PALEOAMERICA
https://doi.org/10.1080/20555563.2019.1602946
Center for the Study of the First Americans
Texas A&M University
Routledge
Taylor & Francis Group

RESEARCH REPORT

A Typology of Florida Fluted Points Using Landmark-based Geometric Morphometrics

David K. Thulman

Department of Anthropology, George Washington University, Washington, DC, USA

ABSTRACT
This typology of Florida fluted points was created from 164 images of fluted-point bases using landmark-based geometric morphometrics (LGM). Three highly distinctive types were discriminated using the shapes of the point bases. LGM is a powerful method for discriminating shapes, so paying close attention to analytical details is crucial for meaningful analyses. In archaeology, LGM is in its relative infancy compared to its use in biology, and archaeologists have not settled on standard procedures for its use in artifact shape analysis. Several general issues in the use of LGM for artifact-shape discrimination are discussed and illustrated, especially the effects of sample size and the Pinocchio Effect, in which highly variable aspects of an artifact shape, such as the fluted point blade, can affect analyses in unintended ways. The choices made in creating this typology are discussed in detail and alternatives tested to show how choices can significantly change results and archaeological interpretations.

KEYWORDS
Fluted point; typology; Florida; Paleoindian; landmark-based geometric morphometrics

1. Introduction

The fluted-point typologies in southeastern North America are not well-developed and tend to follow a general evolution from Clovis to post-Clovis regionally-restricted fluted forms, such as Cumberland and Redstone (Anderson et al. 2011; Goodyear 2006; Tune 2016), followed by myriad usually-but-not-always unfluted lanceolate forms, such as Quad, Beaver Lake, Simpson, Suwannee, and Dalton (Justice 1987). Anderson et al. (2011) proposed that the post-Clovis Younger Dryas period is correlated with a population decline and regionalization, inferred from the relative number of post-Clovis fluted points and illustrated by the distribution of Cumberland and Redstone points in the Paleoindian Database of the Americas (PIDBA). The PIDBA maps are also useful for illustrating broad swaths of the Southeast with no reported fluted-point forms (Anderson et al. 2010). This may mean either or both low population densities or fluted forms that are unrecognized and uncounted. In Florida, the latter explanation holds. This article describes a new fluted-point typology for Florida using landmark-based geometric morphometrics (LGM) and explains in detail – sometimes excruciating detail – the decisions made in its creation. LGM is a powerful technique for comparing shapes, but unthoughtful application of LGM can lead to unsupported inferences. Consumers of archaeological LGM literature should be cognizant of how choices in what and how to model artifact shapes can potentially significantly affect the results.

With the exception of the Paradise Park site adjacent to the Silver River in Marion County (Hemmings 1975; Neill 1958), Florida lacks stratified fluted-point sites. Florida produced one Clovis-age date on an ivory point that probably is related to Clovis (Waters and Stafford Jr 2007) and several Early Archaic notched Bolen point sites that bracket the Paleoindian period, but we can only infer the proper chronological placement of post-Clovis lanceolate points by reference to similar-looking points from other regions of the Southeast (Pevny, Thulman, and Faught 2017). An informal poll of Florida Paleoindian archaeologists found little agreement in identifying the two classic Florida Paleoindian lanceolates – Suwannee and Simpson (Thulman 2012). Everyone agrees these forms exist; few agree on what they are. The lack of chronological data is inversely proportional to the number Paleoindian point typologies developed for the state (Bullen 1975; Dunbar and Hemmings 2004; Farr 2006; Schroder 1995). In 2007, I published *A Typology of Fluted Points from Florida* (Thulman 2007), culling fluted points from about 1000 images of fluted and unfluted lanceolate Paleoindian points from Florida. That database spawned two additional typologies by Louis Tesar and Jim Dunbar (Dunbar 2016, 2013). Unsurprisingly, the typologies do not agree even though Tesar, Dunbar, and I used the

CONTACT David K. Thulman dthulman@gmail.com

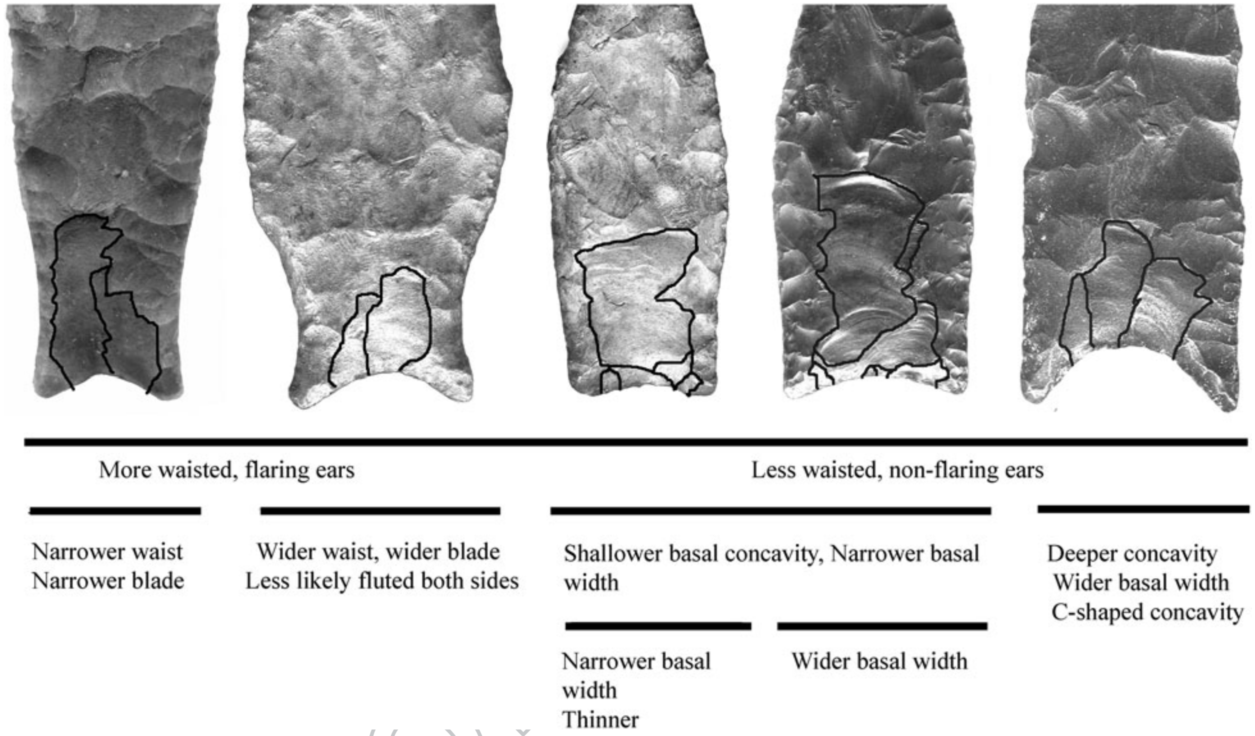

Figure 1 Florida fluted-point typology, modified from Thulman (2007, figure 3).

same 1000-point dataset, in part because we used different techniques, criteria, and units of analysis.

Tesar grouped points by sight relying on shape and size. Dunbar also used shape and size and a technique of overlapping outlines used in my earlier typology (Thulman 2007, figure 10). I used standard distance measures (e.g., minimum basal width, depth of basal concavity), angles, and ratios to characterize the base forms of 72 fluted points; the blades were ignored. The base was defined by the lateral extent of grinding. In the end, I identified five groupings of variation: two waisted and three straight sided (Figure 1; Thulman 2007, figure 3).

2. Using landmark-based geometric morphometrics

In this effort, I worked with 164 images of fluted points from Florida that met the minimum quality standards, described below. Few lanceolate points from Florida have long flutes that distinguish some post-Clovis fluted point varieties in Southeast; I have seen one mid-section of a Cumberland point and fewer than five Redstone points from Florida. Technological fluting to thin bifaces (*sensu* Bradley 1997) was practiced in Florida into the Early Archaic period (Pevny, Thulman, and Faught 2017), but morphological fluting disappeared sometime during the Paleoindian period. Like naming unfluted Paleoindian lanceolates (Thulman 2012), Florida archaeologists often disagree about whether a Florida lanceolate point is fluted. Figure 2 illustrates how I made the distinction in this project between fluted and basally-thinned lanceolates. Virtually all images came from private collections, although 15 of the points from Florida Bureau of Archaeological Research collection were confiscated in recent law enforcement raids for being illegally collected from state lands. One-hundred-thirty points had at least general location information, such as county or river drainage.

The major difference between the 2007 typology and this effort, other than the sample size, is the technique. Here I used LGM, the details of which are reviewed elsewhere (Adams, Rohlf, and Slice 2004; Bookstein 1991; Zelditch, Swiderski, and Sheets 2012). The crux of LGM is it considers shape as a single unit of analysis (Slice 2005), rather than poorly approximating shape

Figure 2 Examples of basal thinning (left) and fluting (right).

Colour online, B/W in print

with linear measurements, angles, and ratios, which is typically done in artifact analyses (Shott and Trail 2010; Thulman 2012). LGM depends on the placement of landmarks (LMs) at homologous places on the specimens of interest (Zelditch, Swiderski, and Sheets 2012). The LMs define the shape of interest, such as the outline of an entire Paleoindian point or just its base. The specimens are aligned for shape analysis through generalized Procrustes analysis (GPA). GPA removes the complicating factors of rotation, translation, and scale, or size, through a least-squares process that minimizes the total distance between all homologous LMs (Slice 2005). LGM is well-developed in biological applications and is growing in archaeology (Adams, Rohlf, and Slice 2004). In the Americas, most researchers working on Paleoindian issues use a version of LGM to describe point outlines, a modification of an approach advocated by MacLeod (1999), in which primary LMs are placed at homologous loci, such as the distal tip and ends of the ears. Secondary LMs (sometimes called semi-landmarks) are placed at equidistant intervals to define curves between the primary LMs (e.g., Buchanan and Collard 2010; Charlin and González-José 2018; Smith, Smallwood, and DeWitt 2015; Thulman 2012).

LGM is highly effective at parsing out subtle, but statistically significant, shape variation defined by the LMs, which is especially valuable when discriminating groups of artifacts. The process for discriminating groups of artifacts and biological species based on shape is similar, both theoretically and methodologically (MacLeod 2018). Both archaeological and biological approaches sort a collection of artifact or biological shapes into coherent groups, typically using discriminate function analysis (DFA) for two groups and canonical variates analysis (CVA) for more than two (MacLeod 2018). The strengths and limitations of these techniques are described below.

2.1. Units of analysis

Biologists spend a great deal of effort ensuring the shape being analyzed (i.e., the unit of analysis) has biological meaning, because they want to ensure that shape differences can be used to reliably infer biological processes. But as Okumura and Araunjo (2018, 4; paraphrasing Cardillo 2010) point out, "the choice of [LMs in archaeology] must be related to research questions, as well as to the topological particularities of artifact types, and technical and morphological criteria." For artifacts, the choice of which shape, or which part of a shape, to analyze depends on the anthropological or behavioral question being addressed. General descriptions of "human behavior," "historical relatedness," "transmission," or "evolutionary patterns" are insufficiently nuanced, because these are inferences, not behaviors, and gloss the underlying behaviors from which they are inferred. The underlying behaviors manifest themselves in different aspects of artifact shape. For example, if one is interested in the transmission of cultural information on general knapping behaviors, then general flaking patterns (which are manifestations of those behaviors) would be the focus, and flake shape and distribution could be the units of analysis (Sholts et al. 2012). But, if one is specifically interested in knapping behaviors used during tool manufacture, the flaking patterns on the base may be better, whereas flaking patterns on the blade would be appropriate for analyzing flaking patterns during resharpening. If tool use-trajectory is the interest, then breakage and resharpening would be the focus, and blade-shapes could be the units of analysis. This level of attention may seem unnecessarily obsessive to some, but LGM is so sensitive to small variations in shape that paying close attention to precisely what one should analyze to address a research question can be critical for producing robust inferences. The following example may elucidate the issue.

What are the proper units of analysis for archaeologists concerned with inferring the distribution of Paleoindian social groups, each making fluted points across a landscape or through time? It should be a shape that preserves the collective cultural behaviors or practices of each group and allows a clear inference tying the behavior to that group (Thulman 2018). For Paleoindian points, an analyst has several options, three of which are considered here: base, blade, and entire point. The points are composed of two functional parts: a blade and a base. As demonstrated below, although integrated, the base and blade can have different life histories; blades were often resharpened and repaired, and bases were likely rarely repaired (Ahler and Geib 2000; Ellis 2004, 213). For any random Paleoindian point, the base-shape is likely nearly the same as when the point was initially made, and the blade-shape is likely different. Thus, between the two shapes, the point base best preserves the initial intents of makers in the social group.

The blade-shape can also preserve cultural behavior that can be tied to a specific group, such as the appropriate time to discard an exhausted point. However, Paleoindian points found in the archaeological record were either intentionally discarded when they were no longer useable or unintentionally lost, whether or not they were still useable.

Intentionally discarded points preserve cultural behaviors, but still-useable lost points do not. The trick is to know whether a point was lost or discarded to ensure it is useful for inferring culturally-specific behavior. For example, points found in a mammoth carcass seem likely to have been lost during the hunt or butchery, but maybe some were discarded. How could one know? Regardless, lost points *could* be used to inform cultural behaviors if they helped reconstruct a group's reduction trajectory for blade resharpening and repair. The reduction trajectory could be a culturally-specific behavior and could be used to identify groups.

In sum, for identifying Paleoindian groups that made points in a particular way, the base-shape best preserves the initial maker's intent, and the blade shape at discard best preserves the user's intent. However, most, but not all (for example, Smith and Goebel 2018), New World LGM analyses use the entire point shape as the unit of analysis (Buchanan and Collard 2010; Charlin and González-José 2018; Smith, Smallwood, and DeWitt 2015), which creates several potential complications. First, although the entire point shape contains the base-shape, the base-shape is obscured or distorted by GPA, because LMs defining the blade influence the alignments of the LMs defining the base. This is known as the Pinocchio Effect, in which a highly variable part of a shape, such as the Paleoindian point blade, creates greater apparent variation in a less variable part of a shape, such as the point base (von Cramon-Taubadel, Frazier, and Lahr 2007). The upshot is that artificial, non-existent variation is created in the culturally-informative base-shapes when the entire point shape is analyzed, which could obscure group identification. Figure 3 illustrates the effect. These figures show the LM variation, represented by the clouds of LMs (black dots) from individual fluted points in the dataset surrounding the consensus LM configuration (blue numbered dots) for the base portion of the entire artifact shape (Figure 3(B)) and just the base (Figure 3(A)). It is apparent that the corresponding LM distributions are different, and the distribution of LMs around each consensus LM position is significantly more dispersed in the LM clouds of the entire point shape (Figure 3(B)) than the base alone (Figure 3(A)), which means the apparent variation is greater on the base configuration when the shape of the entire point is used. In sum, the same shape (the base) is defined differently depending on whether the blade is included. The import for archaeological interpretation of these different analytical results is illustrated below.

The second complication is including lost fluted points in the analysis. If the cultural behavior is to discard points when they are 5 cm long, the inclusion of points ranging from 10 to 5 cm creates artificial variation, because it includes non-exhausted fluted points (i.e., those that are greater than 5 cm in length), which do not preserve cultural-discard behavior. Third, the entire-shape captures two cultural behaviors – base-shape at manufacture and blade-shape at discard – which may have different geographic distributions, i.e., they may cross different social group boundaries, complicating inferences drawn from types of shapes derived in the LGM analysis.

But, maybe none of this matters because the different base-shape configurations do not affect the assignment of individual fluted points to each of the types (described below), or, even if the assignments are different, there is

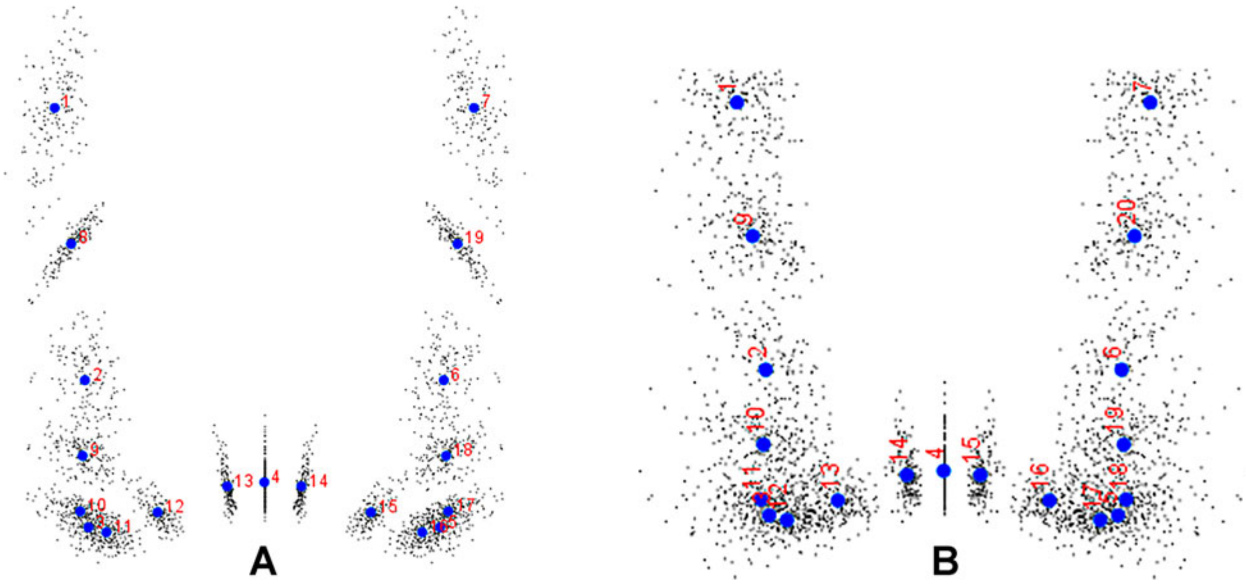

Figure 3 LM distributions for the fluted-point bases from a base-only shape (A) and the entire-shape (B). The larger blue dots are the consensus LMs; the smaller black dots are the LMs of the 168 individual fluted points.

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no significant effect on the inferences of Paleoindian group distributions. For example, in this work, if the different ways to define the base-shape configurations produce identical typologies or have the same geographic distribution, then the base-shape configuration differences are unimportant. However, without comparing typologies of the different base-shape configurations or their geographic distributions, it would be impossible to know whether the differences are important. If such testing is done, it is never reported.

2.2. Defining the shape

Of key importance is how the LMs are arranged to define the shape of interest. For lanceolate Paleoindian points, the simplest shape definition would be three LMs (a triangle), one at the tip and one at the end of each ear (all two-dimensional shapes must have a minimum of three LMs). However, triangles are rarely sufficient to define significant shape differences in lanceolate points. Here, I iteratively tried several variations of LMs to find the most discriminatory, explained below. The first LM configuration included 80 LMs consisting of 8 primary LMs and 72 equidistant secondary LMs. The number of secondary LMs was iteratively decreased until the final configuration was reached of 8 primary LMs and 26 secondary LMs defining the entire-shape. The base and blade were each defined by 19 LMs by dividing the entire-shape at primary LMs 1 and 7, which defined the distal extent of lateral grinding. The shapes were treated as symmetrical, because I assumed the intent of the makers was to produce a bilaterally symmetric shape. The final LM configurations for the base and entire-shapes are shown in Figures 3(A) and 4, respectively.

The effects of individual LMs on shape analysis are not always intuitive. In typical archaeological LGM applications, all LMs have the same mathematical influence in defining a shape, regardless of whether they capture important aspects of the shape for differentiation. Thus, more LMs do not necessarily better define a shape, because less informative aspects of a shape can be over-emphasized at the expense of more informative aspects of shape. Likewise, closely-spaced LMs may be informationally redundant. The informative aspects of a shape are not always obvious. One way around this is to try out different combinations and numbers of LMs until the discrimination is maximized. MacLeod (1999) terms this complexity weighting, where different aspects of a shape are given greater mathematical influence by being defined with relatively more LMs. In Figure 3(A), which is the LM configuration for the final base-shape, the three closely-spaced LMs (2, 10, 11, and 5, 16, 17) emphasize the importance of the ear-shapes in the analysis. It is important to note that just 10 LMs produce 1,814,400 possible LM configurations (the number of combinations of 10 through three LM configurations). Obviously, only a few of the possible configurations can be tested.

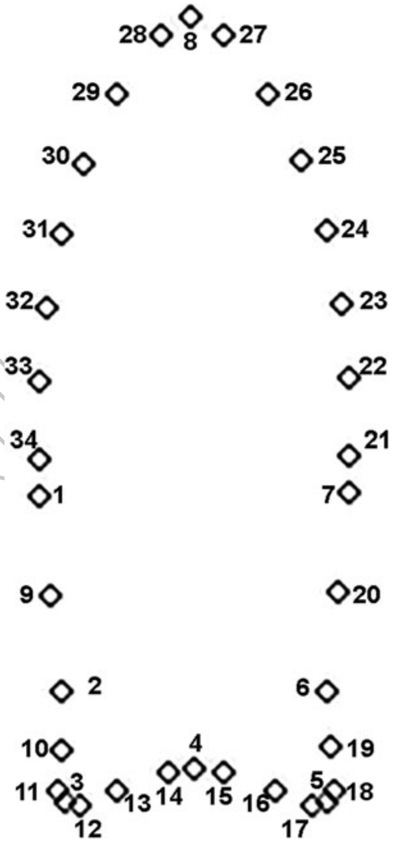

Figure 4 The LMs defining the entire point shape. The base is defined by LMs 1–20 (excepting LM 8). The blade is defined by LMs 1, 7, 8, and 21–34.

3. The typology

The typology was developed by first selecting 164 fluted points from a dataset of over 2000 images of Paleoindian fluted lanceolate points from Florida that met the following criteria. Points had to be intact, although some breakage was tolerated, up to 2 mm on the tip and 1 mm on the edges and ears. Points had to lie flat on the scanner platen, because points that lean change the apparent width of the point. All images were generated by scanning actual artifacts on a flatbed scanner at 600 dpi and saved as tif files. The scanner (Epson Perfection V600 photo) has enough depth of field to render sharp images of the point edges even though they do not lie on the platen. I used an LED light box above the points to minimize shadows. Several artifacts were scanned at the same time to create a single contact sheet with multiple artifact images. During image processing, single artifacts were clipped out, and a new image file was created for each artifact used in the analysis. The individual images were oriented with the blade at the top of the image. An image of a T-square was used to locate the midpoint of the basal concavity perpendicular to the midpoint of the minimum basal concavity (Figure 5). Small dots were placed on the image to locate the positions of the primary LMs. LMs were placed using tpsDig2 (Rohlf 2013).

The LM data were analyzed in MorphoJ (Klingenberg 2011), designating the images as symmetric, which averages the location of matching LMs to produce a symmetric image (Figures 3 and 4). I assume that for virtually all points, the maker's intent was to produce a symmetrical base. Tests (not reported here) confirmed that analyzing the shapes as non-symmetric changed the analytical results.

The base and entire-shapes were analyzed with canonical variates analysis (CVA) and discriminant function analysis (DFA). CFA and DFA are used to distinguish groups, so each fluted point must be assigned to a group. Group assignment is tested with a *p*-value and a classification/misclassification table (sometimes called an assignment or confusion matrix), which shows how many points of each group were properly assigned. A significant *p*-value and good classification success rate are useful for determining whether a grouping is poor, but are not meaningful tools for concluding a grouping is good because a CVA and DFA inflate the likelihood of successful assignment. Often a DFA classification table using uncross-validated results will show perfect or near-perfect discrimination, but those are unreliable. In these analyses, the uncross-validation results showed that only four base-shapes and one entire-shape were misclassified, but the realistic cross-validation results showed a total of 11 base-shapes and 15 entire-shapes were misclassified. Only a leave-one-out classification table (termed cross-validation in MorphoJ) should be relied on for evaluating the strength of a proper assignment (Kovarovic et al. 2011; McGarigal, Cushman, and Stafford 2000). There is no standard level of proper assignment, but I have used 80 percent or better correct classification as indicating an acceptable grouping (Thulman 2012).

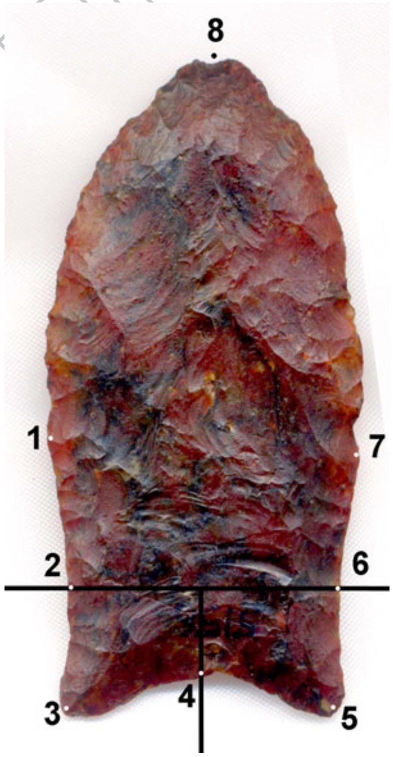

Figure 5 The method for inserting primary LMs. The location of LM 8 is estimated based on the likely original shape before damage to the tip.

Analysis was an iterative exploratory data analytical process of assigning points to groups, glancing at the PCA, which is not always helpful because it does not evaluate groups, closely examining the CVA plot and DFA classification tables and the discriminate function (DF) scores assigned to each point. MorphoJ does not produce a CVA classification table, so each pair of groups was evaluated in a DFA. For three groups, three tables are produced. By examining DF scores for individual specimens, one can identify which fluted points were misclassified, and these can be reassigned in the next iteration. It is important to note that reassignment of an individual fluted point changes the overall configuration of the group, making some previously properly classified points now misclassified.

4. Discussion

The results show three significantly different groups or types (these terms are used interchangeably here), for both the base and entire-shape analyses. Group 1 has 58 members, Group 2 has 73, and Group 3 has 33. The

Table 1 Leave-one-out cross-validation classification for the entire-shape groups.

Type	Group 1	Group 2	Total	Percentage correct
Group 1	57	4	61	93
Group 2	1	69	70	99

Type	Group 1	Group 3	Total	Percentage correct
Group 1	58	3	61	95
Group 3	3	30	33	91

Type	Group 2	Group 3	Total	Percentage correct
Group 2	69	1	70	99
Group 3	4	29	33	89

Table 2 Leave-one-out cross-validation classification for the base-shape groups.

Type	Group 1	Group 2	Total	Percentage correct
Group 1	65	3	68	96
Group 2	4	60	64	94
Type	**Group 1**	**Group 3**	**Total**	**Percentage correct**
Group 1	66	2	68	97
Group 3	2	30	32	94
Type	**Group 2**	**Group 4**	**Total**	**Percentage correct**
Group 1	64	0	64	100
Group 2	0	32	32	100

leave-one-out classification tables (Tables 1 and 2) show the reliable classification percentages range from 94–100 percent for the base-shape and 89–99 percent for the entire-shape, exceeding my minimum-acceptable proper classification rate. Images of the average or consensus shapes for each type are shown in Figures 6 (entire-shapes) and 7 (base-shapes). The bases of the entire-shapes look similar to the base-shapes, but there are differences. Twenty-seven (16 percent) of the entire-shapes were assigned to different groups from the corresponding groups of base-shapes. Thus, the blade-shapes on some points altered the entire-shape enough to put a specimen in a different group. For example, specimen 1BB6 (Figure 8) is classified as Type 1 entire-shape and Type 2 base-shape, which is driven by the shape of its clearly-resharpened blade. In another analysis (not illustrated), three significant groups of blade-shapes were also identified (86–100 percent correct classification), but they were not well correlated with the base-shapes. Classification of blade-shapes using the base-shape group assignments ranged from 56 to 71 percent proper classifications in the classification tables.

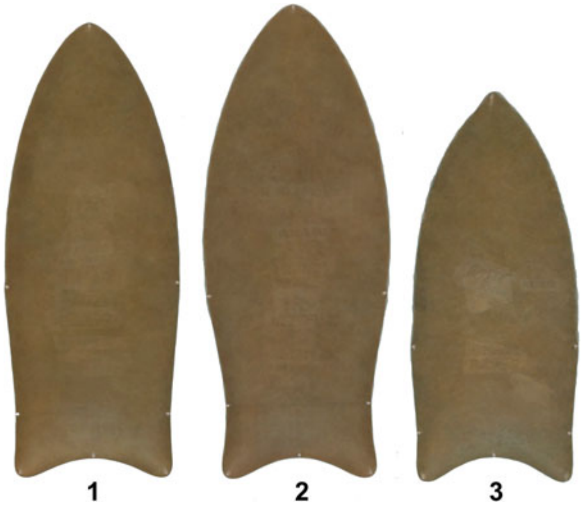

Figure 6 Consensus or average shapes for the entire-shape analysis. Numbers at bottom refer to Types 1–3.

Figure 7 Consensus or average shapes for the base-shape analysis. Numbers at bottom refer to Types 1–3.

It appears the new LGM typology captures all the variation in the 2007 typology but parses it differently (compare Figures 1 and 7). The 2007 and this typology differ in several ways. Most importantly, the earlier typology considers size; this one does not. Size was removed in the GPA. There is another consideration in evaluating the appropriateness of this typology. A proper DFA/CVA has a couple of limitations on sample size to ensure the results reflect differences in the sample and

Figure 8 Point 1BB6 showing why the entire-shapes and base-shapes were classified differently. This point was confiscated by the State of Florida and is in the state collections managed by the Florida Bureau of Archaeological Research.

are not simply mathematical anomalies (Kovarovic et al. 2011). Mathematically, the entire sample size (164 here) minus the number of groups (3) must exceed the number of variables (38; here the number of variables is calculated from 19 LMs×2 dimensions). However, even though the sample size exceeds the required minimum, ideally, each group membership should at least exceed two times the number of LMs, although statisticians disagree on the minimum acceptable size (Kovarovic et al. 2011; Mitteroecker and Bookstein 2011; Williams and Titus 1988; Zelditch, Swiderski, and Sheets 2012). Here, Group 3 has only 33 members, which is five less than the ideal minimum number of 38; tolerable but not ideal. Further, each group should have about the same number, because significantly different sized groups will overinflate the group discriminations (Mitteroecker and Bookstein 2011). White and Ruttenberg (2007) recommend no more than a 4:1 difference in group size, and here the difference between the largest and smallest groups is about 2.2:1. The result of these limitations is that small, but real, groups of distinctive fluted points cannot be reliably discerned in a DFA or CVA, if one follows the guidelines, and small groups that are identified may be false positives.

Assigning fluted-point shapes to named categories of Florida lanceolate points is a fraught exercise (Thulman 2012). I would name Types 1 and 3 as likely Clovis points and Type 2 as a highly waisted variety that most would classify as a fluted Simpson. In contrast, Dunbar and Hemmings (2004) would likely classify Type 2 as a waisted Clovis.

4.1. Do the differences between the base- and entire-shapes matter?

This is the critical question, because if the group differences do not affect the inferences, I may be worrying about unimportant technical details. The 130 points with location information were plotted in six regions, and the number of members of base-shape and entire-shape types and the percentage and number of mismatched points per region are listed in Table 3. A number of differences are apparent. First, only 7 of the 18 groups (three types in six regions) have the same number of members for the base-shape and entire-shape types. In the far western Chipola region (just west of the Apalachicola River), the differences are stark. Types 1 and 3 have 50–75 percent more and Type 2 has 36 percent fewer members when using the base-shape configuration. Second, simply comparing the number of entire-shape and base-shape members is not sufficient for evaluating the effects of using different base configurations. For example, in the Upper Suwannee region, the numbers of entire-shape and base-shape members in the three types are the same, but there are actually two mismatched fluted points. One point switched from entire-shape Type 2 to base-shape Type 1, and the other in the opposite way.

Using the entire-shape, one could infer that Paleoindians in the Chipola region used a significantly higher percentage of Type 2 points (64%) than Paleoindians in the other regions (23–50%). However, the base-shape distributions tell a different story: Chipola Paleoindians made generally the same percentage of Type 2 points (43%) as those in other regions (23–46%). Even though some of the regional sample sizes are small, I interpret the base-shape results to indicate that the different shape types were used across Florida either at the same time for different functions (because the percentages of each type are generally consistent across regions) or at different times. Discriminating between these equifinal inferences is not possible without better chronological control on the types.

5. Conclusion

Compared to its use in biology, LGM is in its infancy in archaeology. Adams, Rohlf, and Slice (2004) noted that biologists averaged about 100–120 articles per year referencing geometric morphometrics in the late 1990s to early 2000s. In contrast, the entire publication output of North and South American archaeologists using LGM to analyze material culture is likely less than 50 publications. Archaeologists almost exclusively focus on stone points and are still sorting through the variety of approaches for choosing the unit of analysis,

Table 3 Number of entire-shape and base-shape (italics) types by region in Florida.

Region	Type 1		Type 2		Type 3		
	Entire	*Base*	Entire	*Base*	Entire	*Base*	Percentage (number) mismatched
Upper Suwannee	5	*5*	3	*3*	1	*1*	22 (2)
Middle Suwannee	8	*10*	9	*7*	4	*4*	14 (3)
Aucilla	6	*6*	3	*3*	4	*4*	0 (0)
Chipola	4	*7*	14	*9*	4	*6*	38 (6)
St. Johns/Tampa	8	*10*	12	*11*	4	*3*	16 (4)
Santa Fe	15	*17*	19	*19*	7	*5*	5 (2)

Note: The percentages and numbers of entire-shapes and base-shapes mismatched in each region are listed in the last column.

describing the shape with LM placement, and analytical methodology. The choices can make a difference in the results and affect the inferences. We have barely begun to extend LGM to 3D images, much less other artifact classes, such as osseous tools, ceramics, non-point stone tools, and other classes of material culture. This article attempts to demonstrate how initial choices of units of analysis, shape, LM number and placement, and symmetry can importantly affect the results. Further, decisions about whether to rely on uncross-validated DFA/CVA classification tables and the minimum percentage of acceptable classifications can also affect the interpretation. Regardless, LGM is much better than point analyses using traditional measurements for parsing subtle and significant shape variation.

I have tried to be honest about many of the limitations of LGM and the inferences that can confidently be made from an LGM typology. The consumers of this research can draw their own conclusions, and these data will be made available for anyone to redo the work or try something different. However, some LGM analyses are frustratingly vague on the methodological choices made, and often data are not available. As Anderson et al. (2010) at PIDBA have advocated for years, data sharing benefits us all.

Acknowledgements

Thanks to Heather Smith and Jesse Tune for inviting me to the SAA session. Thanks also to Michael Faught for commenting on the text and Heather Smith and Michael O'Brien for reviewing it.

Disclosure statement

Q1 No potential conflict of interest was reported by the author.

Notes on contributor

David Thulman is an assistant professorial lecturer at George Washington University and president of the Archaeological Research Cooperative, Inc.

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