A Morphometric Approach to Assessing Late Paleoindian Projectile Point Variability on the Southern High Plains

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Late Paleoindian typology on the southern High Plains has suffered from overlapping definitions and subjectivity in assigning individual projectile points to types. To address perceived projectile point variability in the region, assemblages from several localities on the southern High Plains are examined for statistical differences in shape. Digital photographs of projectile points are used to digitize point outlines. Landmark coordinate data then are used to delineate 10 interlandmark characters. Multivariate analysis of projectile points from eight assemblages reveals that the primary difference in point shape lies between long points with narrow bases and short points with wide bases. Analysis of characters by raw material type or source discerned no significant differences. Variation in point form represented by most of the assemblages, including the Plainview and Milnesand type assemblages, overlaps to a significant degree. The Lubbock Lake FA5-17 assemblage, consisting of long points with narrow bases, appears most distinct in terms of shape and raw material selection indicating the contemporaneity of different point forms and perhaps technological traditions in the region by approximately 10,000 years ago.

Keywords: southern High Plains, Late Paleoindian, projectile points, digitizing, multivariate analyses

The late Paleoindian period on the southern High Plains (ca. 10,000 to 8500 B.P.) is assumed to mark a significant change in the cultural development of the region. More late Paleoindian sites are recorded in the region than Clovis and Folsom sites combined, suggesting an increase in population (or at least presence or visibility; Holliday 1997:185). Early Paleoindian (Clovis and Folsom) archaeologically defined traditions in the region represent relatively long periods of stasis reflected in the continuity of projectile point styles for approximately 500 and 700 radiocarbon years respectively (Haynes 1993). In contrast, numerous post-Folsom unfluted lanceolate point types have been identified on the southern High Plains. The reliability and validity of these types, however, have been called into question (Hofman 1989; Johnson and Holliday 1997; Wheat 1972). Therefore, the nature of late Paleoindian point variation has important ramifications for inferring cultural development in the region as well as implications for the settling in process of Paleoindian populations during the early Holocene (Anderson and Faught 2000; Anderson and Gillam 2000; Meltzer 2002). In this study, we take an inductive approach to the examination of point form vari-
ability. Our objective is to examine the various late Paleoindian projectile point assemblages on the southern High Plains, some of which have been given unique type names, to determine if they can be discriminated in terms of outline form—an important dimension of variability in point types.

This study employs a technique of digitizing, developed in biological morphometrics (Richtsmeier et al. 2002; Rohlf and Marcus 1993), for the quantification and comparison of point forms. This technique uses landmarks and pseudolandmarks to delineate the outline boundaries of projectile points and derives morphometric characters (interlandmark distances) from the digitized coordinates. Analyses of projectile point shape are used to explore patterns of variability in the sample of assemblages. We focus on assemblages because our goal is to shed light on population interactions and it is likely that assemblages are better proxies for past population groups, rather than individual points that emphasize idiosyncratic variation. Within and between assemblage variability is described and raw material type representation, site type, and minimum number of bison killed are examined for possible correlations with point form variability.

BACKGROUND ON THE PLAINVIEW TYPE

Problems have arisen in the typological classifications of late Paleoindian points on the southern High Plains primarily due to the ambiguous definitions of certain types. The Plainview type arguably is the best example of this problem. The Plainview type has long been considered the definitive unfluted late Paleoindian point type on the southern Plains. However, the definition of the Plainview type has become more inclusive, and thus more ambiguous, with the addition of more and more specimens resulting in an inclusive category without discriminating power. As originally described from the type assemblage recovered from the Plainview site located on the southern High Plains, the Plainview type encompassed a large range of variability (Kreiger 1947). Kreiger’s (1947) comparison of the Plainview artifacts to then known assemblages of unfluted and fluted lanceolate points formed the basis for the creation of the type and subsequent discovery of points with similar attributes to the Plainview collection expanded the range of variation for the Plainview type (Kreiger 1947; Suhr et al. 1954) resulting in what is now a “catch all” category that continues to plague typological studies (Frison et al. 1996; Hartwell 1995; Holliday 2000; Holliday et al. 1999; Irwin 1971; Irwin-Williams 1973; Johnson and Holliday 1980; Kelly 1982; Kerr 2000; Knudson 1983).

The original type definition derived from the actual specimens now includes various attribute states that may or may not be present for classification of a point as Plainview. Wheat (1972:140) recognized this problem more than three decades ago and it remains virtually unchanged today. The subjectivity now inherent in assigning points to the Plainview type has resulted in a categorization that carries neither temporal nor spatial meaning (e.g. Frison 1996). To compound the taxonomic problems of classifying points of this period, excavations on the southern High Plains have yielded projectile point assemblages containing a variety of named point types (Haynes 1995; Sellards 1952) and unique types (Knudson et al. 1998; Sellards 1955). The use of both splitter and lumper approaches to the classification of point variability in the region has confounded late Paleoindian systematics (Wheat 1972:140). The exploratory study presented here has been initiated with the aim of describing and delineating the variability within and between assemblages from this time period in order to begin developing a quantitative understanding of the variation in point form.

LATE PALEOINDIAN PROJECTILE POINT ASSEMBLAGES FROM THE SOUTHERN HIGH PLAINS

The assemblages included in the analysis are from sites with a sample of accessible points located in the central portion of the southern High Plains (Figure 1). The southern High Plains physiographic region is a geographically isolated plateau covering over 130,000 km² of western Texas and eastern New Mexico (Holliday 1995). The sites are located between approximately 33°N and 35°N latitude and the eastern to western escarpments of the High Plains plateau. The dry tributaries, or draws, of the Red, Brazos, and Colorado
rivers dissect this section of the southern High Plains. The sites are situated within the only topographic features of the High Plains: draws, dunes, and playas.

The sites represented in the analysis are Plainview, Ryan’s, Lubbock Lake, Ted Williamson, Milnesand, Blackwater Draw Locality No.1, and Warnica-Wilson (Figure 1). Eight late Paleoindian projectile point assemblages from these sites are included in the analysis (Lubbock Lake has two assemblages). Previous type designations for the samples are Plainview for the Ryan’s, Lubbock Lake, Ted Williamson, Warnica-Wilson, and Plainview assemblages. The Milnesand and Lubbock Lake Feature 5-17 assemblages both were identified as separate and unique typological entities (i.e. Milnesand and Lubbock, respectively). The Portales complex assemblage from Blackwater Draw Locality No. 1 includes at least three named types (Eden, Scottsbluff, and Milnesand) and specimens of indeterminate type. Five of the assemblages in the sample have been recovered from ancient bison kills of estimated sizes ranging from 4 to 100 individuals (two separate kills at Lubbock Lake). The Ryan’s site assemblage is from a cache, and the Warnica-Wilson assemblage is from a campsite and adjacent surface collection. The Ted Williamson site is interpreted as a kill, although limited bison bone was recovered and no estimate of the number of bison killed is available (Buchanan et al. 1996; Johnson et al. 1986).

Reliable radiocarbon ages (from Holliday 2000:254 and Holliday et al. 1999:447) are associated with five of these assemblages and range from ca. 10,600 to 8200 B.P. (Table 1). The dating of Plainview and related assemblages has been rather problematic, but an age of approximately 10,000 B.P. generally is accepted as the average (Holliday et al. 1999). The assemblages with ages on the older end of the range include the two assemblages from Lubbock Lake, while the younger is Blackwater Draw Locality No. 1. No firm dates
are associated with Ted Williamson, Milnesand, or Ryan’s site.

The Plainview type site (41HA1) is a large bison kill within Running Water Draw where the remains of at least 100 bison were discovered during quarry operations south of the town of Plainview, Texas (Holliday 1997; Sellards et al. 1947; Speer 1983). Sellards and colleagues (Sellards et al. 1947) suggest the bone bed was the result of a single-event stampede kill, but tooth eruption and wear patterns indicate at least two kills at different times of the year (Johnson 1989). Technological analyses of the type point collection (Knudson 1983:27) suggest uniformity in point production and the possibility that only one or two flintknappers produced the assemblage. An additional four points to the original 16 described by Kreiger (1947), recovered after the original excavations (Speer 1983), are included in this analysis.

Lubbock Lake (41LU1) is near the eastern escarpment of the southern High Plains in a meander of Yellowhouse Draw north of the city of Lubbock (Johnson 1987). Two contemporaneous late Paleoindian assemblages recovered from discrete locales at Lubbock Lake are included in this analysis. Five contracting stemmed projectile points, identified as the Lubbock assemblage, were recovered among the remains of four disarticulated bison in substratum 2s (Feature 5-17 [FA5-17]; Knudson et al. 1998). The other assemblage from Lubbock Lake was recovered primarily from Feature 6-11, a bison kill locale containing the remains of at least six bison recovered stratigraphically above a Folsom bison kill (Holliday and Johnson 1981; Johnson 1987; Johnson and Holliday 1997).

Blackwater Draw Locality No. 1 (Blackwater Draw) is in an ancient basin within the upper reaches of Blackwater Draw in Roosevelt County, New Mexico (Hester 1972; Haynes 1995). The assemblage from Blackwater Draw is part of the 21 points from the Carbonaceous Silt stratum defined as the “Portales Complex” by Sellards (1952:72–74). The eight points examined in this study are from the upper bone bed of Station E (Agogino and Rovner 1969; Hester 1972; Johnson and Holliday 1997). Based on several lines of evidence, the bioturbated Portales bone bed may represent at least two separate kill events within the Carbonaceous Silt layer (Johnson and Holliday 1997). The inclusion of this assemblage in our analysis

Table 1. Reliable Radiocarbon Dates for Late Paleoindian Assemblages on the Southern High Plains Used in this Study.

<table>
<thead>
<tr>
<th>Site</th>
<th>Material</th>
<th>Association</th>
<th>Radiocarbon years B.P. (sample #)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackwater Draw (Portales Complex)</td>
<td>sediment organic</td>
<td>collected some distance</td>
<td>8830±160 (Y-2488)</td>
</tr>
<tr>
<td></td>
<td>residue from bone bed (Unit E?)</td>
<td>from bone bed (Unit E?)</td>
<td>9890 ±290 (A-489)</td>
</tr>
<tr>
<td></td>
<td>humates and soluble lignins from plant remains</td>
<td>collected some distance from bone bed (Unit E?)</td>
<td>8560 ±350 (A-512)</td>
</tr>
<tr>
<td></td>
<td>humates from upper bone</td>
<td>sediment from bone block^c</td>
<td>8690 ±70 (SMU-1671)</td>
</tr>
<tr>
<td>Lubbock Lake</td>
<td>humates</td>
<td>substratum 2B</td>
<td>9990 ±100 (SMU-728)</td>
</tr>
<tr>
<td>Lubbock Lake (FA5-17)</td>
<td>organic-rich mud, humic acid</td>
<td>microstratum 2sLBb</td>
<td>9950 ±120 (SMU-1261)</td>
</tr>
<tr>
<td>Plainview</td>
<td>bone</td>
<td>tooth and bone gelatin</td>
<td>8790 ±60 to 10,660 ±70^d</td>
</tr>
<tr>
<td>Ryan’s^e</td>
<td>humates</td>
<td>below cache</td>
<td>9220 ±220 (SMU-2448)</td>
</tr>
</tbody>
</table>

^Two additional ages from the Portales complex are from bone samples (6300 ±150 [O-169] and 6230 ±150 [O-170]) and are considered unreliable (Holliday 2000:254; also see Hester 1972:174).

^Sediment samples may be from Unit E below the Portales bone bed (Holliday 2000:254).

^Johnson and Holliday (1997:337) indicate these are minimum ages.

^Range of five determinations; for problems with dating the Plainview site see Holliday et al. 1999.

^An additional humate sample from below the cache was dated to 10,650 ±120 (SMU-2447) but Holliday et al. 1999 consider this date unreliable.
study is based on the identification of Milnesand and Plainview type points in the original assemblage (Hester 1972).

The Milnesand and Ted Williamson sites are less than 500 m apart in the Lea-Yoakum dune field of Roosevelt County, New Mexico (Sellards 1955; Warnica and Williamson 1968). Milnesand contained the remains of at least 33 bison (Hill 2002) apparently killed in a topographic low spot among the dunes (Holliday 1997:138–143). Projectile points were recovered from the bone bed by Sellards (1955) and by the landowner (Warnica and Williamson 1968). Sellards (1955) identified three different point types from the site: Plainview, Eden, and a new type, the Milnesand point, named for the locality. The Ted Williamson site, located in a nearby blowout, yielded numerous projectile points from a similar topographic setting. However, no bison kill was recovered (Johnson et al. 1986). Points were recovered from the site by the landowner and primarily were identified as Plainview (Buchanan et al. 1996).

Both sites are interpreted as kill sites and are unique among late Paleoindian locales because they yielded an extensive number of points (Holliday 1997:193). The presence of both traditionally defined Milnesand and Plainview forms in both assemblages suggests that they are contemporaneous (Buchanan et al. 1996). The entire assemblage from the Ted Williamson site and the majority of the Milnesand collection is in possession of the landowner and is affixed to boards that allowed examination of only one face of the points and prevented the measurement of thickness or weight.

The Ryan’s site (41LU72) assemblage is a cache consisting of points, preforms, tools, and flakes found near Shallowater, Texas at the edge of a small, buried playa basin (Hartwell 1995). The majority of the artifacts were recovered from two potholes. Thirteen of the 14 points recovered were identified as Plainview while the remaining point was identified as a reworked Clovis (Hartwell 1995:176). The Ryan’s site assemblage exhibited a high degree of technological consistency, suggesting a limited number of flintknappers were involved in the production of the artifacts (Hartwell 1995:180).

The Warnica-Wilson assemblage includes points recovered from the surface of the Warnica-Wilson campsite and from the area surrounding the site in Roosevelt County, New Mexico (Reutter 1996). The assemblage of points from the Warnica-Wilson campsite and surface collection was identified as Plainview.

**FACTORS INFLUENCING PROJECTILE POINT FORM**

This exploratory investigation of late Paleoindian projectile point variability on the southern High Plains focuses on point shape. A number of researchers have suggested that stylistic variation in Paleoindian projectile points predominantly derives from differences in outline (Bamforth 1991; Bradley and Stanford 1987; Morrow and Morrow 1999). Technological attributes associated with point manufacture can be important in making typological and behavioral inferences. However, some technological attributes, such as flaking patterns—commonly noted in typological descriptions (e.g. Wheat 1972:145)—are little used in making typological assignments. While flake-scar patterning is valuable in the analysis of reworking and resharpening, it is not temporally diagnostic within the late Paleoindian period on the southern Plains (Dick and Mountain 1960; Hester 1972:137; Kerr 2000:115–116; Knudson et al. 1998) and, therefore, is not a discriminating characteristic useful for this study.

The analytical focus on projectile point shape, nevertheless, necessitates the examination of the effects of resharpening on point variability. Much debate has transpired concerning the effect of reworking on overall point shape and the consequences for classification (Bettinger et al. 1991; Flenniken and Raymond 1986; Flenniken and Wilke 1989; Rondeau 1996; Thomas 1981, 1986; Wilke and Flenniken 1991). In studies of reworking and resharpening of Paleoindian lanceolate points, most evidence indicates reduction in blade dimensions in comparison to basal and thickness measures suggestive of the retipping of hafted points (Collins 1999:26; Cox 1986:110–111; Gardner 1983; Gardner and Verrey 1979:17–18). Reworking of Paleoindian point bases, as suggested for Firstview late Paleoindian stemmed points (Wheat 1976, 1977), may have occurred
with other Paleoindian points (Cox 1986:111; Morrow 1995:171) but probably was relatively infrequent compared to basal reworking associated with varieties of stemmed and notched points (Musil 1988). Musil (1988:376) suggests that damage to lanceolate points probably most often resulted in breakage above the hafting area that would not permit further reworking. The effects of resharpening and reworking are analyzed in this sample of late Paleoindian points by examining characters associated with blades in relation to basal characters.

The use of different types of raw materials in the production of points has been noted as a factor contributing to point variation (Andrefsky 1994; Bamforth 1986, 1991; Knudson 1983). Raw material type and, where possible, source is recorded for each artifact examined. Raw material designations are based on macroscopic visual inspection of specimens and comparison with materials collected from specific geologic sources (Banks 1990; Holliday and Welty 1981). As raw material quality was not assessed, type is used as a general proxy for quality. Although this method undoubtedly masks variation in quality within the raw material types, it provides an easy and objective way to categorize the specimens. Generally, the flaking properties of quartzite available on the southern High Plains are relatively poor due to the more grainy texture of the quartzites as compared to chert (Holliday and Welty 1981). We grouped our projectile point sample by raw material type and tested for significant differences in form in order to examine raw material effects on point form.

METHODS

The analysis of form in biology has become increasingly sophisticated with the digitization of images and objects (Lele and Richtsmeier 2001; Richtsmeier et al. 2002; Rohlf and Marcus 1993). Biological forms routinely are digitized using various landmarks and recreated using coordinates. Other approaches analyze characters, or variables, which are calculated from coordinate data as Euclidean distances between pairs of landmarks (Strauss and Bookstein 1982). In this study, interlandmark distances are used for analysis because of the need to measure distances along the margins of the forms as well as directly between landmarks. Digitizing images and identifying point boundaries allows for the computation of an unlimited number of measurements and the ability to capture measurements that previously were impossible to take using calipers.

Using the thin plate spline digitizing program (tpsDIG) developed by Rohlf (2002), digital images of specimens were imported into the program for outlining (Figure 2a). Digital photographs were taken using the same 5-megapixel capable camera (Nikon “Coolpix” 5000). The camera was mounted on a tripod and photographs were taken at the same distance (20 cm) above artifacts placed flat on a surface and aligned with a standard scale (see Buchanan 2005 for a detailed description of this methodology).

Thirty-two landmarks and pseudolandmarks were used to define point boundaries. Thirteen landmarks define each edge and nine define the base (with overlap). Only three landmarks, one at the tip and two at the base, are considered to be “homologous” (type I) landmarks (Bookstein 1991). In biological terms, a homologous landmark is fully comparable in histological and to-
the morphometric approach to assessing point variability. The term is used here to identify positions that can be directly comparable across projectile point forms used in the analysis. Several landmarks represented maximum and minimum positions along the point outline (type II), and the remainder were used to define the rest of the point outline (the pseudo- or type III landmarks). The same sequence for digitizing projectile point outlines was followed for each artifact. The tip landmark followed by the basal landmarks was digitized first and then the edges and base. The edges and base were digitized sequentially by approximating half of each length to be digitized and moving from the base toward the tip. Pairs of Cartesian coordinates associated with the landmark data were converted to Euclidean distances in Matlab 6.0 (release 12) based on a standard scale. These sets of points and interlandmark distances capture the main aspects of form and form-variation in silhouette, but do not describe aspects of thickness.

Complete and nearly complete points were used in the analysis. Because multivariate statistical methods require complete data matrices, missing data on fragmentary points (points that had slight damage to the base, e.g. missing a basal ear, tip, or edges) were estimated and replaced from the remainder of the data rather than omitting the specimen. For points with small fragments missing, digitized positions were left out and missing coordinate data were estimated using the expectation-maximization (EM) method of imputation, that uses information about covariation among variables to predict missing values (Strauss et al. 2003). Of the two primary methods of data replacement, expectation-maximization and principal component estimation, simulation studies showed that the EM method was more precise (Strauss et al. 2003). Reliability in replacing missing data using the expectation-maximization method was found to be greatest using a moderate number of characters (6–12) and larger sample sizes (Strauss et al. 2003).

The analysis of projectile points focused on projectile point outline to measure variation. Because object shape cannot be defined uniquely, shape was defined on the basis of a chosen surrogate for size (i.e. PC1), although shape is never completely independent from size (Richtsmeier et al. 2002). Ten characters were chosen to describe the form of each point (Table 2; Figure 2b). The moderate number of characters used and the large sample size (n = 190) permitted reliable replacement of missing data using the EM method. The characters chosen were designed to capture the complexity of specimen shape (character 1), as well as the individual components that comprise point form (characters 2–10). The objective of using the numerous measurements was to have complete coverage of the point (Strauss and Bookstein 1982).

The characters used in the analysis include some traditionally employed linear measurements (Kelly 1982:4; Kerr 2000:18; Wheat 1972:131) and measurements that cannot be taken accurately with calipers (such as characters 2 and 7), but, as shown below, are useful in the description of point variation. Although some redundancy occurs across the characters chosen, the use of cross measurements has been shown to enhance dis-

<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Square root of the point area</td>
</tr>
<tr>
<td>2</td>
<td>Average of edge boundary lengths</td>
</tr>
<tr>
<td>3</td>
<td>Average of the tip to basal landmark linear lengths</td>
</tr>
<tr>
<td>4</td>
<td>Average of the distance from tip to basal landmark (character 3) to maximum edge inflection point</td>
</tr>
<tr>
<td>5</td>
<td>Average of the distance from the maximum edge inflection point (character 4) to the tip</td>
</tr>
<tr>
<td>6</td>
<td>Average of the distance from the maximum edge inflection point to the midline</td>
</tr>
<tr>
<td>7</td>
<td>Base boundary length</td>
</tr>
<tr>
<td>8</td>
<td>Base linear length</td>
</tr>
<tr>
<td>9</td>
<td>Midline length</td>
</tr>
<tr>
<td>10</td>
<td>Overall length</td>
</tr>
</tbody>
</table>
Prior to analysis, data were log-transformed to make differences in size relative rather than absolute (Keene 1995). Principal components analysis (PCA) was used for multivariate outlier detection and exploratory size and shape examination of point forms. Using this procedure, three specimens (a point each from Ryan’s, Plainview, and Ted Williamson) were removed from the analysis due to faulty digitizing. Multivariate analysis of variance (MANOVA) was used to test for significant differences in the characters across raw material types and localities. Because the P-values from MANOVA are highly dependent on the underlying assumption that group distributions are multivariate-normal with homogeneous covariance matrices, P-values were estimated from null distributions simulated by random permutation (5,000 iterations per analysis). Cluster analyses were used to examine the relationships among localities. The unweighted pair group method with arithmetic mean (UPGMA) clustering approach used a sequential clustering algorithm in which local topological relationships are identified in order of similarity, with the nearest two clusters joined iteratively until one final cluster is formed (Michener and Sokal 1957). Relationships were calculated using Mahalanobis distance to measure the distance of a single multivariate observation from the center of the population from which the observation is derived, taking into account information on covariation (Manly 1994:63). Multidimensional scaling was used to better illustrate the multivariate relationships expressed in the cluster analysis, representing as faithfully as possible the Mahalanobis distances between localities in the 10-dimensional character space compressed into two-dimensional space (Manly 1994:14).

Point assemblages from localities are analyzed using discriminant function or canonical variate analysis, a multivariate technique that identifies relationships between qualitative criteria (in this case, point assemblages by locality) and quantitative predictor variables (the 10 characters) to determine boundaries between groups (Albrecht 1980; Manly 1994; Reyment 1991). The discriminant function analysis (DFA) identifies the linear combinations (vectors of among-group variance) that maximally separate the localities analyzed (Hand 1981). Interpretation of DFA is based on the vector coefficients for individual variables and eigenvalues for the amount of among-group variance accounted for by each linear or discriminant function. A size invariant, or “size-free”, DFA also is used in order to describe the dimensions of variability across localities taking into account the confounding factor of size. Size is considered a confounding factor because point size differences can be primarily attributable to differential reworking and resharpening after use (Gardner and Verrey 1979). The characters were transformed to size-free residuals by regressing each character on the first within-group pooled principal component and then using the residues obtained from the regression in the analyses (Strauss 1985). The primary assumption for size-free DFA is that size represents the major source of variation. All statistical analyses were carried out using functions written for Matlab 6.0 (release 12).

RESULTS

Breakage Patterns

A total of 337 points were examined, 190 of which (56 percent) were complete enough for further morphometric analysis (Table 3). Of the 6,080 digitized landmarks used to define point outlines for the subsample of complete or mostly complete points, 3.1 percent were estimated using the EM method. Of the total sample of points, 59 percent were identified as complete during initial analyses (this count was made regardless of minor tip, edge, or basal fractures), 17 percent as tip fragments, 21 percent as basal fragments, and 3 percent as medial fragments.

The highest proportion of complete points in an assemblage is from the Ryan’s cache (85.7 percent; Table 4). Assemblages from bison kill locales generally have high proportions of complete points (ranging from 37.5–60 percent) and moderate proportions of tip fragments (16–50 percent). An exception is the Milnesand assemblage, where a higher proportion of basal fragments than tip fragments were recovered. The presence of basal fragments may indicate the replacement of points into hafts and the disposal of unusable bases at the site (Davis 1953; Judge 1973; for other
possibilities, see Hofman 1999). The Ted Williamson assemblage also has high proportions of tip and basal fragments (15.5 percent and 27.7 percent, respectively).

Analyses by Raw Material Type

Of the total sample of points examined (n = 337), different types of chert were used almost exclusively (93 percent). Of the chert points in the sample (n = 313), 64.5 percent could be associated confidently with an identifiable geologic source or outcrop. More than two-fifths of the chert points (42.8 percent) are made of Edwards Formation chert from the Edwards Plateau region of central Texas and approximately one-fifth of the chert points (18.5 percent) are made of Alibates agate from the Quartermaster Formation exposed north of Amarillo, Texas. Other identified cherts represented in minor amounts in the sample include: Tecovas jasper (1.6 percent) from Briscoe County, Texas; Potter member chert (1 percent) from within the Ogallala Formation; and Pedernal chert (0.6 percent) from the Jemez Mountain region of New Mexico. Other cherts without identifiable geologic sources represent 33 percent of the total sample and 35.5 percent of the chert sample; other cherts include orange, opaque black, brown, gray, tan, white, pink, and red varieties. Many of these cherts most likely came from the Ogallala and Dakota formations. Other raw materials represented in the assemblages include: quartzite (5 percent) with varieties in purple, brown, tan, and gray colors most likely derived from the Ogallala and Dakota formations; silicified caliche (0.9 percent) available in the Blanco Formation; basalt (0.6 percent) from an unknown source most likely in the New Mexico volcanic region; and obsidian (0.6 percent) sourced to the Jemez Mountains of north-central New Mexico (Johnson et al. 1985).

Due to limited sample sizes of Tecovas jasper, Potter member chert, silicified caliche, basalt, and obsidian, these raw materials were omitted from the analysis testing for differences across raw material types. The test for raw material effects examined a subsample (n = 183) of the total points in the sample consisting of points made of Edwards Formation chert, Alibates agate, quartz-
ite, and unknown cherts. A randomized one-way MANOVA testing the hypothesis that the population mean vectors across raw material types are identical exhibited no significant difference between raw material types on the characters \( F = 1.26; p = 0.165 \). With no statistically significant difference across the raw material types examined, raw material type was not controlled for in the following analyses by locality.

**Analyses by Locality**

A randomized one-way MANOVA testing the hypothesis that the population mean vectors across localities are identical exhibited significant difference between localities \( F = 2.68; p < 0.001 \). The lack of a correlation between overall assemblage variability (normalized from the covariance matrix) and assemblage size \( r^2 = 0.22, p = 0.239 \) suggests that assemblage size does not unduly influence point form variability. Examination of the overall variation in all characters by locality shows that the Ryan’s assemblage has the lowest variation and Ted Williamson has the most variation (Figure 3). The most variable characters across all localities are different measures of length (characters 5, 9, and 10) and the least variable characters are related to overall size and width (characters 1, 4, and 6).

Differences in point form were explored using PCA. The plot of the scores from the first two principal components shows differentiation of the localities along PC1, accounting for 77.5 percent of the variation, with Milnesand on the smaller end and Plainview and Blackwater Draw on the larger end of the axis (Figure 4a). Along PC2, accounting for 8.8 percent of the variation, Lubbock Lake FA5-17 is the most dissimilar. A cluster of localities, including Milnesand, Lubbock Lake, Ted Williamson, Warnica-Wilson, Ryan’s, and Plainview, vary more by size (along PC1) than shape (along PC2). A vector plot of character loadings, showing the direction of character variation (arrows show the polarity and magnitude of loadings), displays length dimensions juxtaposed with basal dimensions (Figure 4b). The third PC, accounting for 8.3 percent of the variation, indicates increasing width measurements (characters 4 and 6) contrasting with length measurements (characters 3, 9, and 10; Table 5).

Cluster analysis using the log-transformed data in a UPGMA is illustrated in a dendrogram to represent the relationships among samples (Figure 5). The Lubbock Lake FA5-17 and Blackwater Draw assemblages are the most distant from the other assemblages, but none of the assemblages form distinct clusters. In the multidimensional scaling plot of these relationships, however, clustering of the Plainview, Ted Williamson, Warnica-Wilson, Ryan’s, and Milnesand assemblages is evident (Figure 6a). Lubbock Lake FA5-17, Blackwater Draw, and Lubbock Lake are separate from the cluster and from each other. A vector plot (Figure 6b) associated with the multidimensional scaling shows five characters representing area and length (1, 2, 3, 9, and 10) pointing up, basal characters (7 and 8) juxtaposed to those and juxtaposed with character 4 and also width characters (5 and

![Figure 3. Plot of overall variation in the 10 characters by locality.](image-url)
In general, the vector plot shows that assemblages to the left of zero (Lubbock Lake and Lubbock Lake FA5-17) are composed of long, thin points with narrow bases, and assemblages to the right are composed of short, wide points with wide bases. The Lubbock FA5-17 assemblage is further distinguished by having a large character 4 and a narrow base. The Blackwater Draw assemblage is represented by particularly long and narrow points and the Lubbock Lake assemblage is represented by particularly short and wide points.

In the DFA by locality, DF1 represents 38.4 percent of the variation while DF2 represents 28 percent of the variation (Figure 7a). The Lubbock Lake FA5-17, Blackwater Draw, and Milnesand assemblages are clustered at the smaller end of the DF1 axis. On the DF2 axis, Lubbock Lake FA5-17 is the most distinct from the other assemblages. A cluster of localities composed of Warnica-Wilson, Ryan’s, Plainview, Ted Williamson, and Milnesand indicate they share closely related forms. A vector plot portrays increasing overall size and blade dimensions (except for character 4 which is negligible) to the right on the DF1 axis (Figure 7b). High values along the DF2 axis indicate long narrow points and low values indicate...
short points with broad bases.

In the size-free plot (Figure 8a), Lubbock Lake FA5-17 is most distinct. A vector plot corresponding to the size-free discriminant analysis (Figure 8b) again distinguishes Lubbock Lake FA5-17 and to a lesser degree Blackwater Draw assemblages as long thin points with narrow bases and small blades. The characters that probably best capture differences in the resharpening of blades, the distance from the maximum inflection point to the tip (character 5) and the distance from the maximum inflection point to the midline (character 6), respectively, exhibit limited variation and do not correspond directly with a particular assemblage. The main juxtaposition between characters in the size-free analysis is between broad bases and long narrow blades.

The distinctiveness of Lubbock Lake FA5-17 compared to the other late Paleoindian assemblages requires a closer examination. A DFA between Lubbock Lake FA5-17 and the other assemblages as a group demonstrates the distinctiveness of the Lubbock Lake FA5-17 assemblage (Figure 9a). Significant differences are found in a pairwise comparison of Lubbock Lake FA5-17 with all other assemblages ($F = 4.45; p = 0.009$). Directions of character variation for Lubbock Lake FA5-17 and the other assemblages shows that Lubbock Lake FA5-17 is discriminated by long points with narrow bases (Figure 9b). In this plot, characters defining area and the width and length of blades (characters 1, 5, and 6) are not useful in discriminating between Lubbock Lake FA5-17 and the other assemblages. The characters that contribute most to discriminating Lubbock Lake FA5-17 from the
Figure 7. Discriminant function analysis of all points by locality: a) group centroids indicated by crosses and corresponding convex polygons which minimally enclose sets of points (DF scores) for each locality (TW, Ted Williamson; MN, Milnesand; PL, Plainview; L17, Lubbock Lake FA5-17; LL, Lubbock Lake; BW, Blackwater Draw; WA, Warnica-Wilson; RY, Ryan’s); b) vector plot showing the directions of character variation within the DFA scatter plot (numbers correspond to defined characters in Table 2).

Figure 8. Size-free discriminant function analysis of all points by locality: a) group centroids indicated by crosses and corresponding convex polygons which minimally enclose sets of points (size-free DF scores) for each locality (TW, Ted Williamson; MN, Milnesand; PL, Plainview; L17, Lubbock Lake FA5-17; LL, Lubbock Lake; BW, Blackwater Draw; WA, Warnica-Wilson; RY, Ryan’s); b) vector plot showing the directions of character variation within the size-free DFA scatter plot of localities (numbers correspond to defined characters in Table 2).
other assemblages are length characters (9 and 10) and character 4, the distance from the tip to base segment to maximum inflection point along the edge.

Differences in point forms are illustrated in Figure 10, using five (5, 6, 8, 9, and 10) of the 10 characters measured to reconstruct average point form. Each point outline represents the average of each characteristic for each locality. The objective in this exercise is not to produce an archetype for each locality in an essentialist approach (sensu Mayr 1981) but for comparative purposes to provide an adequate representation of the five characters for visual discrimination. Although only half of the characters are represented, differences in point forms among assemblages are clear. Lubbock Lake FA5-17 and Blackwater Draw point forms in particular stand out from the other point representations. The point forms in the upper row are distinguished from the bottom row by their straight bases. Points from the Lubbock Lake FA5-17 and Blackwater Draw assemblages are further distinguished from the other assemblages based on their narrow basal widths. Lastly, Lubbock Lake FA5-17 and Blackwater Draw are different from each other based upon the position of greatest width. The Lubbock Lake FA5-17 forms have their greatest width close to the distal end of the point, whereas Blackwater Draw forms have their greatest width at the base.

DISCUSSION

The sources of variation in projectile point form identified and described in this study include the consideration of possible constraints on form imposed by type of raw material used in point manufacture. Previous studies suggested that fracturing properties of different raw materials and the ability of flintknappers to control the shape of the intended product may be constrained by the quality of raw materials employed (Bamforth 1991; Gardner and Verrey 1979; Hayden et al. 1996; Luedtke 1992; Tankersley 1994). Only a subsample of the points could be used in the analysis by raw material due to the small sample size of some of the raw material types. No direct assessment of raw material quality was made. Based on experience with the available quartzites in the region, however, quartzite was considered of the...
lowest quality. No significant differences were
found in the defined characters across major raw
material types or sources in the analysis. For this
study, then, projectile point form was not consid-
ered to be constrained significantly by the prefer-
etial use of any of the major raw materials in the
assemblages analyzed. Nonetheless, it should be
reiterated that several of the raw material types,
represented only in minor amounts and not in-
cluded in the analysis across raw material type,
may have influenced the desired form of points.

Results of the multivariate analyses of point
form suggest that the effects of resharpening or
reworking of points was not a primary factor in
the discrimination of the Lubbock Lake FA5-17
from the other assemblages. Points from the Lub-
bock Lake FA5-17 assemblage can be character-
ized in shorthand as long and narrow, whereas
points from the other assemblages (excluding
Blackwater Draw) are generally short and wide.
Vector plots of loadings showed that characters
defining blade width and length—characters that
arguably are associated with resharpening—did not
correspond to the juxtaposition of long-narrow
points and short-wide points. If long and narrow
points were reduced in length through
resharpening, then they may become short and
narrow but not short and wide. Wheat (1976) noted
that some broken blade portions or distal ends of
late Paleoindian projectile points had been modi-
fied to refit into a haft. In this situa-
tion, short and wide points could have
been reworked blade portions of for-
merly complete long and wide points.
However, the paucity of such com-
paratively long and wide points in
these assemblages suggests that this
scenario was rare for this time period
on the southern High Plains.

The most variable characters
across all localities were different
measures of length, suggesting that
resharpening among other possible
factors undoubtedly produced vari-
ation in point form. Variation in point
length also may be attributable to
original core size, which may be de-
termined by available raw material
nodule size or organizational determinants of mo-
bility (Bamforth 1986; Binford 1977, 1979). The
character defining blade length, however, did not
play a part in the discrimination of long and nar-
row points from short and wide points.

Overall variability in the 10 characters by as-
semblage demonstrated that Ted Williamson,
Blackwater Draw, and Milnesand had the highest
variability. Although no bison remains were recov-
ered at Ted Williamson, the Ted Williamson and
Milnesand sites originally were described as bi-
son kill sites (Sellards 1955, Warnica and
Williamson 1968). Both had anomalously large
point assemblages (Buchanan et al. 1996) and
hearth features. The comparatively high overall
variability within these assemblages suggests the
possibility of multiple occupations or that both
localities had several groups coming together to
participate in a communal kill (however, see
Hofman 1994). A communal kill could have
brought together various flintknappers that resulted
in an increase in observed point variability because
of either an increase in individual variability (id-
iosyncratic variation) or by bringing together dif-
ferent technological traditions.

The possible explanation that point variation
increased through the work of many flintknappers
represented at large kills—in some cases, large
kills may represent a communal kill—is not well
supported by the data in this study. In contrast to

Figure 10. Point form reconstructions using characters 5, 6, 8, 9, and 10.
the Ted Williamson and Milnesand assemblages, the Plainview assemblage displays low within assemblage variation yet contains the highest number of estimated bison (MNI = 100) from a kill site. Milnesand contains only a third of the bison estimated at Plainview. Although the Plainview kill may have been the result of at least two events, the number of bison estimated in half of the Plainview kill (n_H•50) was still the largest kill in the sample. Nevertheless, the point assemblage from Plainview displays low variation. Bamforth (1991) suggests that it is possible that between assemblage variability may be higher when associated with smaller kills rather than large kills because points from large or communal kills may have been manufactured by a limited number of specialist flintknappers. This situation may explain the low variation in both the Ryan’s cache and the Plainview assemblage. The Ryan’s cache has the lowest overall variation in projectile point form and the points may have been manufactured by a single flintknapper (Hartwell 1995). Low variation is found in the Plainview assemblage supporting Knudson’s (1983:27) observation that the work of only a few flintknappers is represented in the assemblage. Based on the large number of bison recovered from the site, this low variation tentatively supports Bamforth’s (1991) idea that specialist flintknappers may have produced the assemblage.

The high within-assemblage variation in the Blackwater Draw assemblage (Portales complex) recovered from the Carbonaceous bone bed lends support to the possibility of occupational mixing, as noted in weathering patterns across the kill and significant differences in radiocarbon assays (Johnson and Holliday 1997). The assemblage also is differentiated in most analyses from the other assemblages. At least three different point types originally were identified in the assemblage (Hester 1972). This mixing of different point forms may explain the discrimination of this assemblage from the others. Some of the forms mixed in the assemblage may be associated with the younger Firstview complex (e.g. Wheat 1972), providing some indication of temporal differentiation from the other assemblages. These analyses support the interpretation of occupational mixing of different point forms; therefore, further comparison of this assemblage was not considered.

Between assemblage distances represented in the multivariate analyses demonstrate small differences in basal shape, blade length, and width characteristics among the Ted Williamson, Milnesand, Ryan’s, Plainview, Warnica-Wilson, and Lubbock Lake assemblages. Multivariate explorations indicate that all these forms are closely related in terms of the characters examined. The relatively small stylistic differences between the assemblages are consistent with high levels of intergroup cultural transmission of technological knowledge as each assemblage represents similar point forms.

The Lubbock Lake FA5-17 assemblage is the most different of the assemblages. The Lubbock Lake FA5-17 assemblage was recovered from a stratified bison kill and butchering locale that was interpreted as a discrete occupational episode sealed rapidly by marsh sediments (Knudson et al. 1998). The Lubbock Lake FA6-11 assemblage was recovered from a separate kill (less than 50 m away from Lubbock Lake FA5-17) along the marshy edge of the same pond. Radiocarbon assays from both kills indicates they were contemporaneous (Table 1). Temporal differences, therefore, do not explain the differences between at least these two assemblages found at Lubbock Lake and most likely cannot account for the differences between Lubbock Lake FA5-17 and the other assemblages given the general contemporaneity of these assemblages.

Raw material use represents evidence from an additional dimension of variability that differentiates the Lubbock Lake FA5-17 assemblage from the others. The Lubbock Lake FA5-17 points are made of exotic raw materials not found in the other assemblages. One of the points is made of obsidian and two are made of Pedernal chert from the Jemez Mountains of north-central New Mexico. These exotic raw materials are not included in the raw material analyses due to limited sample sizes. Therefore, the effect of the Pedernal chert points (the obsidian point from the Lubbock Lake FA5-17 assemblage was only the distal blade and not included in the shape analyses) could not
be determined and may represent a confounding factor in the uniqueness of the Lubbock Lake FA5-17 points. Pedernal chert, however, has similar properties to the other cherts in the sample (Banks 1990:69) and obsidian has excellent flaking properties. It is assumed, therefore, that points made of Pedernal chert and Jemez obsidian would not significantly impact a flintknapper’s ability to manufacture a desired form based on their fracturing properties. Taken together, the statistical distance of the Lubbock Lake FA5-17 points from the other assemblages and the unique use of raw materials from New Mexico suggest that the assemblage represents a distinctive technological tradition.

This study was constrained by the lack of thickness measurements due to the inability to gather such data on a majority of the points. Tankersley (1994) demonstrated that thickness is an important factor in differentiating Paleoindian fluted points. Thickness also may be important in distinguishing non-fluted points. Varying thickness in points may have significance in relation to different reduction strategies (e.g. thicker points may be associated with bifacial reduction whereas thinner points may be linked to flake reduction) or to hafting requirements (Knudson 1983; Knudson et al. 1998). To reiterate, points from the Ted Williamson and Milnesand assemblages were glued to boards and, therefore, it was not possible to take thickness measures. If the points in the Milnesand and Ted Williamson collection were detached from their mountings in the future, cross-sectional digital images and measurements could be made on these artifacts and thickness measures added to this analysis.

Flaking ability, as reflected in point thickness across raw material types, may be an important factor in differentiating assemblages. Qualitative observations on cross section and mode of point production have been recorded in this study where possible. The Lubbock Lake FA5-17 points are diamond-shaped in cross section whereas a number of points from Ryan’s site and Plainview retain the ventral surface of the flake on which they were made. These differences in point forms appear to be reflective of differences relating to point manufacture providing some additional evidence that the Lubbock Lake FA5-17 points are quantitatively and qualitatively different from other point assemblages in the region.

SUMMARY

The analysis of late Paleoindian point assemblages on the southern High Plains demonstrates the presence of at least two statistically different point forms. The two point forms, described in shorthand as long and narrow and short and wide, are from Lubbock Lake FA5-17 and the six other assemblages (Plainview, Ryan’s, Lubbock Lake, Ted Williamson, Milnesand, and Warnica-Wilson), respectively. The two distinct point forms are considered generally contemporaneous, and, in the case of Lubbock Lake, the two point forms were deposited within meters of each other at discrete bison kill locales.

Although various late Paleoindian point types had been proposed for the southern High Plains, their differentiation from the broadly defined Plainview type has not been demonstrated. The results of the analyses presented here suggest that in terms of outline form, two different point forms occur that were contemporaneous around 10,000 years ago in the region: the Lubbock Lake FA5-17 form and the more general Plainview form. This situation marks a change from the preceding Clovis and Folsom archaeologically defined traditions in the region that represent relatively long periods of stasis reflected in the continuity of projectile point styles for approximately 500 and 700 years respectively (Haynes 1993). Although the Midland point tradition may have been contemporaneous with Folsom, it is unclear if the unfluted Midland points actually are a different point type or just a functional response to limited raw material resources (Agogino 1969; Amick 1995; Judge 1970).

The reasons for point differentiation in the late Paleoindian period undoubtedly result from a number of interacting factors such as adaptive strategies, climate change, population growth, and perhaps cultural isolation. Adaptation in terms of subsistence change is negligible for the region under investigation, as the hunting of ancient bison continues to be a staple throughout the Paleoindian period in the region (Johnson 1987; Johnson and Holliday 2004). Climatically, the late
Paleoindian period corresponds with the end of the Younger Dryas. What effect this global climatic change may have had on the southern High Plains and population dynamics in the region is unexplored. Population growth, and the various repercussions of such growth such as territoriality, may provide a viable route to explore an explanation for the regional diversification of point forms. Territoriality or other cultural population isolating mechanisms (see Durham 1991) with subsequent cultural drift (or sampling error) may have worked to increase projectile point differentiation. This possible explanation does not rely on finding an adaptive cause for change in point form.

Morphometric analysis of projectile points can benefit from the digitizing method employed in this analysis. Digitizing enables numerous characters to be derived objectively from point outlines; some of the characters cannot be measured using calipers, but can provide potentially important characters in the delineation of point form. The use of numerous characters provides overlapping coverage of point forms and is suitable for robust multivariate statistical analyses. The new digitizing method employed here has been used in an attempt to begin to provide quantitative descriptions of within and between assemblage variation in point forms dating to the late Paleoindian on the southern High Plains. Future research needs to bring together the quantitative approach with descriptions of technological data such as reduction strategies using mixed model procedures that handle both quantitative and qualitative variables.

We had the objective to inductively examine the various late Paleoindian assemblages on the southern High Plains, some with unique type names, in order to determine if they could be discriminated in terms of outline form—an important dimension of variability in point types. The results indicate that many of these assemblages have point forms that significantly overlap and, therefore, suggest that some type names (e.g., Milnesand) should be reconsidered. The Lubbock type (from Lubbock Lake FA5-17), however, appears to be significantly different in outline form from the other assemblages.

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