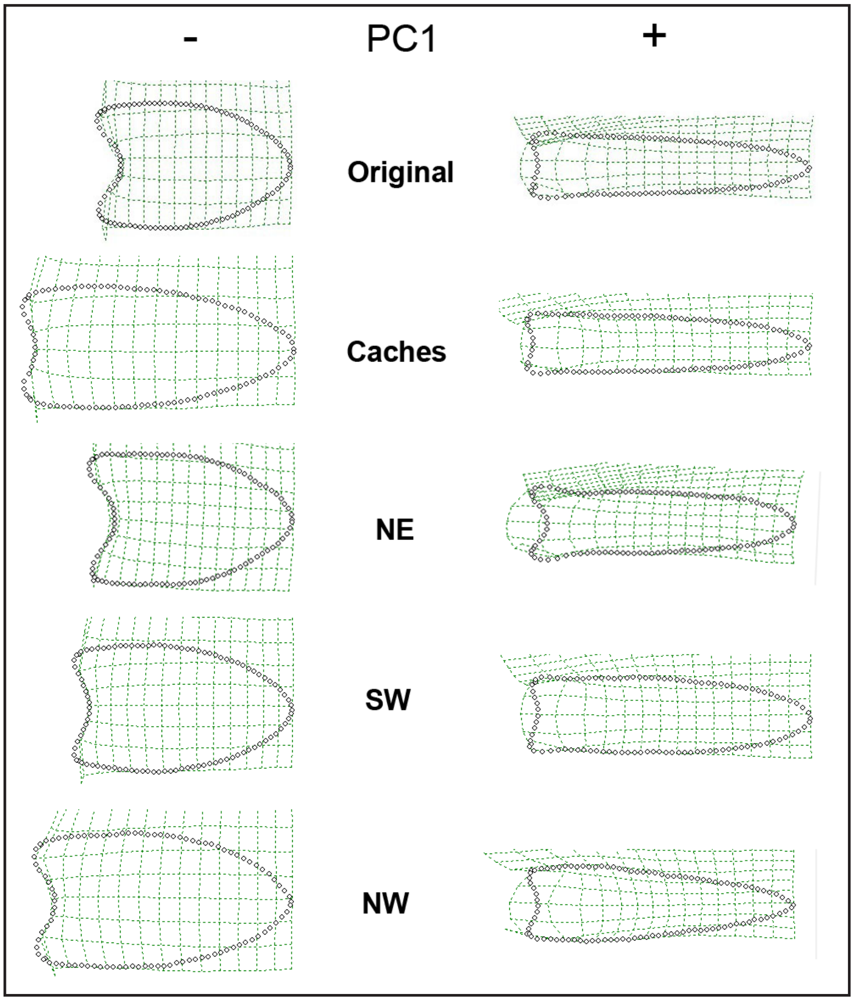


Figure 3.22. Comparison of original PC1 (top) with PC1s generated for caches and individual regions.

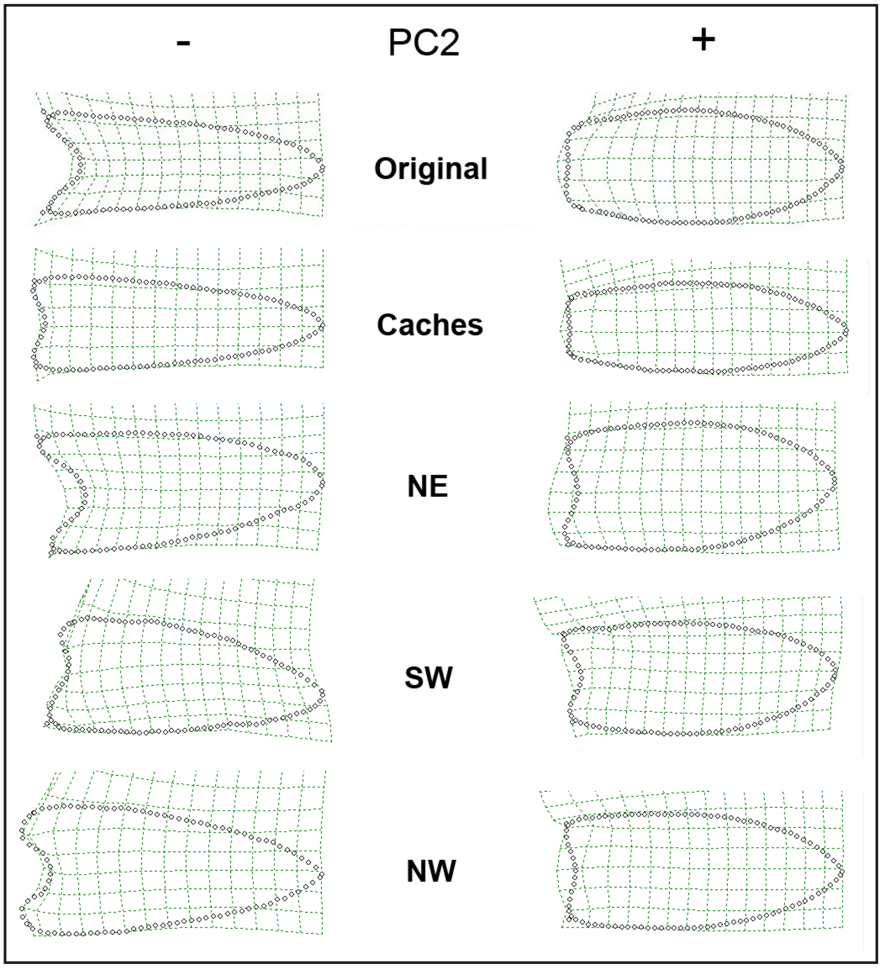


Figure 3.23. Comparison of original PC2 (top) with PC2s generated for caches and individual regions.

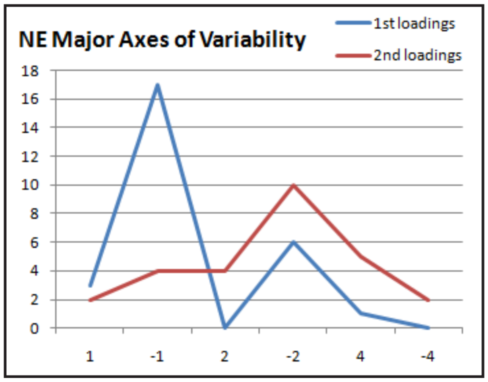


Figure 3.24. Frequencies of 1st and 2nd original principal component loadings for NE projectile points.

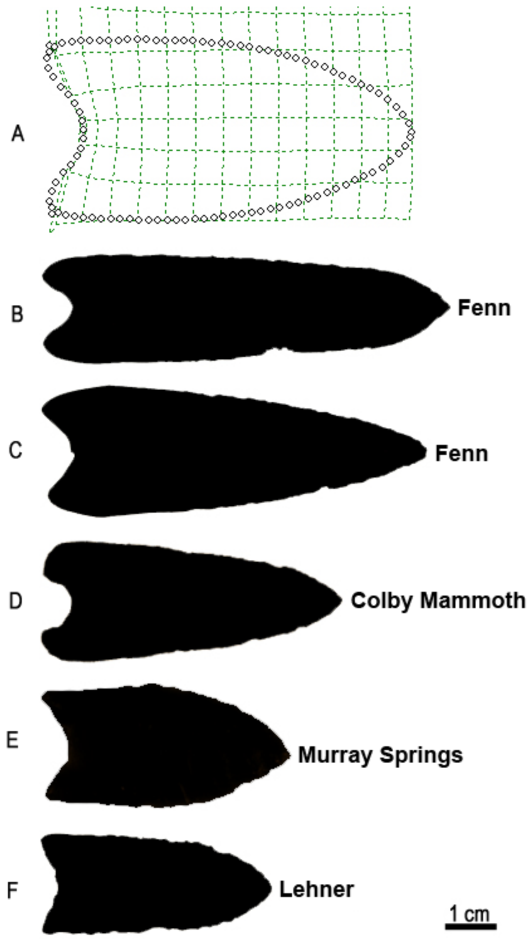


Figure 3.25. Point-shape characteristic of the NE region and examples of projectile points (ppt) misclassified to the Northeastern region by discriminant function analysis. A) NE type prediction; B) Fenn ppt; C) Fenn ppt; D) Colby Mammoth ppt; E) Murray Springs ppt; F) Lehner ppt.

Southwest

The principal components generated for the SW region alone are displayed in Figures 3.22 and 3.23. PC1 reflected the same length-to-width ratio as the original principal components, but the fluctuation in basal width from the negative to the positive end of the axis was less dramatic, and the decrease in length from the positive to the negative end of the axis was less extreme. PC2 reflected variation in the slope of the arc forming the blade edge. The location of maximum blade width and basal width did not fluctuate as dramatically from the positive to negative end of the axis as it did in the original principal components. PC2 was also highly correlated with asymmetry, whereas, asymmetry was captured in PC3 of the original principal components. Both PC1 and PC2 reflected a degree of lateral waisting at the base on the negative side of the axes.

Analysis of the principal components generated for the entire data set determined that PC1 was highly negatively correlated with the majority of the SW projectile points and that PC2 loaded next with a high positive correlation (Figure 3.26). These shape characteristics suggested that most SW points were characterized by relatively shorter projectile points with a small degree of lateral waisting at the base, the maximum width located near the midline of the long axis of the point resulting in a bulbous arc-shape of the blade edges, a gradual decline in slope toward the tip, and a somewhat shallow basal concavity. Figure 3.27 displays the diagnostic point shape for the SW region (top) and those points misclassified to the SW with varying degrees of "SW projectile point" characteristics.

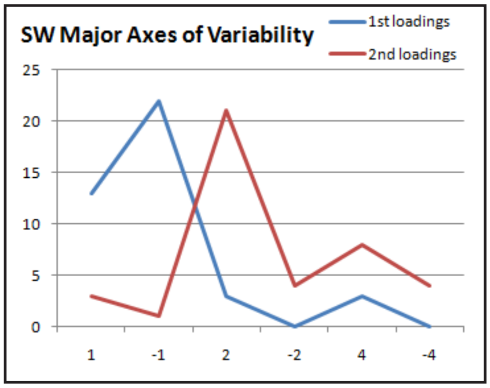


Figure 3.26. Frequencies of 1st and 2nd original principal component loadings for SW projectile points.

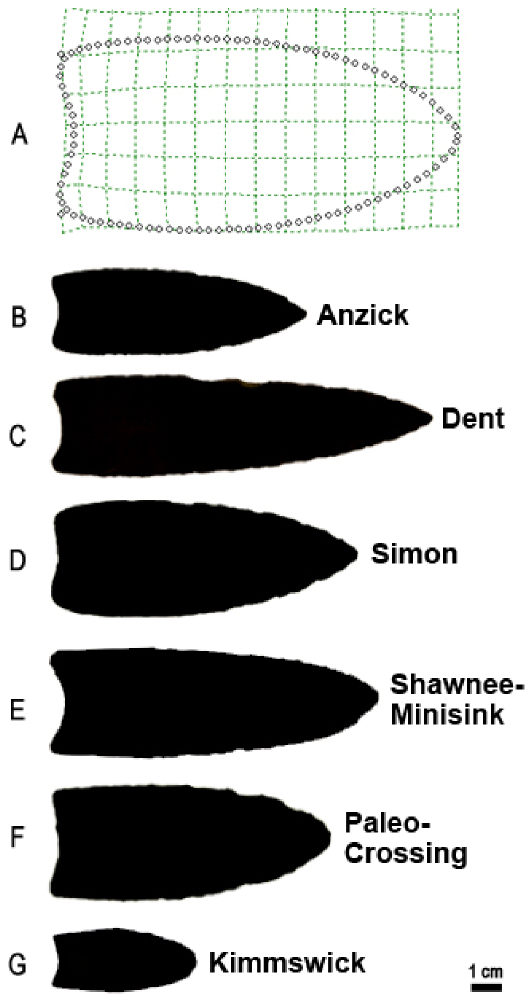


Figure 3.27. Point-shape characteristic of the SW region and examples of projectile points (ppt) misclassified to the Southwestern region by discriminant function analysis. A) SW type prediction; B) Azick ppt; C) Dent ppt; D) Simon ppt; E) Shawnee-Minisink ppt; F) Paleo-crossing ppt; G) Kimmswick ppt.

Northwest

The major factors of variability for the NW assemblage inherent in the principal components generated specifically for this region are shown in Figures 3.22 and 3.23. PC1 demonstrated the same length-to-width ratio. A somewhat deep basal concavity was present but did not fluctuate in depth from the negative to the positive ends of the axis. At the positive end of PC1, blade margins remained straight from the basal area and then plunged at a steep angle toward the tip. PC1 reflected extreme fluctuation in the placement of maximum blade width between the negative and positive ends of the axis. At the negative end of the PC2 gradient, basal concavity was relatively deep and basal ears curved inward which seems to be a specific influence of the Colby site. The location of maximum blade width was at the base, from which point the blade margins form a steep angle toward the tip. The positive side of the PC2 axis displayed a shallow basal concavity and basal corners that do not curve inward. The location of maximum blade width was at mid-length resulting in blade edges that gently arc from the basal corners to the tip, creating a bulbous look similar to the SW projectile points.

The loadings of the original principal components suggestedd that PC1 was highly positively related to the majority of the NW assemblage and PC4 was negatively related to the majority of the NW projectile points (Figure 3.28). Both the positive and negative ends of PC2 were also loading as characteristic shape attributes of the NW assemblage. The high positive correlation of PC1 and negative correlation of PC4 produced a point shape that is long in relation to its width. The point of maximum width was just beyond the base with a small degree of lateral waisting at the base that was evident in the positive relation of PC2. The blade edges formed a low arc that increased in edge angle toward the tip. Figure 3.29 shows the diagnostic point shape resulting from the combination of these PC loadings, and a selection of those points misclassified to the NW with varying degrees of "NW projectile point" characteristics.

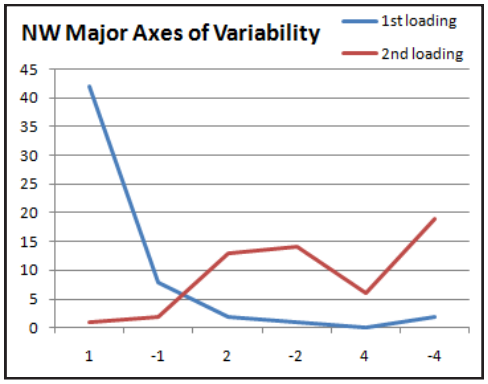


Figure 3.28. Frequencies of 1st and 2nd original principal component loadings for NW projectile points.

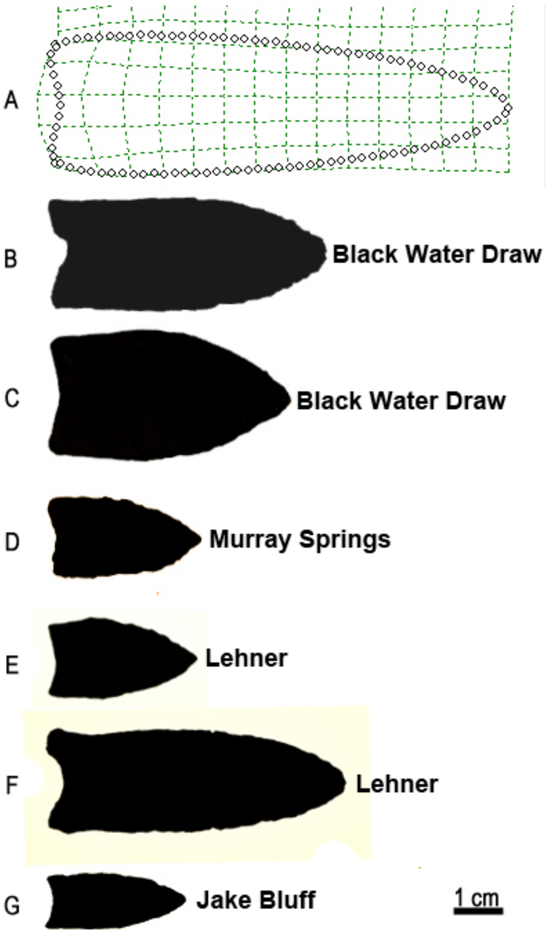


Figure 3.29. Point-shape characteristic of the NW region and examples of projectile points (ppt) misclassified to the Northwestern region by discriminant function analysis. A) NW type prediction; B) BWD ppt; C) BWD ppt; D) Murray Springs ppt; E) Lehner ppt; F) Lehner ppt; G) Jake Bluff ppt.

Caches

When caches were considered alone, their considerable influence on the diagnostic shape of NW points was expressed. The principal components generated for the caches still presented the ratio of length to width inherent in PC1 (Figures 3.22 and 3.23). Width retained the same degree of fluctuation as in the original principal components, but the decrease in length towards the negative end of the axis was not as extreme. The extreme decrease in length of the original PC1 was therefore influenced by the non-cached sample. The non-cached sample includes those points that have been resharpened and are in varying stages of their use-life yet continued to generate principal components which demonstrated shape variables characteristic of the regional group. PC2 continued to reflect fluctuation in the placement of maximum width along the blade's long axis. The degree of basal concavity represented by negative PC2 was barely significant. In the same fashion as the majority of the NW sample, PC1 was highly positively related to the cache point shape (Figure 3.30). PC4 was negatively related to the cache point shape, as was both positive and negative PC2, albeit to a lesser extent. The principal component loadings for the NW points without the influence of caches, however, suggested only one major distinction. PC1 was negatively related to the non-cache points suggesting shorter lengths resulted from rejuvenation events over the tools' life histories (Figure 3.31). The second-most significant loading remained negatively related to PC4. Therefore, the overall difference in shape between the cached points and non-cached points of the NW region was highly dependent on the decrease in length due to resharpening.

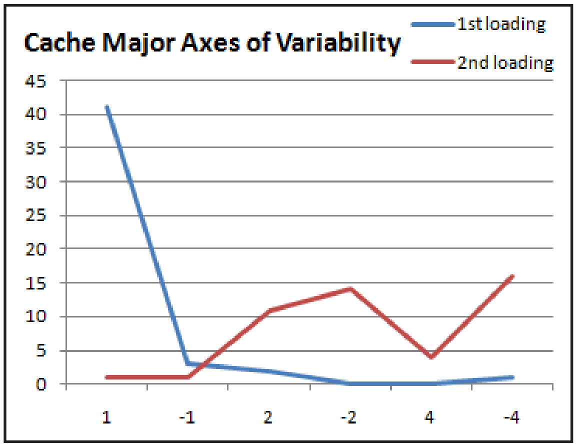


Figure 3.30. Frequencies of 1st and 2nd original principal component loadings for cached projectile points.

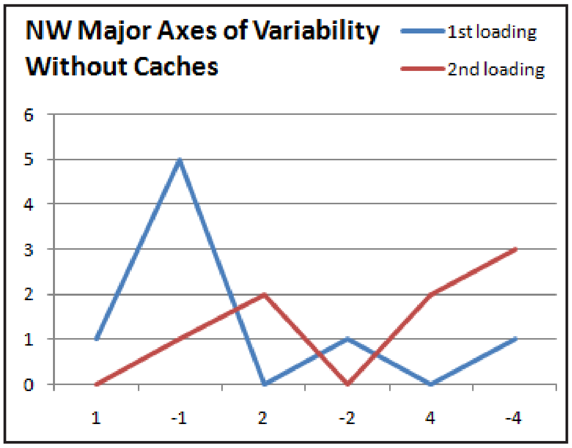


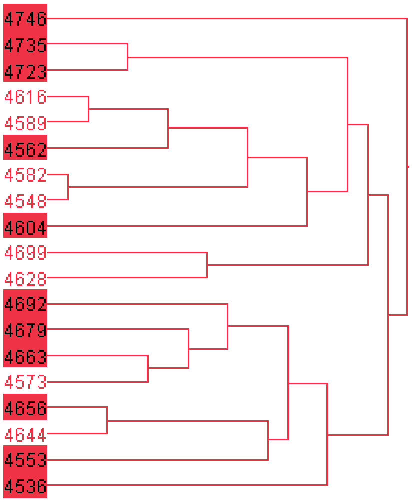
Figure 3.31. Frequencies of 1st and 2nd original principal component loadings for NW projectile points without caches.

Multivariate Cluster Analysis of Raw Material Constraints

To determine if projectile point shape was constrained and thus determined by raw-material type and not the manufacturer, a multivariate cluster analysis was conducted within the assemblages of three sites for which raw material data were available: Fenn, Drake and Lehner. Each of these analyses is presented below.

Fenn Cache

The test for shape relationships due to raw-material type conducted on the Fenn cache examined whether the projectile points made from Utah agate clustered closer together than the remaining points made from Green River chert, obsidian, quartz, red jasper, and chert potentially from the Amsden Formation in Wyoming (Figure 3.32). If raw-material did impact point shape, then I expected tools made from Utah agate to be most closely related in shape to each other, whereby generating the shortest Euclidian distances. According to the resulting Euclidean distance matrix, the two most closely related projectile points within the Fenn Cache were made from Green River chert (4582) and red jasper (4548). One artifact made of Green River chert (4589) and one of red

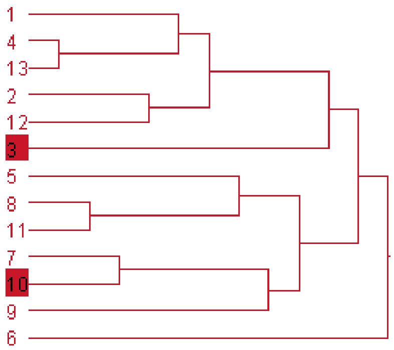


Artifact Number	Raw Material	Euclidean Distance	Point Relationships
4746	Utah agate	0.2929398	4582 - 4548
4735	Utah agate	0.52150561	4616 - 4589
4723	Utah agate	0.65646449	4656 - 4644
4692	Utah agate	0.692678	4735 - 4723
4679	Utah agate	0.69872148	4663 - 4573
4663	Utah agate	0.72092494	4616 - 4562
4656	Utah agate	0.78827361	4679 - 4663
4604	Utah agate	1.05458065	4699 - 4628
4562	Utah agate	1.07037265	4692 - 4679
4553	Utah agate	1.17598474	4616 - 4582
4536	Utah agate	1.18584059	4656 - 4553
4582	Green River chert	1.52046342	4692 - 4656
4589	Green River chert	1.60147566	4616 - 4604
4644	Quartz	1.7782677	4692 - 4536
4628	Quartz	1.95552394	4735 - 4616
4616	Red Jasper	2.46608711	4735 - 4699
4548	Red Jasper	2.63286163	4735 - 4692
4699	Obsidian	3.69571572	4746 - 4735
4573	Amsden Formation chert		

Figure 3.32. Raw material analysis on the Fenn Cache. Left: artifact number and corresponding raw material; Center: dendrogram form multivariate cluster; Right: projectile point relationships according to Euclidean distance.

jasper (4616) also formed the next-closest projectile-point relationship. The third-closest relationship is between projectile points made from quartz (4644) and Utah agate (4656). Further, the pair of projectile points within the Fenn Cache that are considered to be the least similar in shape according to their Euclidean distances are both made from Utah agate (4746 and 4735). Obviously, for the Fenn Cache as a whole, projectile points made from specific tool stone did not cluster together. Thus raw material was not a factor of shape variability in the Fenn Cache.

Artifact Number	Raw Material
1	Alibates dolomite
2	Alibates dolomite
3	Edwards chert
4	Alibates dolomite
5	Alibates dolomite
6	Alibates dolomite
7	Alibates dolomite
8	Alibates dolomite
9	Alibates dolomite
10	Chalcedony
11	Alibates dolomite
12	Alibates dolomite
13	Alibates dolomite



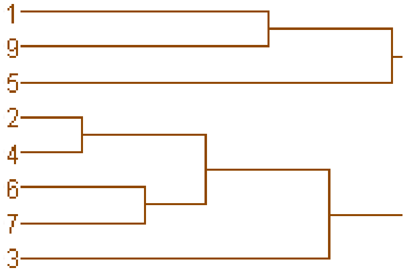
Euclidean Distance	Point Relationships
0.55667552	4 - 13
0.80424893	8 - 11
0.92500417	7 - 10
0.98262266	2 - 12
1.11930163	1 - 4
1.46634335	1 - 2
1.50153439	5 - 8
1.73240853	7 - 9
1.83538025	5 - 7
1.92839352	1 - 3
2.61989037	1 - 5
3.45561094	1 - 6

Figure 3.33. Raw material analysis on the Drake Cache. Left: artifact number and corresponding raw material; Center: dendrogram form multivariate cluster; Right: projectile point relationships according to Euclidean distance.

Drake Cache

The multivariate cluster analysis conducted on the Drake cache hypothesized that if raw material constrained shape variables, then the two projectile points not made from Alibates dolomite would fall outside of the cluster of the Alibates points (Figure 3.33). The first two relationships within the Drake point assemblage are represented by four points of Alibates dolomite; however, the third-closest relationship is between a chalcedony point and an Alibates dolomite point. Likewise, the point made from Edwards chert does not fall within the Drake cluster. Two projectile points, both made from Alibates dolomite, are considered to have even less in common with the majority of the Drake cache than the Edwards chert point. Raw material is, therefore, not a determining factor of shape within the Drake cache.

Artifact Number	**Raw Material**
1	Quartz
2	Quartz
3	Quartz
4	Chalcedony
5	Chert
6	Chert
7	Chalcedony
9	Jasper



Euclidean Distance	**Point Relationships**
0.35379359	2 - 4
0.78464329	6 - 7
1.74598873	2 - 6
1.82443559	1 - 9
2.11964574	2 - 3
2.60714376	1 - 5
2.83043817	1 - 2

Figure 3.34. Raw material analysis on the Lehner site. Left: artifact number and corresponding raw material; Center: dendrogram form multivariate cluster; Right: projectile point relationships according to Euclidean distance.

Lehner Site

The raw material utilized in the Lehner projectile point assemblage was also analyzed to gauge the influence it had on formation of individual clusters of shape relationships. If point shape was affected by toolstone, then these should form specific groups in the cluster diagram (Figure 3.34). However, the two most closely related projectile points were made of two different materials, quartz (A-12678) and chalcedony (A-12685), and the second-most significant shape relationship consisted of points made from chert (A-12677) and chalcedony (A-12676). Conversely, the two points with the greatest Euclidean distances (least related) represented the only occurrence of two points made from the same material: quartz (A-12683 and A-12678). Thus, the points at the Lehner site do not form four clusters according to their raw material.

Therefore, given the three experiments reported here, raw material was not a determining factor in projectile-point shape variability.

Results of this analysis determined that the first four principal components described almost 95% of the shape variability present in the data-set and facilitated the identification of the specific shape characteristics that were imposed on each projectile point. The results of the MANOVA ultimately suggested a regional trend in shape variability. Significant variability was greatest amongst the 3 major regions which suggested the presence of large areas with similar point shape which differed from that of an adjacent large area. When size was removed from the analysis, the same pattern of geographic variance increased in significance suggesting that size is not a determining factor in variability across the continent. When the analysis was conducted without the cached artifacts, the degree of significant variance decreased, however, the pattern of significant geographic variance remained. Analysis of the distribution of variance suggested that sites in the West are very homogeneous within themselves, whereas in the East, there was significantly more within-site variance. Results of the multivariate cluster analysis resulted in two major regional groupings which divided sites in the East from sites in the West. Within the western group, two subgroups formed a division between sites in the SW and the cache and kill sites in the NW. DFA served to identify shape-relationships between the regions represented by individual projectile points. Results suggested a stronger relationship in artifact shape between the NW and SW than either have with the NE. Additionally, the NE points, had greater similarity in shape with the SW than the NW. When this analysis was conducted without the cached artifacts the pattern remained. To identify the specific elements of shape which were influencing the results of the DFA, principal components were generated for each region and for the cached artifacts alone. Results suggested that a deep basal concavity and short tool length was typical for the NE. SW projectile point shape was dominated by a conservative basal concavity and point of maxiumum tool width close to the midline of the long-axis. The NW sample was dominated by characteristics similar to those of the SW except for the deep basal concavity of the negative loading of PC2 which seems to have been influenced by the Colby site. The PCs generated for the cached artifacts were dominated by a low length-to-width ratio which suggested that the decrease in length described by the original negative PC1 was influenced by the non-cached data. The multivariate cluster analysis conducted within the assemblages of the Fenn, Drake and Lehner sites determined that projectile point shape was not constrained by raw-material type. The results of my analysis provided a means of addressing research questions concerning the widespread presence of fluted artifacts on the North American landscape. The correlation between these results and the spread of Paleoindian projectile point technology is discussed below.

CHAPTER IV

DISCUSSION AND CONCLUSION

Introduction

In this chapter, results of the analysis are utilized to address regional variation in projectile point shape in regards to Paleoindian behavior, movement, and technology. Following a summary of the results, a series of inquiries are addressed. First, the regional pattern of shape variability apparent in the MANOVA results is applied to hypotheses of Paleoindian population dynamics and movement. The potential of size, caching, resharpening, and raw material to influence point shape are considered in regard to their principal component loadings in this section. The nature of the variability, in terms of morphological relationships between assemblages within the data-set, is then addressed in a discussion of the complementary results between the distribution of variance, multivariate cluster, and discriminant function analyses. In the final section, these relationships are explored further on a regional basis and compared to hypotheses generated in previous studies of Paleoindian technology conducted by Kilby (2008) and Morrow and Morrow (1999).

Defining Variability by Principal Component Analysis

The first four principal components describe 94.75% of the variability in shape for the data set. Principal component (PC) 1 describes a length-to-width ratio. PC2 described the relationship between basal concavity depth and the location of maximum tool width along the long axis of the artifact. PC3 demonstrated asymmetry inherent in the data set, although according to the canonical axis plot PC3 described a trivial amount of shape information and was therefore dismissed from analysis in both considerations of form and shape. The remaining PCs were not negatively affected but actually increased in descriptive power. PC4 described the relationship between basal concavity depth and maximum tool width; however, it did so inversely to PC2. When applied in concert, the principal components described almost 95% of variability in shape of this data set. The examination of each PC individually can identify the specific shape characteristics that were imposed on each projectile point.

To determine if variance in shape was present across the continent, a multivariate analysis of variance (MANOVA) was conducted. Results of analyses conducted of both form and shape (form minus size) showed that significant variance was present amongst all grouping variables. Variance was most significant in tests considering latitude and longitude. This ultimately suggests a regional trend in variability which is evident in the significant variance found in the test against five consolidated regions. Significance of variance was even greater when five regions were consolidated into three major regions, suggesting that large geographic areas contain a homogenous point shape which differs from that of an adjacent large area. When size was removed from the analysis, the same pattern of geographic variance increased in significance suggesting that size was not a determining factor in variability across the continent.

The cache sites, however, are located in the Northwestern Region and consist of points discarded very early in their use-life compared to points from kill and habitation sites. To test whether these collections of pristine artifacts could have skewed the results of the MANOVA, the cached artifacts were removed from the analysis. The resulting degree of significant variance decreased; however, the same pattern of significant geographic variance remained.

Analysis of within-site distribution of variance ultimately suggested that sites in the West were very homogeneous within themselves. In the East this does not seem to be the case, as there is greater within-site variance. If a point of origin of a diffused technology is expected to consist of homogeneous forms, then this distribution of variance suggests a western location for an original projectile point shape, at least in as far as the analyzed data-set is concerned.

The multivariate cluster analysis between sites resulted in two major groupings. The first major grouping consisted of sites primarily in the west. These were further divided into two groups. The first sub-group was dominated by sites in the southwest (SW), Texas, and Southern High Plains (SHP) and included some sites in a northwest (NW) and northeast (NE) direction such as Lange-Ferguson, Kimmswick, and Paleo-crossing. The second sub-group consisted of the cache and kill sites in the NW region. The other major grouping consisted of the Northeastern sites Cactus Hill, Debert, Vail, and Sheridan Cave.

When the caches were removed from the analysis the two major groups representing a division between the western and eastern sites remained. The first was dominated by Western sites and was joined by Shawnee-Minisink in a NE direction. The second was dominated by the Eastern sites and was joined by the Colby Mammoth Site. Dent and Indian Creek formed an outlier group which suggests that there is a still a NW grouping without the caches.

The investigation of shape relationships between individual points was conducted by means of discriminant function analysis that utilized the three major regions as grouping variables. The points whose shape characteristics were more similar to those of another region were represented by the percentage of points that misclassified. The majority of the points from the NW that misclassified suggests that they are more similar in shape to those in the SW. Likewise, the majority of the SW points that misclassified are attributed to the NW region. This suggests a stronger affinity of artifact shape between the NW and SW than either has with the NE. The NE points, however, were found to have greater shape similarity with the SW than the NW. When this analysis was conducted without the cached artifacts this pattern remained the same.

To identify the specific shape elements that characterized each region, principal components were generated for each region and for the cached artifacts alone. According to the PCs generated specifically for the cache sample, a decrease in artifact length was not represented in either PC 1 or 2. This suggests that the decrease in length described by the original negative PC1 was influenced by the non-cached data. These points are those that have been resharpened and are in varying stages of their use-life yet continue to generate principal components which demonstrate shape variables characteristic to the regional group. For example, the NE sample contained both extremes of PCs 1 and 2, demonstrating that deep basal concavity and short tool length are typical for the NE. In the SW sample, the PCs were dominated by a conservative basal concavity and point of maximum tool width close to the midline of the long-axis giving the blade a swollen, bulbous look. The NW sample was dominated by characteristics similar to those of the SW, except for the deep basal concavity of the negative loading of PC2, which seems to have been influenced specifically by the Colby site. The shape characteristics demonstrated by these region-specific PCs replicate the geographic pattern of original principal component loadings generated for the entire data set.

Raw material was not found to contribute to projectile point shape variability according to the site-specific multivariate cluster analysis. Within the Fenn, Drake, and Lehner assemblages, those projectile points whose shape characteristics were found to be closely related did not group according to their raw material. Therefore, whereas the quality of a raw material may allow for the manufacture of a formal, predetermined point shape, the resulting artifact was not dictated by the type of raw material.

Regional Shape Variability

If the majority of Paleoindian projectile points found in the archaeological record are there by way of discard at the end of their use-life, do they represent a large collection of morphologically homogeneous remnants of a once richly variable typology? The morphological signature of the data-set analyzed here demonstrates significant variability in regards to each grouping variable. The most significant of these is latitude and longitude. The significant variance here corresponds ultimately to the high degree of variability between geographic regions.

While variability among sites was also significant, it was much less so than among regions. This is especially apparent when the five geographic regions were further consolidated into three major regions of variability. Individually, sites had a lower degree of variance in that the projectile points from multiple sites within a region often had a similar morphological signature. It is thus likely that the same cultural group, possessing a particular normative manufacturing technology, was responsible for multiple archaeological deposits within a region. Therefore, the significant variance between large regions implies the presence of a fairly large geographic spread of specific cultural groups whose style of projectile point manufacture contrasted with those of another region. These groups consisted either of one large population occupying a large territory or small groups nomadically exploiting a large geographic expanse. Each potential effect of size, caching, resharpening, and raw material type is discussed in detail below.

Size Effect

There is great potential, however, for variance to be an effect of biasing factors such as size, the presence of cached artifacts, and resharpening. When size was removed from the analysis the geographical variance increased. The difference in the overall size of artifacts, especially of cached projectile points, is, therefore, not responsible for the regional variance. It is then probable that the variability present is a result of shape despite the differing size of the artifacts in the data-set.

Cache Effect

When cached projectile points were removed from the analysis, the degree of significant variance lessened but remained present. This outcome was to be expected given the nature of the caches. The decrease in significance is a result of the removal of the disparity between the pristine cached points in the early stages of their use-life and many reworked projectile points in later stages of use-life. The significant regional variance was, therefore, influenced by the western location of all of the cached sites. It is also likely that the large sample size available at the cache sites served to skew results. Despite the potential of the cached points to skew the results, variability remained between regions at significant levels once they were removed. Therefore, factors such as shape, rejuvenation or raw material type remain potentially responsible for the variance present across North America.

Resharpening Effect

The first principal component utilized in geometric morphometrics is generally a reflection of allometry (Bookstein 1991). Likewise, the first principal component generated for this data-set was a measure of the ratio of length to width. As other lithic analysts have suggested, decrease in length and steeper edge angles result from the subtractive nature of stone-tool reworking (Buchanan 2006; Frison 1968; Keeley 1982). The first principal component is, therefore, highly evident of reharpening. When principal components were generated for cached artifacts alone, the decrease in length described by the negative loading of PC1 was significantly less extreme. Without the influence of reworked points, characteristically short artifacts were not represented by the principal components of shape variability. Non-cache sites examined in this analysis are consistent with a shorter length demonstrated by the high negative loading of PC1 and can be hypothesized to contain reworked tools. However, a high width-to-length ratio like that evident in the NE region may still be due to raw-material constraints. The high loading of negative PC1 in the NE assemblage could reflect characteristics of reworking or mean nodule size of the raw material available in the region.

The high loadings of PC2 and PC4 reflect major shape and style characteristics present in projectile-point morphology despite the allometric effects of reworking. If all variability in projectile-point morphology was a result of reworking, then results of the discriminant function analysis would have misclassified a majority of the non-cached points due to a random exhausted shape. In this analysis, however, 60-70% of points within each region classified correctly. This suggests that characteristics imposed by the crafts-person remained inherent in artifact shape throughout its use-life. Likewise, a percentage of cached artifacts was also misclassified in the discriminant function analysis, suggesting that the shape characteristics of pristine artifacts can be correlated with those in varying stages of their use-life. Thus, despite factors such as size, presence of cached artifacts, and resharpening, normative aspects of shape are still a factor.

Raw Material Effect

Situations such as raw material availability could be demonstrated by the diagnostic short and wide points in the NE regions if raw material was restricted to small nodules. In addition to nodule size, raw material type was hypothesized to have influenced or determined the resulting artifact shape; however, the raw material analysis conducted here suggests that raw material was not a factor determining finished projectile point shape. Artifact shape can, therefore, be better attributed to the skill level and normative behavior of the knapper.

Knapper Effect

Results of the discriminant function analysis provided evidence of a close relationship between Southwest (SW) and Northwest (NW) sites with and without the influence of cached point morphology. This finding contradicts that inferred by Bettinger and Eerkens (1997) who found in their data-set of late Archaic points that variability decreased throughout the life-span of the artifact as resharpening obliterated specific characteristics resulting in a more uniform morphological signature of exhausted and discarded projectile points. However, after consideration of the rest of the artifacts included in their study, the authors found that attributes of an established standard did remain constant in the data-set and are a result of the transference of a specific behavior, the departure from which would require costly experimentation and would, therefore, result only from necessity induced by varying situations such as material availability (Bettinger and Eerkens 1997:170). Evidence of the close relationship of the SW and NW points that remains with and without the influence of the cached artifacts supports this hypothesis.

Homogeneity

The nature of variability can also be investigated with geometric morphometrics. Cache sites were extremely low in artifact variance. One reason for this is that cached fluted points may have been manufactured by a single individual. According to personal observation, evidence for this may exist in the distinct diagonal overshot flaking patterns on many of the points in the Fenn cache. Low cache variance is also attributed to the fact that many of the artifacts were at the beginning of their use-life when discarded. However, the SW/Southern High Plains (SHP) sites such as Domebo, Naco, Gault, Lehner, and Jake Bluff clustered among the cache sites in level of variance. This suggests that there is significant homogeneity in variance between the caches and SW/SHP sites.

Within this group, it is interesting that a habitation/quarry site such as Gault clusters in the low variance group. Lithic quarry workshops and habitation sites were prime activity centers for retooling hafted artifacts such as projectile points (Keeley 1982). They, therefore, typically contain a greater variety of tool forms and greater quantity of tools that are at the end of their use-life (Gramly 1980). In contrast, kill sites, not being activity centers for retooling, typically contain only lost and damaged points at some intermediate stage of their use-life (Keeley 1982). Therefore, the three site types under investigation theoretically should contain tools at different periods of their use-life: caches with points at the beginning-stages of use-lives, kill site with points at the intermediate-stages of use-lives, and habitation/quarry sites with points at the end-stages of use-lives. Despite the novel state of the cached artifacts, the effects of refurbishing that occurred at

Paleoindian habitation sites and the variability expected, as well as the use and retouch of points occurring at the kill sites, all such sites in the SW and NW showed little variance indicating that resharpening does not significantly affect Clovis point shape. It should be noted that degree of within-site variance did not strongly correlate with sample size.

The small Euclidean distances between Lehner, Naco, Jake Bluff, Gault and BWD also suggest homogeneity of the SW/SHP region in particular. According to the distribution of variance, the proximity of the NW and SW sites attests to a close relationship between the two regions. When cache sites are removed, the level of variance in NW assemblage increases; however, it still remains in close proximity to SW/SHP sites.

Results of the multivariate cluster analysis independently consolidated the dataset into three major regional groups, or clusters. This is highly suggestive of the cohesiveness within each region. When cache sites are removed from the equation two clusters remain, the NE and SW. The non-cache sites of the NW are not so clearly distinguished, because some of them are distributed between the two main clusters. This could be evidence of a limit past which high levels of rejuvenation caused distinctive shape characteristics to be obliterated. An intensity of reworking in this region may also demonstrate why the NW area was supplied with caches in the first place. None of the non-cache NW sites, however, are positioned as outliers but are assigned to groups according to their shape characteristics. This suggests that the non-cache sites represent forays of groups coming from both the SW and NE regions. It is interesting to note that PC2 positively and negatively loaded onto a large number of NW points. This suggests that the diagnostic characteristics of the NW points contain elements of both the SW points suggested by the positive PC2 and the NE points suggested by the negative PC2. At the negative end of the PC2 gradient, basal concavity is relatively deep and basal ears curve inward accommodating the deep basal concavities of the NE assemblage. The location of maximum blade width is at the base, from which point the blade edges form a steep angle toward the tip. The positive side of the PC2 axis displays a shallow basal concavity and basal corners that do not curve inward. The location of maximum blade width is at mid-length, resulting in blade edges that gently arc from the basal corners to the tip, creating a bulbous look similar to the SW projectile points. The Dent and Indian Creek sites are exceptions to this as they clustered together and independently from the two main clusters. This may suggest that they are more closely related to one cache in particular, as in the case of Dent, than to any other site in the region.

Toward a Premise

The results of this analysis found that the use of geometric morphometrics was able to identify major factors of variability in Clovis point shape across North America. This variability was patterned regionally across the landscape. These patterns were ultimately found to demonstrate shape characteristics that were specific to a large geographic area. Point shapes in the SW and NW have more in common with each other than either has to NE points (Figure 4.1). Yet points in the NE share shape similarities first with the SW artifacts. Within-site variance in point shape suggested that cached sites represent a homogeneous collection of little-used forms. In addition to the caches, however, sites in the SW have the most homogeneous forms. A variety of inferences into Paleoindian behavior and movement can be made by comparing these findings to that of previous research into Paleoindian projectile points.

Western Relationships

The morphological connection between the SW and NW regions is complementary to an investigation of raw material present in the caches conducted by Kilby (2008). He noted a significant pattern of raw-material transport from the SW/SHP region, such as Alibates dolomite and Edwards formation chert, north-northwest to the location of the cache sites (Kilby 2008). Kilby concluded that while raw material was available in the NW area, the presence of raw materials in the caches that were transported from great distances is evident of "the relocation of preferred raw materials" (Kilby 2008:200 [emphasis in original]). This raw-material preference is also suggestive of a normative manufacturing behavior. According to Andrefsky (1994), formal tools such as bifacial projectile points are consistently made from high-quality lithic material. High-quality material, by definition, refers to the ability of a stone to fracture in a predicted and controlled manner during the manufacturing process (Andrefsky 1994). The preference for high-quality raw material may testify to the internalized necessity of Clovis knappers to have raw stone that can accommodate the imposition of a normative point style.

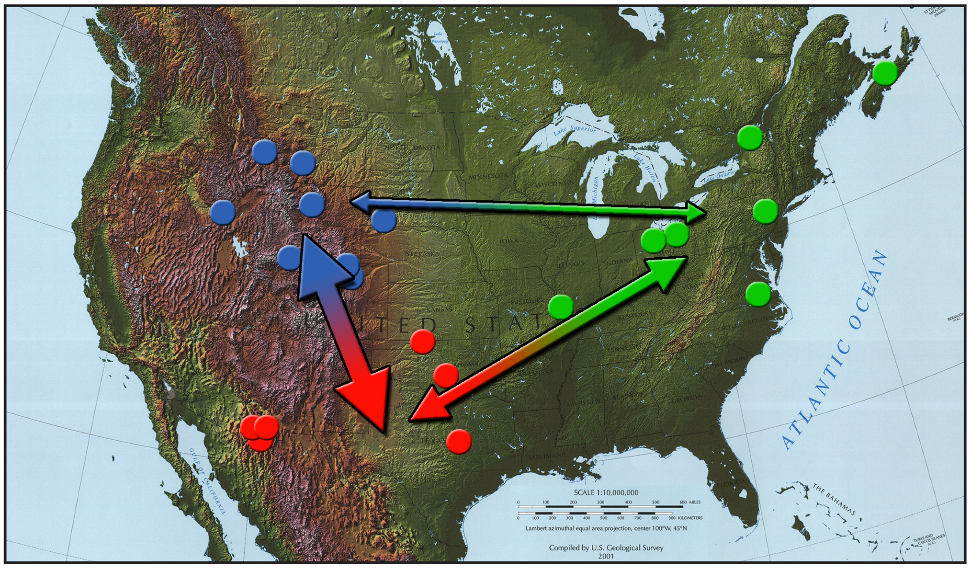


Figure 4.1. Relationship between the three regions demonstrated by thickness of arrows connecting the SW (red), NW (blue), and NE (green).

The similarities in projectile point morphology between the SW and NW regions in conjunction with raw-material evidence, suggesting that much of the cached stone in the NW was brought to the region from the SW, is implicative of SW/SHP groups travelling north-northwest. The evidence of southwestern peoples' presence in the NW may indicate seasonal movements such as hunting forays into the area from a SW point of origin. Furthermore, the significant homogeneity found within and between the SW sites also reflects a place of form origin from which Pleistocene peoples may have carried their fluted point technology (Beck and Jones 2007).

Eastern Variation

Vail and Debert consistently cluster amongst themselves, while other NE sites eventually demonstrate a relationship with the western points. NE projectile points can be distinguished diagnostically as having a deep basal concavity as opposed to a characteristic shallow basal concavity in the western points. Morrow and Morrow (1999) also reported an increase in basal concavity depth in points that ranged from the Mid-Atlantic Coast north towards southwestern Canada and no change in concavity depth in points ranging between the continental United States and South America. Thus trends in basal concavity depth apparent in this investigation complement the regional trends plotted by Morrow and Morrow (1999:225).

Tantamount to the younger radiocarbon age of Vail and Debert, this pattern of increased basal concavity could represent a significant alteration of diffused technology in the northeast. Morrow and Morrow (1999:227) interpreted this pattern as "stylistic drift" which ensued after generations of incremental alterations. The segregation of these two sites from the rest of the NE assemblage may also suggest a stylistic bottleneck resulting from some geographic or cultural barrier. They are also younger than most of the other points in the analysis, being "post-Clovis" in age. Regardless, the alteration of a diffused technology is especially implied given the great deal of commonality between the morphological characteristics of the SW and NW projectile points and the lack of significant commonality as site location increases toward the northeast.

Therefore, there is a pattern of distinguishing characteristics from west to east. Results of this analysis suggest that the SW region is a potential origin of Clovis point technology. The close relationship in point morphology and raw-material preference provides evidence as to the frequent exploitation of the NW region by SW groups. The increase in basal concavity toward the NE combined with the younger age attributed to Vail and Debert suggest that when Clovis point technology eventually reached the NE coast, point form had altered as a result of some form of stylistic drift.

Conclusion

Central to this research was identification of a culturally normative process of manufacture that was maintained throughout the use-life of Paleoindian projectile points. The presence of such a phenomenon can help explain the archaeological signature of Clovis artifacts across North America and address issues such as Clovis population movements and technological diffusion. To facilitate this investigation, my thesis focused on three major questions: (1) can shape analysis identify major factors of variability in Clovis point shape across North America, (2) is variability in Clovis point morphology geographically patterned, and (3) is a changing pattern of Clovis point morphology due to a shape imposed by the producer or a result of resharpening?

Previous studies of Clovis and fluted-point technology such as those conducted by Morrow and Morrow (1999), O'Brien et al. (2001), and Buchanan and Collard (2007) have also focused on the time-transgressive movement of Paleoindians. Their analyses are based on standard interlandmark distances and indices. While these studies have made significant contributions to defining early fluted-point variability, they hazard loosing details of the original shapes of the analyzed points themselves. My study utilized geometric morphometrics in a way that preserved the entire geometry of the artifact throughout analysis.

The projectile points utilized in this analysis had to meet three criteria in order to be included in the study. First, they had to be complete in order to avoid the danger of false information resulting from interpolation. Second, points must have been found to be either associated with a reliable radiocarbon date corresponding to the late Pleistocene, recovered from a cache with diagnostic Clovis-type artifacts, or represented the first occupation of humans in a region such as Vail and Debert in the northeast. Third, they had to be available for analysis. A resulting sample of 123 projectile points from 23 archaeological sites in North America met these criteria.

My use of geometric morphometrics consisted of two-dimensional analysis using standardized photographs of specimens. Analysis focused on shape outline upon which adjacent semi-landmarks were assigned using the tpsDig software (v. 2.12; Rohlf 2008a) developed by J. Rohlf at the State University of New York, Stoney Brook. The semi-landmarks were saved as Cartesian coordinates and imported into the tps Relative Warps program (v. 1.46; Rohlf 2008) where they were projected onto a grid. As the shape of individual projectile points vary, the grid warps accordingly. The bending energy calculated from the warping of the grids relative to the original grid generated relative warps. These relative warps served as principal components for statistical analysis.

The first four principal components described almost 94.75% of the variability in shape for the data set. Principal component (PC) 1 described a length-to-width ratio, PC2 described the relationship between basal concavity depth and the location of maximum tool width along the long axis of the artifact, PC3 represented artifact asymmetry which consisted of a trivial amount of shape information and was therefore dismissed from analysis, and PC4 described the relationship between basal concavity depth and maximum tool width inversely to that of PC2.

A multivariate analysis of variance (MANOVA) determined that latitude and longitude presented the greatest degree of significant variability. This suggested a regional trend in variability. Significance increased when five regions were consolidated into three major regions, suggesting that large areas with similar intra-area point shape differed from adjacent large areas. When size was removed from the analysis, the same pattern of geographic variance increased in significance suggesting that size was not a determining factor in variability across the continent. The cached artifacts were removed and the analysis was repeated, resulting in a decrease in the degree of significance. However, the same pattern of significant geographic variance remained.

According to the distribution of within-site variance, sites in the West were very homogeneous within themselves. In the East, however, sites were inherently more variable.

The multivariate cluster analysis of sites resulted in two major groupings which were partitioned into West and East. The Western group was subdivided into Southwest (SW) sites and Northwest (NW) cache and kill sites. The Northeast (NE) group consisted of Cactus Hill, Debert, Vail, and Sheridan Cave. When the caches were removed from the analysis the two major groups remained. The first group was dominated by Western sites and was joined by Shawnee-Minisink in a NE direction. The second group was dominated by the Eastern sites and was joined by the Colby Mammoth Site. Dent and Indian Creek formed an outlier group which suggested that there was still a NW grouping without the caches.

The discriminant function analysis stipulated that points whose shape characteristics are more similar to those of another region should be represented by the percentage of points that misclassified. Almost 75% of the points from the NW classified correctly, suggesting an overall similarity in shape for that region. The majority of the points from the NW that misclassified were attributed to the SW. Over 68% of the points from the SW classified together suggesting similarity in shape, and those that misclassified were attributed to the NW region. This suggested a stronger affinity in artifact shape between the NW and SW than either had with the NE. When this analysis was conducted without the cached artifacts, the pattern remained unchanged.

The principal components generated for individual regions and the cached sample alone demonstrated that PCs derived from the cache sample did not represent significant decrease in length. This suggested that the decrease in length described by the original negative PC1 was influenced by the non-cached data consisting of points which have been resharpened and are in varying stages of their use-life. However, these points generated principal components that demonstrated shape variables characteristic of the regional group. Therefore, normative shape characteristics are present on artifacts that have been resharpened and discarded.

As a result of this investigation, it has been demonstrated that shape analysis using geometric morphometrics can serve as a tool for identifying major factors of variability in Clovis point shape across North America. This variability was found to be patterned geographically. While factors such as raw-material nodule size and rejuvenation may affect the overall size of Clovis points, shape was still identified as the major factor of variability, remaining so after size was removed from the analysis. Thus, if all points in the non-cache sites were subject to resharpening, and their shape characteristics originally imposed by the producer were obliterated by reworking, then there should be very little variability in point shape across the landscape. This analysis demonstrated that despite the amount of resharpening present in all artifacts, variability remained between regions. This variability was also found to be regionally specific.

If one expects the origin of a diffused technology to demonstrate the greatest amount of homogeneity in artifact morphology, then the results of this study suggest a Southwest point of origin for Clovis point morphology. This similarity in western point shape and shape variables assigned to the west by the region-specific principal components simulates the hypothesized “Classic Clovis Point Type” or “Clovis Type I” proposed by Wormington (1957) and Hester (1972). The similarities between SW and NW points suggest that SW peoples may have been seasonal visitors to the NW area. This is also supported by raw-material-sourcing studies of cached artifacts (Kilby 2008). The difference in tool shape and increased variability in the NE may represent a diffusion of people or technology. Therefore, the Southwest (AZ, NM, TX, OK), exhibiting significant homogeneity within sites and between sites, is a potential place of origin of Clovis point technology.

Although the data set presented here is small, it is statistically meaningful. In contradiction to suggestions that Clovis originated in the north proposed by Fiedel (2004), Buchanan and Collard (2007), and Haynes (2005), the results of this analysis leads me to hypothesize that prior to the development of Clovis technology, there were humans on the North American landscape occupying the American SW, Texas, and SHP who developed the Clovis fluted point style. These were small populations of culturally related peoples. They were highly mobile, either residentially or logistically, and left archaeological evidence of their projectile point style throughout the SW and SHP regions. From this locus, these Paleoindians travelled to the NW, perhaps on seasonal hunting expeditions, bringing with them formal Clovis points and preforms, many made from Edwards chert and Alibates dolomite, and deposited them in caches for future use. As these people travelled northeast, or their technological style spread northeast through existing populations, the morphology of the original Clovis point style altered. This may reflect cultural or technological diffusion. As people adopted the projectile point style, alterations resulted from incorrectly copying the point style, adapting the fluting technique to pre-existing tool forms, or adjusting the morphology to better exploit differing ecological settings. As the effects of these circumstances were impressed upon the morphology of the original Clovis point, variability in the northeast increased. The hypothesis derived from this morphological analysis correlates with arguments of the peopling of the Americas proposed by Beck and Jones (2010), Mandryk et al. (2001), and Morrow and Morrow (1999), which suggest that a population existed in the North American interior prior to the invention of Clovis fluted points in the west.

Further research may more conclusively address Clovis demographics and population movements. However, when the results of this investigation are combined with hypotheses of previous continent-wide studies of Clovis technology, some significant inferences can be made. Prior research has suggested that the formalized and curated technology of Clovis represents a mobile population or adaptation (Kelly and Todd 1988). Evidence of the relationship between points from NW caches and SW camps and kill sites, in terms of both morphology and raw material (Kilby 2008), suggests that cultural groups may have traveled large distances over the landscape, perhaps as colonizing groups.

This research suggests that Clovis projectile-point shape is a result of normative cultural behavior. As Bettinger and Eerkens (1997) point out, it is more costly to experiment with alternatives than it is to implement what one has been taught. The stylistic patterning identified is not likely a conscious implementation of style serving as a cultural symbol, but instead a cultural trait of normative manufacturing behavior that constituted the idea, enculturated throughout generations of knappers, of how to produce a proper form. The specific projectile point forms that resulted are suggested here to be unique to particular cultural groups.

Before these data can be used to confidently track Paleoindian movements and demographics, however, future research must address problems inherent in this investigation. My study would, without doubt, benefit greatly from the incorporation of a larger sample size. Available projectile point information from relative voids in the geographic distribution of the samples lacks a great deal of important data. Data from the

Southeast, more non-cache sites in the Northwest and the large expanse across the Great Plains and Mississippi bottomlands would lead to more robust results and the opportunity to track changes in tool morphology systematically across North America. The expansion of the raw-material data, to include information from the NE region might shed light specifically on exchange networks and population movements providing greater insight into Clovis-period demographics.

This research has utilized geometric morphometics to preserve the entire geometry of the artifact throughout analysis. The investigation suggests that this method of shape analysis has detected a geographic pattern across the landscape that is related to both latitude and longitude and is ultimately regional. Shape is maintained throughout the resharpening life of a projectile point. Therefore, variables in projectile point shape, proven to be characteristic of specific cultural groups who occupied a given region or territory, may be useful for tracking time-transgressive Paleoindian movements across the Western hemisphere in lieu of less precise variables such as the radiocarbon record. While a preliminary investigation, this research strongly suggests that the Southwest may have been the point of origin for the Clovis fluted projectile point in North America and may serve as such in future research.

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