A Geometric Morphometric Approach to Casas Grandes Ceramic Specialization

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A Thesis

presented to

the Faculty of the Graduate School

at the University of Missouri

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts

By

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MAY 2016

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ACKNOWLEDGEMENTS

Many people supported me throughout this long process. My thesis supervisor and advisor, Dr. Todd VanPool, was tremendously helpful. Only because of his guidance was I able to complete this project. Thanks to Dr. Christine VanPool, who provided the type-sorted ceramic vessel photographs, without which this research would have been impossible. She also contributed invaluable comments, especially those that shaped conclusions. Thanks to Dr. Marcus Rautman for his comments and help in continuing to refine this research. To my committee members listed above, thank you.

Two friends also aided me a great deal in learning the methods. Through a collaborative study on measurement error, Kyle Waller and Philip Leflar helped me learn how to conduct geometric morphometric analyses. Thank you both so much.

I also thank my parents to whom I owe so much, other family members, and friends for all of their continued support.

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A GEOMETRIC MORPHOMETRIC APPROACH TO CASAS GRANDES CERAMIC SPECIALIZATION

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ABSTRACT

Recent studies use geometric morphometrics, the quantitative study of shape and its variation, to examine aspects of the archaeological record. This thesis builds on such applications by applying morphometrics to the analysis of whole ceramic vessels from the Casas Grandes culture of the Southwest. More specifically, I quantify variation in vessel shape and size, and find that Ramos and Babicora polychromes were likely made by specialists, but that other Casas Grandes ceramic types likely were not. This bolsters previous arguments for Medio period (A.D. 1200 to 1450) specialized production above the household level, but indicates that specialized production was limited to a subset of economically valuable goods. The analysis provided contributes to the study of at least three important anthropological topics: 1) the study of the Medio period Casas Grandes culture, and by extension the organization of production in mid-level hierarchically organized societies; 2) geometric morphometric analysis of archaeological collections; and 3) the Standardization Hypothesis and the relationship between artifact standardization and the organization of production in vessel morphology.

Chapter 1

Introduction

Recent works use geometric morphometrics, the quantitative study of shape and its variation, to examine aspects of the archaeological record (Buchanan and Collard 2010; Gingerich et al. 2014; Sholts et al. 2012). These analyses vary widely in focus. Archaeologists have used morphometrics to create or evaluate projectile point and ceramic typologies, while also emphasizing digital curation, discerning aspects of standardization, and constructing arguments of phylogenetic relatedness (Buchanan et al. 2014; O'Brien et. al 2014; Selden et al. 2014; Wilczek et al. 2014). This thesis builds on such applications by applying morphometrics to the analysis of whole ceramic vessels from the Casas Grandes culture of the Southwest. More specifically, I quantify variation in vessel shape and size, and find that Ramos and Babicora polychromes were likely made by specialists, but that other Casas Grandes ceramic types likely were not. This bolsters previous arguments for Medio period (A.D. 1200 to 1450) specialized production above the household level (Rakita and Cruz 2015), but indicates that specialized production was limited to a subset of economically valuable goods.

Statement of Problem

In his seminal work, "Casas Grandes: A Fallen Trading Center of the Gran Chichimeca", Charles Di Peso (1974) outlined a general chronology for the region that focused on the Viejo (now dated A.D. 700–1200), and the Medio (now dated A.D. 1200–1450) periods. According to Di Peso and other researchers who have worked in the area, social differentiation, religion, political organization, and economic systems changed drastically in the thirteenth century as the Medio period developed (Rakita 2009; VanPool and VanPool 2007; Whalen and Minnis 2009). A major component of this is the creation of specialized production and economic integration above the household level, especially at settlements such as Paquimé, the economic and political capital of the Medio period world. This specialization both reflected and reinforced increased political complexity, causing the Casas Grandes region to be an excellent case study for studying the relationships between craft production and the development of political complexity. Yet, while it is generally accepted that some artifacts/resources were produced by Medio period specialists, the shift to a specialized economy was incomplete. As a result, the structure of craft production is an empirical question that must be determined for each class of artifacts.

One of the central issues is the organization of ceramic production. The Medio period is most clearly delineated by beautiful polychrome pots with red and black designs on a white background (Plate 1). This pottery is socially and economically central to the Medio period culture, and served as a hallmark of participation in its associated ritual and symbolic system (VanPool and VanPool 2007). Authors such as Sprehn (2003) and Woosley and Olinger (1993) have argued at least some of these were produced by specialists, but this conclusion remains debated (Rakita and Cruz 2015). Here I am going to use the Standardization Hypothesis to evaluate whether morphological variation supports arguments for specialized production. The Standardization Hypothesis holds that variation decreases as the degree of specialization increases (Crown 1995). Thus, the central hypothesis for this study is that increased specialized production of pottery will be reflected by: 1) increased standardization in Medio period pottery relative to Viejo period pottery, and 2) possible differentiation within Medio period pottery if some types were produced by specialists and others were not. The results demonstrate that Ramos and Babicora polychrome were made by specialists above the household level, while the other Casas polychromes are consistent with household production.

Plate 1. Ramos Polychrome Vessel

Courtesy of El Paso Museum of Archaeology, photograph by Christine VanPool

Thesis Significance

Adding shape and size data to previous information about specialization will strengthen understanding of craft production and Casas Grandes pottery. This might include fine-tuning the date of transition from generalized to specialized ceramic craft production. It might also indicate specific types with ties to the production change. I will expound on these specific issues in the discussion. The analysis provided thus contributes to the study of at least three important anthropological topics: 1) the study of the Medio period Casas Grandes culture, and by extension the organization of production in mid-level hierarchically organized societies; 2) geometric morphometric analysis of archaeological collections; and 3) the Standardization Hypothesis and the relationship between artifact standardization and the organization of production in vessel morphology.

Casas Grandes represents one culture area among a partitioned, but connected, Southwest. As such, better comprehension of specialization has implications for the entire Southwest. Further, while the primary goal is to add shape data to arguments for Casas Grandes ceramics, the methods used here are broadly applicable and will prove useful to any ceramicist. In Chapter 2, I present background information regarding the Casas Grandes region and geometric morphometrics. In Chapter 3, I outline my analytic methods, focusing on the conceptual underpinnings of the Standardization Hypothesis and the use of geometric morphometrics to quantify variation in shape and size, and present results. Chapter 4 is the discussion of my data, and Chapter 5 provides my final conclusions.

CHAPTER 2

BACKGROUND

I divide the following discussion into two sections focused on the culture history of the Casas Grandes region and the development of geometric morphometrics. I will address the actual methodology of geometric morphometric analysis used in this study in Chapter 3.

Casas Grandes Environment and Culture History

The Casas Grandes culture occupies a 500-by-400km region of modern day Mexico, New Mexico and Texas (Rakita 2009). Though it extends into all three, most of the culture area is in Chihuahua, the largest state in Mexico (Bradley 2000). The environment of the region is split into three topographic zones: the western Sierra Madre Occidental, eastern basin and range, and an intermediate area between the two (Rakita 2009). Key river systems are located in the area, and form the Northern Interior Drainage Basin (Rakita 2009). These alluvial valleys of northwestern Chihuahua were home to the majority of the region's prehistoric inhabitants (Bradley 2000).

The three primary topographic zones each have distinctive flora, while there are distinct fauna in the western mountainous regions and eastern basin and range areas, with an admixture in the intermediary. Sierra Madre areas are typified by conifer forests at higher elevations, woodland environments at lower altitudes, and semi desert grasslands that cover much of Chihuahua (Bradley 2000). At low elevations, these also adjoin the prevalent Chihuahuan desertscrub zones. Desert-dwelling small reptiles and mammals are common in many parts of the state, while larger mammals persist in the woodland and conifer forests (Bradley 2000). Alluvial regions contain riparian flora and fauna, and are present throughout the state.

The Sierra Madre is home to a diversity of plant and animal species, which prehistoric populations exploited with patterns of seasonality and scheduling (Bradley 2000). One such group is the Tarahumara, who have existed in the area for hundreds of years by using this type of seasonality/scheduling approach (Bradley 2000). Precipitation increases in the western mountainous regions, while temperature decreases (Rakita 2009). The inverse is true in basin and range areas as temperature increases, with a marked decrease in rainfall (Rakita 2009). Few studies have been conducted on the prehistoric climate of the region, however, the available works indicate a relationship between climate change and patterns of settlement aggregation, whereby more favorable climatic zones were more densely occupied (Rakita 2009). The highest annual temperatures occur at low elevations, while the lowest temperatures occur at the highest elevations in the Sierra Madre (Bradley 2000).

A number of early Spanish explorers visited the region, beginning in the 16th century. General Francisco de Ibarra's 1564-1565 expedition recorded the first descriptions of Paquimé. Conversations with neighboring nomadic groups described Paquimé's occupants as enemies of western Sierra populations, who left the region after being defeated in war (Kidder 1916). Later, Jesuit and Franciscan missionaries entered the region during the 1620s. The 1680 Pueblo Revolt led to Spanish settlement in the northern Sierra Madre, subsequent revolts among other Puebloan peoples, and the movement of the Apache into the area (Bradley 2000). Apache occupation limited significant European contact with the Casas Grandes region for roughly two hundred years (Bradley 2000:223).

The first anthropologist to work in the region was Adolph Bandelier, whose 1885 expedition recorded numerous sites, described artifact types and distributions, and produced one of the first maps of Paquimé (Bradley 2000). Bandelier's survey also noted a high frequency of sites west of the Casas Grandes valley. The groundbreaking work paved the way for a number of explorers, and later archaeologists, including Alfred Kidder (Bradley 2000). In the Casas periphery Kidder and the Cosgroves excavated Pendleton Ruin, which helped establish that the Animas and Ramos phases are contemporaneous (Bradley 2000).

Around the time of the Pendleton Ruin excavation, two large-scale reconnaissance surveys took place. Sauer and Brand began survey in 1930. Brand's efforts were particularly successful as he recorded over 500 sites with his students, published the first detailed study of Chihuahuan ceramics, and the Casas Grandes region's relationship with nearby cultures, including Mesoamerican groups (Bradley 2000). In a separate but nearly concomitant survey project, another prominent Casas scholar, Sayles, recorded over 200 sites in an attempt to define the southern extent of the Hohokam. The research better established a regional chronology, while also identifying site types (Bradley 2000). Fueled by the work of Sayles, Gladwin argued that previous Mimbres occupations influenced a "Babicora phase", while the Salado greatly affected a "Ramos phase", although these phase distinctions were soon discarded (Bradley 2000). More recent investigations focus on the influence of Casas Grandes, and its relation to the rest of the Southwest, as well as Mesoamerica.

Charles Di Peso (1974) and Eduardo Contreras began excavation of the large site, Paquimé, during the 1950s in a joint project sponsored by the Amerind Foundation and the Instituto Nacional de Antropología e Historia. The Joint Casas Grandes Expedition lasted numerous years, focusing on recovering as much information as possible about the region's preeminent sites. A culmination of the many years of excavation and research, Di Peso et al. (1974) published a multi-volume set, expounding Casas archaeology from its inception through the end of Paquimé and post-aggregation (Bradley 2000). The report spurred continued interest in the culture area and the Southwest as a whole.

Di Peso's Paquimé work resulted in a wealth of data, which influenced later researchers. J. Charles Kelley focused on the origins of Casas Grandes, especially potential Mesoamerican influence (Bradley 2000). Working to better understand areas north and west of Paquimé, Whalen and Minnis (2001, 2009) defined zones of interaction based on distance from the site. The greatest level of political complexity and intercommunity integration was focused on the areas 30km around Paquimé. The authors further identified a middle zone, within 30 to 60km, which was influenced but not directly controlled by Paquimé, and a periphery beyond that distance that was generally independent (Whalen and Minnis 2001, 2009). Jane Kelley and Joe Stewart (1999) pursued excavation in the southern portion of the Medio period regions, while Rafael Cruz, Tim Maxwell and Robert Leonard excavated to the east and north of Paquimé (2004). James Skibo and William Walker

(2002) conducted fieldwork at Joyce Well, and Christine VanPool, Gordon F.M. Rakita and Todd VanPool (2013) initiated a project in the Janos area north of the United States-Mexico border. Both projects found evidence of integration with Paquimé in the far northern Casas Grandes frontier.

In terms of culture history, evidence of the first occupation of the Casas Grandes region is sparse. Although Di Peso (1974:63) notes that Clovis points and other Paleo-Indian artifacts indicate human presence by at least 10,000 B.C., and projects such as Hard and Roney's (1998) work on the Archaic period Cerros de Trincheras settlements indicate substantial occupations before A.D. 700, fieldwork has, for the most part, focused on ceramic period (Viejo and Medio period) sites. Reconnaissance surveys often focus on sites most visible from the surface, which, in the area, are typically Medio period structures (Bradley 2000).

Viejo Period

In early research of the Viejo period (A.D. 700–1200), Lister recorded cave sites that contained Viejo ceramics, while others reported that small campsites were typical of the time, especially in the Medanos dunes (Di Peso 1974:117). More recent research found distinctions between northern and southern groups, including settlement patterns. Settlements in the northern zone (around Paquimé) were more evenly spread as a result of available arable land, whereas southern settlements in the headwaters of the Rio Santa Maria and the Babicora Basin south of Paquimé were in upland basins where occupants could access higher elevation resources (Kelley and Searcy 2015). Viejo groups practiced dry land farming and were reliant on different types of maize. There was likely limited social differentiation during the Viejo based on modest site hierarchies and some burial good differentiation (Kelley and Searcy 2015).

Ceramics from the Viejo include textured wares, plainwares and red-on-brown decorated vessels (Kelley and Searcy 2015). Viejo period vessels typically have long necks that are frequently corrugated and/or incised. Bodies of the red-on-brown jars have simple banded designs, often with repeating triangles (Di Peso et al. 1974; VanPool 2003). Viejo pots also typically lack the duality and interlocking designs that are paramount on Medio Period jars (VanPool 2003). VanPool (2003) suggests that this indicates potters were less structured by the societal rules that appear during the Medio period, and she also argues that non-specialists made these vessels.

The Viejo is separated into three phases: the Convento (A.D. 700–900), Pilon (A.D. 900–950) and Perros Bravos (A.D. 950–1200)(Kelley and Searcy 2015). The first phase is named after the eponymous Convento, and is also based on the nearby Reyes sites (Di Peso 1974:97). Corncobs and other organics provided the carbon dates for the phase, while Mimbres Bold Face and black-on-white ceramics found in superimposed Convento strata of a later occupation helped solidify presence before the known construction of these pottery types (Di Peso 1974:104). Sites of this time demonstrate a shift in settlement from more ephemeral and seasonally occupied structures, such as caves and small huts, to aggregations of ten or more small houses-in-pits with non-plastered floors and walls (Kelley and Searcy 2015).

Additionally, hearths were not finely constructed and structure entryways do not have a clear directional patterning (Kelley and Searcy 2015).

The Pilon phase is dated A.D. 900–950. This represents the middle of the Viejo and was initially defined by material remains over-laying the older Convento type-site (Di Peso 1974:137). Populations increased, based on a greater number of burials and the presence of a large community house. There is a transition to pithouses, though these are more irregular than houses-in-pits (Kelley and Searcy 2015). Most structures had plastered floors, walls and hearths.

Perros Bravos (A.D. 950–1200) is the last phase of the Viejo. Living spaces switched to clusters of aboveground adobe structures that might have had a palisade wall (Di Peso 1974:180; Kelley and Searcy 2015). Larger houses in this arrangement might indicate that people lived in these structures with non-kin. The change in village construction and aspects of material culture such as the appearance of shell jewelry and ball courts suggest the migration of people into the Casas Grandes region (Di Peso 1974:182; VanPool et al. 2008). These groups brought different ideas that represent the Aztatlan complex; behaviors associated with an elite merchant-class from southern Mexico and Central America (VanPool et al. 2008).

Medio Period

The Medio period (A.D. 1200–1450) represents a significant change in the archaeological record of the region (Philips and Gamboa 2015). Even large Viejo sites housed only extended families living in a few clustered surface structures surrounding plazas (Di Peso 1974:180; Kelley and Searcy 2015). During the Medio, we see rapid urbanization at Paquimé, a large, aboveground pueblo with extensive religious/ceremonial structures, and other large communities such as Galeana (Cruz et al. 2004). Based on Mesoamerican traits such as artifact types, architectural styles and early ethnohistoric accounts, many believe the settlement reflects the spread of Mesoamerican (especially West Mexican) culture and even people (Di Peso 1974; VanPool et al. 2008). Di Peso in particular proposed Mesoamerican traders brought with them the above traits and used their wealth and authority to bring about the construction of an urban center (Di Peso 1974).

Di Peso (1974) identified three Medio phases: the Buena Fe, Paquimé and Diablo. Buena Fe and the transition to the Medio period are typified by an increase in material goods (Di Peso 1974:298). Dates for the phases and abandonment are problematic and have led to a great deal of debate (Philips and Gamboa 2015). Some researchers, including Whalen and Minnis (2009), suggest separating the Medio period into Early and Late periods, with the Early Medio distinguishable by polychromes like Babicora, Dublan and Villa Ahumada (Whalen and Minnis 2009).

Regardless of the designations, during the 13th century, we see an increase in the manufacture of material goods of Mesoamerican influence, such as copper, turquoise and shell ornamentation. Additional Mesoamerican influences appear through architectural styles. Large aboveground pueblos appear, especially in the aggregated Paquimé (Di Peso 1974). Ballcourts were a hallmark feature of some Mesoamerican sites and these are present during the Medio period (Di Peso 1974). The nature of aggregation was a new concept in the region, especially at such a large scale. Along with the expanded, dense population, trade and material production/specialization are present at grander scales. Some aspects of religious iconography also shift during this time. One of the most apparent is the horned serpent, a religious figure common in Mesoamerican areas and one that is found with regularity among Casas Grandes groups from Medio times onward (Di Peso 1974). There were also changes in ceramic technology, typified by an increase in jars, larger vessel sizes, the introduction of effigy vessels, and an increase in elaborate polychrome decoration (Rakita 2009; VanPool and VanPool 2007). Paquimé's Buena Fe population was likely one hundred to seven hundred individuals (Rakita 2009:38).

The Paquimé Phase marks the high point for the site. The city grew from single-level clusters of houses, to a substantial multi-leveled adobe complex (Di Peso 1974:313). Some aspects of the former site were repurposed, including the water system. New additional features were added to Paquimé's outskirts, including ball courts, effigy mounds, open 'stately plazas' and a marketplace (Di Peso 1974:313; Rakita 2009:40). It is important to note that public structures of this scale require ruling or elite oversight. This represents another substantial alteration from earlier times. Hundreds of surrounding sites are interpreted as satellite locations that were used to bolster specific resources and offer support to the burgeoning city (Cruz et al. 2004; Di Peso 1974:314). The population of Paquimé during this time was likely nine hundred to fifteen hundred people (Rakita 2009:40).

Certain products were primarily produced at Paquimé and widely distributed. These include pottery, shell ornaments, groundstone metates, agavaceous resources and macaws (Bradley 1996; Minnis 1988; Sprehn 2003; VanPool and Leonard 2002). As these goods were produced in the city and distributed, they were crafted at various levels of specialized production. These will be later discussed in a section focused on craft specialization. The next phase represents the time of abandonment, disaggregation and change.

The Diablo Phase remains are much different from the booming zenith of Paquimé. At its height, the population of Paquimé was likely fifteen hundred to two thousand (Rakita 2009:40). During this phase, significant portions of the city were abandoned, while others were repurposed and used until they reached a state of disrepair (Di Peso 1974:320). Ramps and other structures were built over previous architectural features. Some areas of the site were still occupied and production of distributable goods continued at a smaller scale (Di Peso 1974). Paquimé was eventually burned and abandoned around 1450 (Philips and Gamboa 2015). Di Peso (1974:320) suggested several hundred people were killed, their bodies scattered throughout the city, although Casserino (2009) suggests these bodies were deposited over a longer period of time. The reason for the collapse is indeterminate, and some argue it was likely the result of multiple causes. Climate change is evident at the time, and the bodies and burned site could represent an act of warfare (Di Peso 1974). Other significant Southwest sites were destroyed or abandoned around this time. Some believe groups revolted against Mesoamerican elites whom had ruled in the region for a substantial duration (Di Peso 1974; Philips and Gamboa 2015). While the causes are unclear, Paquimé is abandoned and the Casas Grandes region becomes a significantly different area, with disaggregated, smaller concentrations of people (Di Peso 1974; Philips and Gamboa 2015; Rakita 2009).

Casas Grandes Pottery

Casas Grandes ceramic types are split between the Viejo and Medio periods, with some overlap between the two. Types are primarily differentiated by finishing techniques and painted elements (Brand 1935; Sayles 1936; VanPool et al. 2008:60). Viejo types include: Anchondo Red-on-Brown (R/Br), Leal R/Br, Pilon R/Br, Fernando R/Br, and Mata R/Br textured (Di Peso et al. 1974; VanPool et al. 2008:59). Anchondo R/Br is completely polished, and is decorated with 'V' and star pattern bands (VanPool et al. 2008:63). Leal R/Br is identified by surface polishing except for painted elements. Designs include cross-hatching, 'V' shapes and small circles/dots (VanPool et al. 2008:63-64). Pilon R/Br vessels are only polished on red-painted areas, and have complex designs with narrow parallel lines (VanPool et al. 2008:64). Fernando R/Br is identified by polishing after painting. These typically have wide, solid design elements like rectangles and/or triangles (VanPool et al. 2008:64). Mata R/Br vessels have finely painted narrow lines that usually do not overlap scored or incised portions (VanPool 2008:64).

Some regional plainwares were constructed from the Viejo period through the end of the Medio period (A.D. 700-1450). Casas Grandes Plainware is brown in color, but can appear black if soot-covered, or red-brown if it was fired in an oxidized environment. It can have a wide range of surface treatments, including scoring, smoothing, polishing, incising, and, they might also be corrugated, punched or tool-punched (VanPool et al. 2008:60). Convento Plainware also has a variety of colors, including brown, black and red-brown. Surfaces are typically smudged with ‘fire clouds’ (VanPool et al. 2008:60). El Paso Brownware is either brown or dark brown with coarse sand tempering and a dark gray core (VanPool et al. 2008:62). It is not a Casas Grandes type, but is found in high numbers throughout the region. Playas R/Br has multiple variants with red-slipped smooth or polished vessels that are often incised, punched or scored (VanPool et al. 2008:62). Ramos Black vessels were fired in reduced oxygen conditions that produced a black appearance, and are often polished. Some have a red paste with a black core, while other variants have black paste with patches of red paint (VanPool et al. 2008:62). Ramos Plainware can be white, cream or coffee colored, with a light paste and fine temper (VanPool et al. 2008:62).

Polychrome vessels represent the main ceramic components of the Medio period. There are multiple variants for most types, but I will focus on the standard versions. Babicora Polychrome has thick red and black lines on a brown/orange surface, with a thin wash (VanPool et al. 2008:65). Jars are the most common vessel for the type. Carretas Polychrome is similar to Babicora, but has red and black sub glaze paint and does not have polishing (VanPool et al. 2008:65). Bowls are the most common Carretas form. Corralitos Polychrome is usually incised, or punched with a slipped surface, but is not always textured (VanPool et al. 2008:65). Thick red and black lines are typical painted elements. Dublan Polychrome has red and black lines that are closely painted together, textured shoulders and necks on jars, with a gray-brown surface (VanPool et al. 2008:66). They might also represent a Viejo-Medio transitional type. El Paso Polychrome vessels have red and black painted lines on an unslipped brown or black surface, and a dark gray, coarse-grained paste (VanPool et al. 2008:66). Huerigos Polychrome has black glaze paint, with white-slipped, black-lined interiors (VanPool et al. 2008:66). Ramos Polychrome have a light paste color, are polished, have a fine-grained temper, and red and black surface lines, with red portions outlined by black (VanPool et al. 2008:67). Gila and Tonto Polychromes have black and white elements on red slipped vessels (VanPool et al. 2008:67). Additionally, red paint is incorporated into the design of Tonto Polychromes. Escondida Polychrome has light pastes with red ribbon-like motifs (VanPool et al. 2008:67). Villa Ahumada vessels are constructed with a dark paste, white slip and red elements outlined by black (VanPool et al. 2008:67).

Sayles (1936) and Brand (1935) represent two of the early culture-historical researchers of the region, while Di Peso (1974) also provided many type definitions (Rakita 2009). The authors focused on the presence of ceramic motifs throughout time (Brand 1935; Sayles 1936). More recent works on Casas ceramics build on the prominent early studies by expanding on the ideas, tracking the occurrence of decorative elements. Rakita and Raymond (2003) noted these patterns and applied an evolutionary approach to identify a model of seriation for Casas Grandes ceramics. In their sample, Villa Ahumada was prevalent before most other Casas Grandes polychromes (Rakita and Raymond 2003). Whalen and Minnis (2009) found that Babicora is one of the oldest polychrome types in the region. Dublan and Villa Ahumada were introduced before 1300 A.D., during the Early Medio. The remaining polychromes, including Ramos, were produced after 1300 A.D. during the Late Medio (Whalen and Minnis 2009).

When considering the switch to ceramic specialists, researchers note that, intuitively, vessels should be more finely constructed. There have been few quantitative analyses to examine this conclusion in regard to total vessel shape and size. Geometric morphometrics offers effective means to study the morphology of ceramics and detect if, in fact, vessels are more uniform.

Geometric Morphometrics

Geometric morphometrics (GM) is the study of shape and its variation (Zelditch et al. 2012). The first major application of geometric morphometrics, by Kendall and Kendall (1980), was aimed at answering questions about alignments at Stonehenge and other megalithic structures. Since the initial foray, the methods have been used extensively in biology, paleontology and physical anthropology, and to examine organismal morphology (Zelditch et al. 2012), but less commonly in archaeology. The methods have also been greatly improved. Early applications were restricted to length, depth and width measurements (Zelditch et al. 2012). These measurements did not reflect non-linear data, which resulted in less informative conclusions regarding irregularly shaped objects. These studies also did not correct for size, which certainly affects shape data. Using primary, homologous landmarks effectively captures specific shape information about each specimen, but curvature data were still lacking (Zelditch et al. 2012). Secondary landmarks capture additional information by sampling points along homologous curves (Zelditch et al.

2012). Three-dimensional data goes even further in that it characterizes shaped surfaces completely, but the equipment needed to capture 3-D data is expensive and the results are difficult to present in a two-dimensional medium such as a journal page (Zelditch et al. 2012). In most cases, two-dimensional data sufficiently captures shapes and allows comparison/analysis.

Shape in geometric morphometrics is the geometric information that remains when location, scale and rotational effects are removed (Zelditch et al. 2012). This is accomplished during a process called Procrustes superimposition, which leaves only morphological information. Morphometricians create Procrustes superimposition by fixing the homologous landmarks recorded on different objects to a single, fixed point called the centroid. This is a center point, representing the geographical average of the landmarks. The landmarks for each individual object are then "scaled", keeping their relative position the same so that the amount of variation between it and the other objects is minimized (Webster and Sheets 2010; Zelditch et al. 2012). For example, if two projectile points shared the exact same proportions with the exception that one was half the size of the other, Procrustes superimposition would scale both sets of landmarks so that they were overlying one another. By doing so, this process removes size differences and allows differences in shape to be isolated.

Variables related to size are more difficult to define, as they are case-dependent. Size can refer to inter-landmark length, square roots of area, and sums of inter-landmark differences (Zelditch et al. 2012). This should not be conflated with absolute size, but instead measures how far points are from the centroid.

Shape is measured using landmarks, which come in three types: primary, secondary, and tertiary (also called sliding). Primary landmarks are homologous, unambiguous loci such that they designate corresponding points that match within and between populations (Zelditch et al. 2012:461). A secondary or semilandmark is a point on a curve, edge, or surface that is defined in terms of its position on a feature (Zelditch et al. 2012:466). These are used to incorporate information about curvature in a geometric analysis. While they provide less specific information than primary landmarks, they are necessary to capture additional shape variation, such as that resulting from curvature. Sliding or tertiary landmarks comprise a third type, and are often conflated with semilandmarks. These extend the Procrustes superimposition procedure and are captured by sliding points along the outline of a curve until best fit (Perez et al. 2006:770). The measured curves should be homologous among subjects, but the individual points along those curves can vary (Perez et al. 2006). Further, tertiary landmarks might not be useful as stated landmarks, but can still provide meaningful data. One of the most notable morphometricians, Bookstein, (1991) stated that: landmarks should be locally defined, and that the explanations for which landmark data can be used should receive strong consideration.

Additionally, there are five important criteria for landmark designation. The first is homology, which specifies that the points on one specimen correspond to the same points on others (Zelditch et al. 2012). In recording ceramic vessel shape, points should be consistently placed at the widest points of the rim, as an example. Second is adequate coverage of form. Landmarks must adequately capture shape in order to detect corresponding geometric variation. Circular artifacts require additional secondary and tertiary landmarks to effectively record curvature. The third criterion is repeatability. Landmark positions should be found reliably, as difficulty in locating specific positions would result in error with repeated measurements (Zelditch et al. 2012). Secondary landmarks record a region or part of a feature, which creates some ambiguity. Clearly defining the number and general location of landmarks is key. Fourth is consistency of relative position. It is important that landmarks do not switch positions relative to each other. Landmarks should be recorded in the same order for each artifact in a group. Altering the designation order could lead to significant errors in results. The fifth and last criterion is only applicable to two-dimensional landmarks. In such cases, landmarks must lie within the same plane (Zelditch et al. 2012). Attempting to record or interpret three-dimensional aspects using two-dimensional software such as tpsDIG2 and CoordGen8, which are used here, negatively affects shape data.

Criterion 5 touches on an issue central to this analysis: projecting a three-dimensional object, such as a Casas Grandes pot onto a two-dimensional plane can cause distortion, which can skew results and interpretations. With photographs of pottery, the images must be taken from a consistent angle in order to adequately assess shape variation. Here I use only head-on photos (Image 2) where the edge and rim of the pot are clearly visible to minimize minor variation and ensure comparable data. Images such as Image 3 (downward-angled pot) were not used, because even this slight skew greatly alters the shape data relative to the head-on profile.

Plate 2. Head-on Photograph, No Angling, of a Villa Ahumada pot, included in the sample

Courtesy of El Paso Museum of Archaeology, photograph by Christine VanPool

Plate 3. Photo of a Carretas pot, taken at downward-facing angle, which causes parallax relative to Plate 2 and prevents its inclusion in this study.
Courtesy of the Centennial Museum at the University of Texas El Paso, photograph by Christine VanPool

In some cases, such as this study, there might be no primary landmarks. Capturing the curvature of pottery requires secondary and tertiary landmarks, because there are no discrete, homologous locations on rounded objects. Instead, consistently recorded secondary landmarks capture a point on a feature, such as the highest midpoint of the rim, lowest midpoint of the base, or widest points of the vessel body. Other instances require only primary landmarks, such as a projectile point recorded by designating the tip and points of the base-blade junctions. Most morphometrics studies assessing projectile points also record secondary landmarks to include blade edge.

Geometric Morphometrics in Archaeology

Geometric morphometrics has only recently been consistently applied to archaeological analyses and the number of studies using the methods has increased drastically during the last ten years, spurred by Slice's (2007) description of their utility. Most applications focus on Paleoindian projectile points or bioarchaeological analyses (Buchanan and Collard 2010; O'Brien et al. 2014). In one of the most well known applications, Buchanan and Collard (2010) used geometric morphometrics to evaluate projectile point shape, finding that typological categorizations do not adequately reflect the archaeological record, especially when considering shape. One minor concern is that the study did not account for base shapes at hafting locations, which, other authors argue, is the least likely area for reshaping (Goodale et al. 2015). Including the entire outline of each point's base could provide additional shape information, but, despite any possible flaws, this study helped pave the way for later archaeological applications.

O'Brien et al. (2014) also used morphometrics to study Paleoindian points, finding less variation in those from the Southwest and Plains than the eastern portion of North America. The authors then used a phylogenetic approach to examine patterns in point shape and cultural transmission. Related studies followed the trends set by Buchanan and Collard (2010) and O'Brien et al. (2014). Gingerich et al. (2014) use 3-D morphometrics to assess fluted point manufacture. Results demonstrate difficulties in differentiating ‘styles’, but effectively identified individual artifact producers in an experimental setting. Conclusions also indicate a potential shift in production techniques identifiable through flake scar patterns (Gingerich et al. 2014).

Although more limited, some analyses have focused on pottery. Selden et al. (2014) use 3-D geometric morphometrics to capture the shapes of Caddoan pots, which were then repatriated through the Native American Graves Protection and Repatriation (NAGPRA) act. The study argues for increasing use of morphometrics as a means of digital curation, for later study and exhibition (Selden et al. 2014). In another work focused on ceramics, Wilczek et al. (2014) use 2-D geometric morphometrics to assess ceramic typologies by capturing vessel profiles and surface faces. The study primarily demonstrates that morphometrics methods are useful for studying the shape-based classification of ceramics, and could be useful in determining levels of standardization.

The Standardization Hypothesis

Archaeologists recognize that the organization of production is a central component of economic organization within a culture, and have developed various methods to measure it (Costin 1991). Specialized craft production stretches on a continuum from each individual within a larger group making a product, to a single individual or group of individuals making the product for a larger social group above the household level. While in truth a continuum, a useful approach is to distinguish between “generalized production”, in which members of each household make the product for that household's consumption, and "specialized production" in which a limited number of individuals organized above the household level make the product for a community.

One of the most effective means of identifying the presence of craft production above the household level is the Standardization Hypothesis (Crown 1995). The Standardization Hypothesis holds that the morphology of artifacts becomes more standardized as specialization increases, because: 1) there are fewer producers manufacturing any given number of artifacts relative to the number of generalized producers required to make the same number of artifacts; 2) specialized producers have more skill and are therefore more able to make better formed/more standardized artifacts relative to generalized producers; 3) specialized manufacturers focused on streamlining production will establish habits and production sequences that efficiently produce the product; and, 4) standardization allows consumers not directly involved in production to evaluate the suitability and quality of a product (Costin 2001; Costin and Hagstrum 1995). In this context, then, standardization is the reduction of artifact variation (VanPool and Leonard, 2002). Items produced by specialists tend to be more uniform than those made by non-specialists, and uniformity can refer to many aspects of each object, but is especially focused on morphology (VanPool and Leonard, 2002). An assemblage cannot be completely standardized, but is instead considered standardized relative to other groups of artifacts (VanPool and Leonard, 2002). The subject has a long history of study. Early standardization works were published in the 1960's and focused on assemblages from North Africa to Rome (Balfet 1965; Rottlander 1966). Since that time, the topic has received a great deal of attention in experimental studies and ethnographic analyses (Costin and Hagstrum, 1995; Crown 1995; Eerkens and Bettinger 2001).

Two such studies outline guidelines for recognizing standardization through the use of coefficients of variation. The coefficient of variation (CV), which is the standard deviation standardized by the mean, is a unit-free percentage that measures the dispersion of a probability distribution regularly used to measure precision and repeatability (VanPool and Leonard 2011:54-56). Eerkens (2000) conducted an experimental study in which 30 individuals were asked to reproduce a number of artifacts from memory, after the artifacts were recently viewed, or in repeated productions—recreating the same artifact 20 times consecutively. The resulting coefficient of variation of 4-5% provides a guideline for construction from memory. When constructing an item from memory, variation from 4-5% is the limit of human ability to morphologically standardize the object.

Crown (1995) focused on the production of Salado polychromes, including standardization and specialization. Through a sample collected from previous authors with ethnographic and historic collections, she proposed that ceramic specialization is indicated by coefficients of variation approximately 10% or less. Based on common metric traits, ceramic types with coefficients of variation of roughly 10% were likely produced by specialists, though she concluded that declining CVs that were above the 10% threshold likely reflected increased specialization. These CVs were associated with large vessels used for feasting that were likely made by only the most skilled potters. VanPool and Leonard (2011:138–

142) further considered Crown's data, and determined that the products of specialized producers can be expected to be above the 10% cut-off 37% of the time (i.e., the 10% demarcation will misclassify products made by specialists roughly 1 out of 3 times). They conclude that the 10% cut-off is excessively conservative, and instead propose that any assemblage with CVs between 10% and 14% could reflect specialist or generalist production (24% of the assemblages produced by specialists and 33% of the assemblages produced by generalists fall within this range). Following Crown's (1995) logic though, decreasing CVs through time and/or across ceramic types are likely to reflect differences in the organization of production, even in cases when the CV is above 10% so long as it is below 14%.

Since Crown's (1995) study, the Standardization Hypothesis has been used to examine the amount of morphological variation of multiple artifact types, especially pottery, but also ground stone and flaked stone (Arnold 2000; Blackman et al. 1993; Eerkens and Bettinger 2001; Rice 1991; VanPool and Leonard 2002). With this approach, researchers found a way to assess the degree of standardization and determine if craft specialists were present in a prehistoric group.

There are additional factors that can affect the degree of standardization. Costin and Hagstrum (1995) make a distinction between two types of standardization. Mechanical standardization is the unintentional decrease in variation due to repeated production by the manufacturer (Costin and Hagstrum 1995). Intentional standardization is found in aspects of an artifact that are consciously made more uniform by the producer and impact performance characteristics, which make an item useful for a task (Costin and Hagstrum 1995).

The authors conclude that the Standardization Hypothesis should be applied to attributes of mechanical standardization, but not those that were intentionally standardized. Perimeter shapes of ceramics are not central to performance characteristics, and are, therefore, not intentionally standardized, but represent mechanical standardization.

Another useful distinction is the difference between attached and independent specialists (Costin 2001). Attached specialists are sponsored by (and hence attached to) elites who have them produce specialty items that serve as badges of rank. Independent specialists, in contrast, produce materials for some sort of open market, in which they compete for others' resources. While attached specialists can make standardized crafts, there are also times in which originality or creative elaboration are valued specifically because the elites wish to have distinctive items (e.g., elaborate statues or decorated swords). In these cases, the Standardization Hypothesis might not be applicable. In contrast, the Standardization Hypothesis will more consistently be applicable in contexts of crafts made by independent specialists, given that the consumers will want to be able to easily evaluate the qualities of the potential purchases and compare between them. Standardized items will facilitate this comparison while also facilitating efficient production, meaning that those craftspeople who standardize their wares have a benefit in the marketplace (Costin 2001; Costin and Hagstrum 1995). Still, it would be incorrect to conclude that the Standardization Hypothesis will never be applicable in the context of attached specialists, or will always be applicable in the context of independent specialists.

Specialized Production in the Medio World

As previously mentioned, a number of studies address standardization and specialization of Casas Grandes artifact types. Bradley's (1996) dissertation examined shell exchange networks centered at Paquimé. Comparisons of worked shell specimens from many Casas Grandes sites found consistent design elements and morphologies. While specialization was not directly stated, Bradley notes strong shape and design uniformity that might indicate craft specialists. The conclusions correspond well with Di Peso and Fenner's (Di Peso et al. 1974) original analysis. Rakita and Cruz (2015) state that most shell at Paquimé was in finished form, indicating that the region's type-site was largely a consumer of the product, not a substantial producer. Interestingly, most of the 3.7 million shell beads were cached in several large rooms. The sheer number demonstrates their importance at the site, likely as an ideological symbol (Rakita and Cruz 2015; Whalen 2013).

Minnis' (1988) publication focused on shell, macaws, turkeys and agave products from Paquimé. Production of the four items was specialized to various degrees at the regional center. Shell and macaws were less centralized, indicating more potential production by non-specialists, though Paquimé was likely the primary area provider of those resources. When considering abundance and intra-site location, turkeys and agave resources were likely more centralized and distributed in relatively close proximity. Rakita and Cruz (2015) find more evidence of agave and macaw specialization at Paquimé than other products.

VanPool and Leonard (2002) analyzed specialized ground stone, specifically metate construction at Paquimé. Square-cornered metates recovered from the site yield less variation than other types, indicating construction by specialists. They also mention that craft specialists might have produced other metate forms, but performance characteristics central to use could have led to increased variation (VanPool and Leonard 2002). Other forms also might have been constructed at an earlier date.

Maria Sprehn's (2003) dissertation examined ceramic specialization in the Casas Grandes system. A large sample of Casas pottery types was measured in terms of height, circumference, line width, sponsored production and political and economic symbolism. Ramos variants showed the most indications of specialization and the greatest dispersal in the region. Results point to a well-established trade network organized through Paquimé. In a separate, more recent study, Rakita and Cruz (2015) find standardization of symbolic images on Ramos vessels, although they note that not all archaeologists are convinced Ramos was made by specialist producers. Paquimé might not demonstrate goods suggesting large-scale full-time ceramic specialists, but there is evidence for some specialization above the household level.

Chapter 3

Research Design and Results

The focus of this research is to apply the Standardization Hypothesis using geometric morphometric methods to determine which, if any, of the Chihuahuan polychromes were produced by specialists above the household level. Dr. Christine

VanPool provided scaled photographs of Casas Grandes pots from her dissertation research. As previously mentioned, only photographs directly facing the front of each vessel, head-on, were analyzed. The pots used here are also ideal types. Type designations can be difficult at times, but the pots chosen for this analysis are ideal versions, and thus are more easily distinguishable than most.

Images from a total of 89 pots were separated by type and include 20 Babicora, 10 Carretas, 4 Corralitos, 6 Dublan, 20 Ramos, 2 Santa Ana, 11 Viejo and 16 Villa Ahumada vessels. Kelley and Searcy (2015) note that there is a great deal of inconsistency in classification and definition of Viejo subtypes. Because of these issues, Viejo subtypes were collapsed into a single category. All of the vessels used in this study are curated at four Southwest museums: the Miles Museum at Eastern New Mexico University, Portales; the El Paso Museum of Archaeology; the Centennial Museum at the University of Texas El Paso; and, the Laboratory of Anthropology Museum in Santa Fe, New Mexico.

The software program tpsUtil was used to convert each group of photographs into tps files. This was necessary in order to use common geometric morphometrics landmark placement and analytical packages, grouped into Integrated Morphometrics Package 8 (IMP8). Landmarks were placed for each pot with tpsDIG2. Because ceramics do not have discrete, homologous points matching within and between populations, no primary landmarks were used. Instead, six secondary landmarks were designated on each vessel to indicate points on a curve defined in terms of positions on a feature (Zelditch et al. 2012). Beginning at the left edge of the rim’s lip, and moving clockwise, the six secondary points were:

1. The beginning of the left edge of the rim's lip;
2. The middle of the rim, which was found using tpsDIG2's measuring tool;
3. The right edge of the rim's lip;
4. The widest right point of the vessel body;
5. The midpoint of the base, which was found by using the measuring tool to bisect the pot by clicking on landmark 4 and the widest left point of the body, determining the middle of the resulting line, and drawing another line from the midpoint to the pot's base;
6. The widest left point of the vessel body;

15 sliding landmarks were placed between each set of secondary landmarks starting with 1 and 2, and moving clockwise. Each set of 15 was resampled, which is a process during which they are placed equidistant along the curve created by the sliding landmarks. This resulted in a best fit that optimally captured the outline of each curve. The procedure produced 90 tertiary and 6 secondary landmarks for each pot, which seems to effectively characterize the vessels' shapes without oversaturating the shape data.

Plate 4. Ramos Vessel with Landmarks (gray dots are secondary landmarks; sliding landmarks were placed around the vessel's perimeter)

Courtesy of El Paso Museum of Archaeology, photograph by Christine VanPool

The tps data was then checked for inconsistencies in the number and placement order of landmarks. This cleaning process confirmed that each pot had the same number of landmarks, recorded in the same order. Consistencies in both are necessary in order to then measure/compare variation. CoordGen8 is a program used to analyze geometric morphometric tps data. It was used to create Procrustes superimposition graphs for each ceramic type, resulting in figures that allow one to visually assess variation (Figure 1). The Procrustes superimposition (Figure 1) displays recorded Ramos secondary landmarks. Each circle is an individual landmark, while the darker center of each cluster is the average.

Figure 1. Secondary Landmark Procrustes Superimposition for Ramos

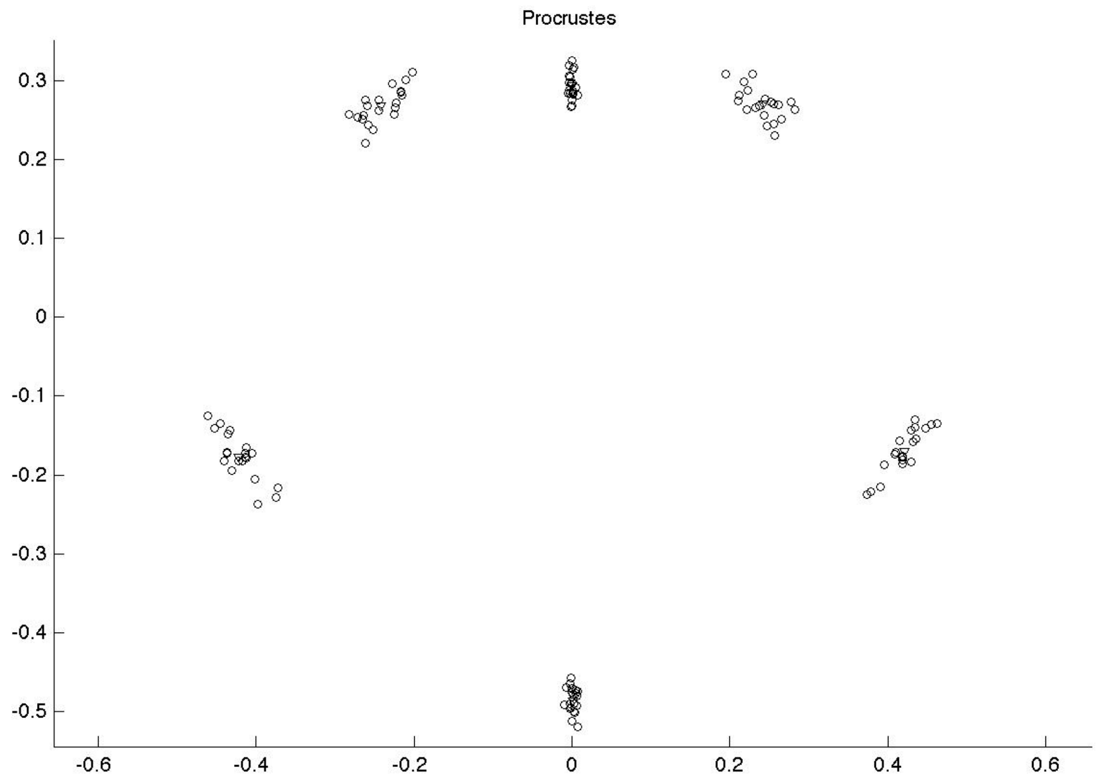
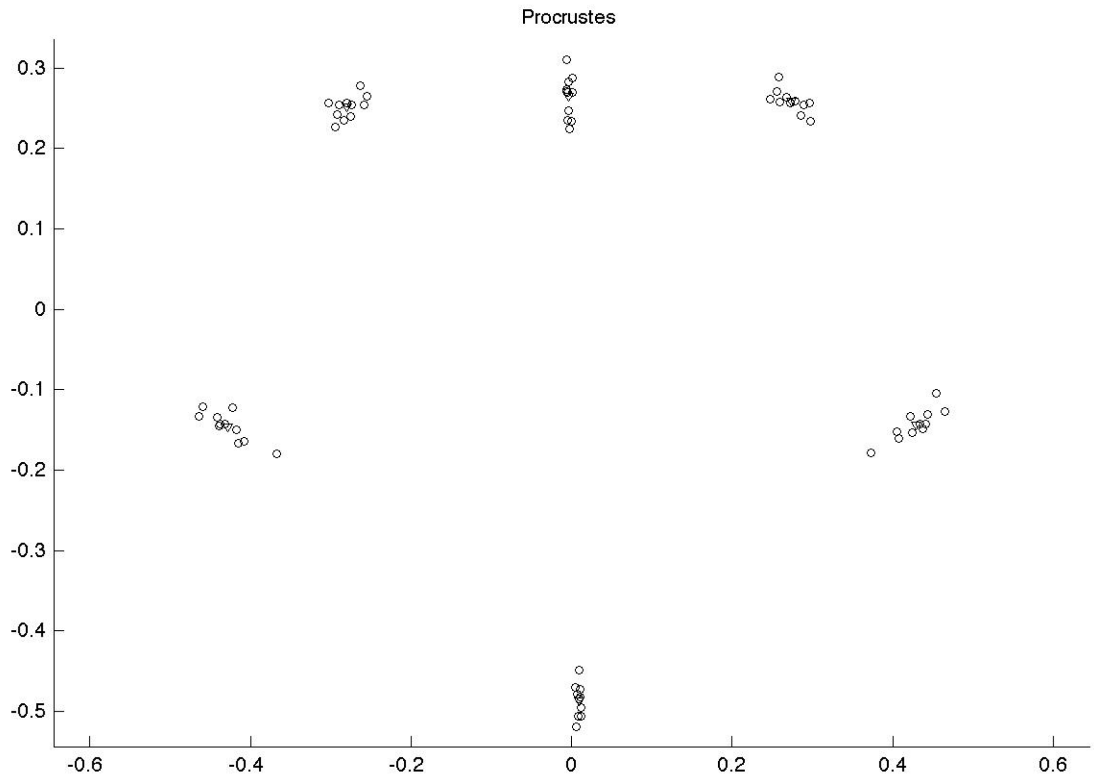


Figure 2 reflects the secondary landmark geometric morphometric data for the Viejo period pottery. Given that the Viejo types are the earliest pots and are certainly associated with household production, they serve as a good marker of the variation typical of generalized production.

Figure 2. Secondary Landmark Procrustes Superimposition for Viejo



The visual differences can be quantified. Procrustes results give statistics, including morphological variances, shape and size means, and standard deviations. 'Simple statistics', a feature within CoordGen, gives information of two types: shape and size. To examine size, I used Traditional Morphometrics Generator (TMorphGen), a program within CoordGen, to take separate measurements based on secondary landmarks. The software requires a protocol that specifies measurements between specific points. In this case, I set it to record three distances: between Landmarks (LMs) 1 and 3 (used to determine rim diameter; line 1 on Figure 3), LMs 4 and 6 (vessel body width; line 2), and the lines from LMs 2 and 5 (vessel height; line 3). The results reflect attributes comparable to those possible using calipers to measure outer rim diameter, maximum pot width, and vessel height. These measurements are consequently the most easily quantified using standard statistical approaches and are most similar to the data used for analyses such as Crown (1995) based on the Standardization Hypothesis. As mentioned, studies by Crown (1995) and Eerkens (2000) indicate that specialization is recognizable by coefficients of variation equal to or less than 10%. Graphical illustrations of the measurements are presented in Figures 3-10 and results of descriptive statistics, including coefficients of variation, are presented in Tables 1-3.

Figure 3. Babicora TMorphGen Measurements

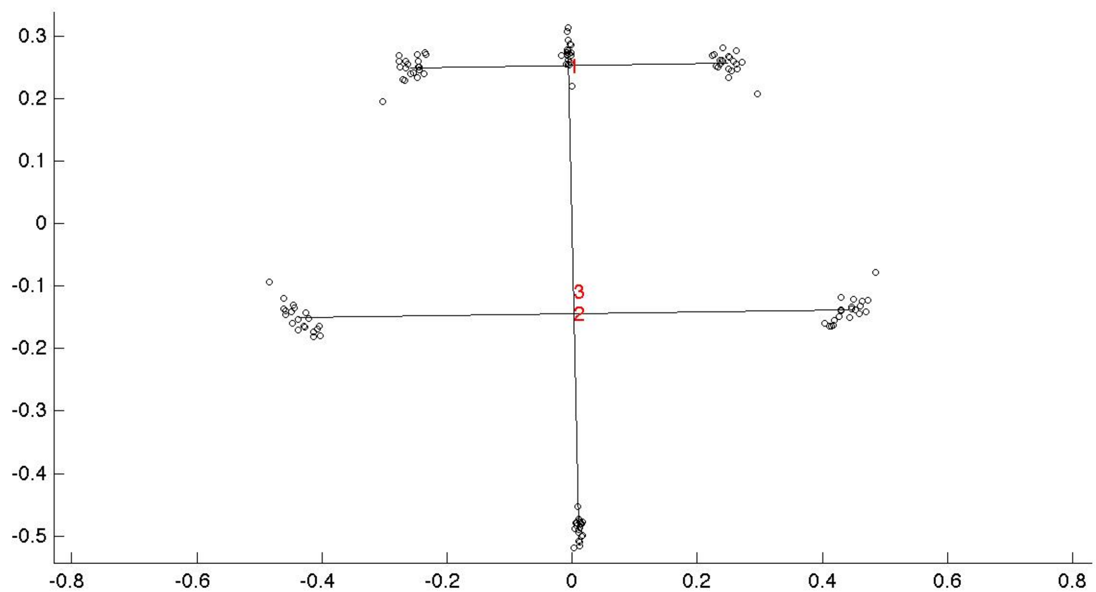


Figure 4. Carretas TMorphGen Results

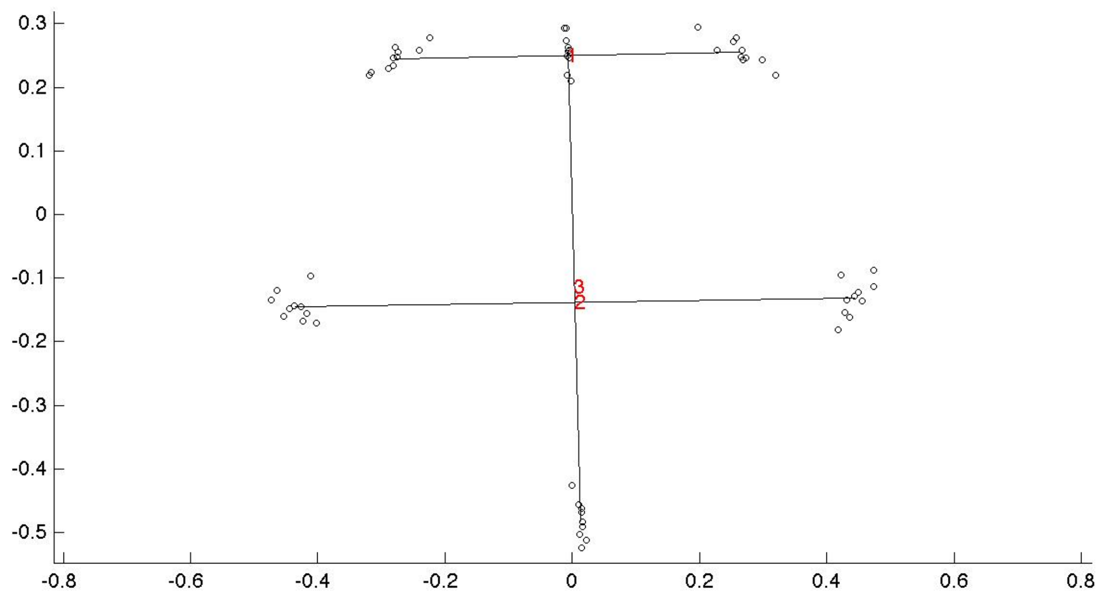


Figure 5. Corralitos TMorphGen Results

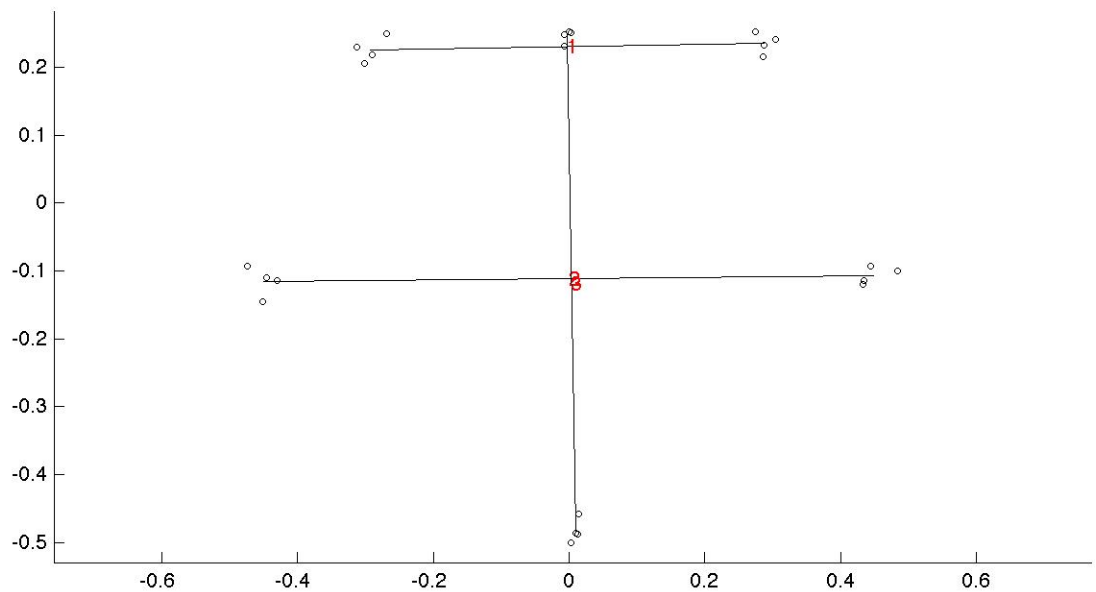


Figure 6. Dublan TMorphGen Results

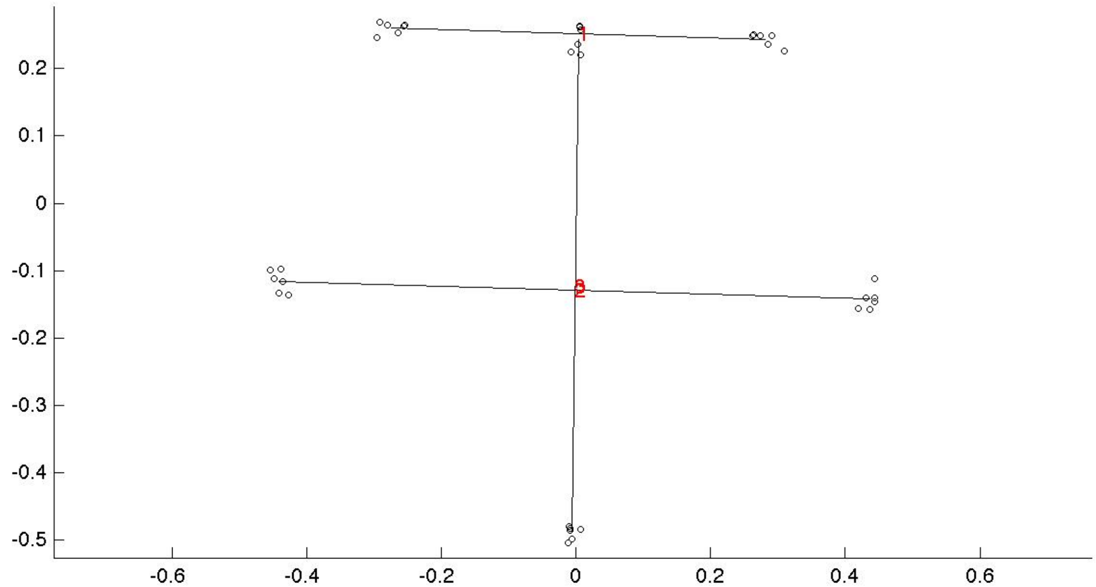


Figure 7. Ramos TMorphGen Results

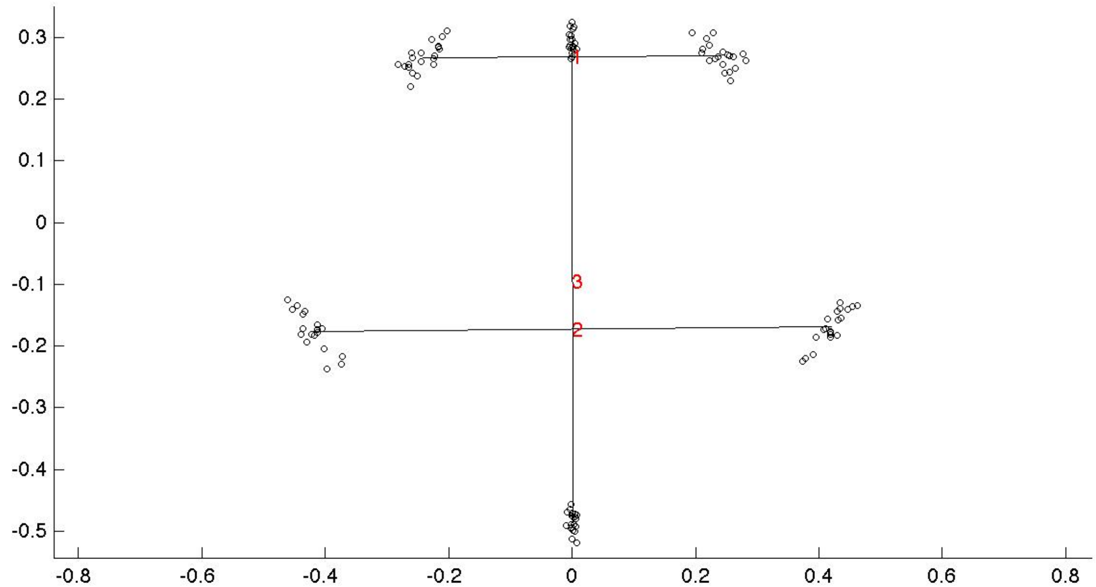


Figure 8. Santa Ana TMorphGen Results

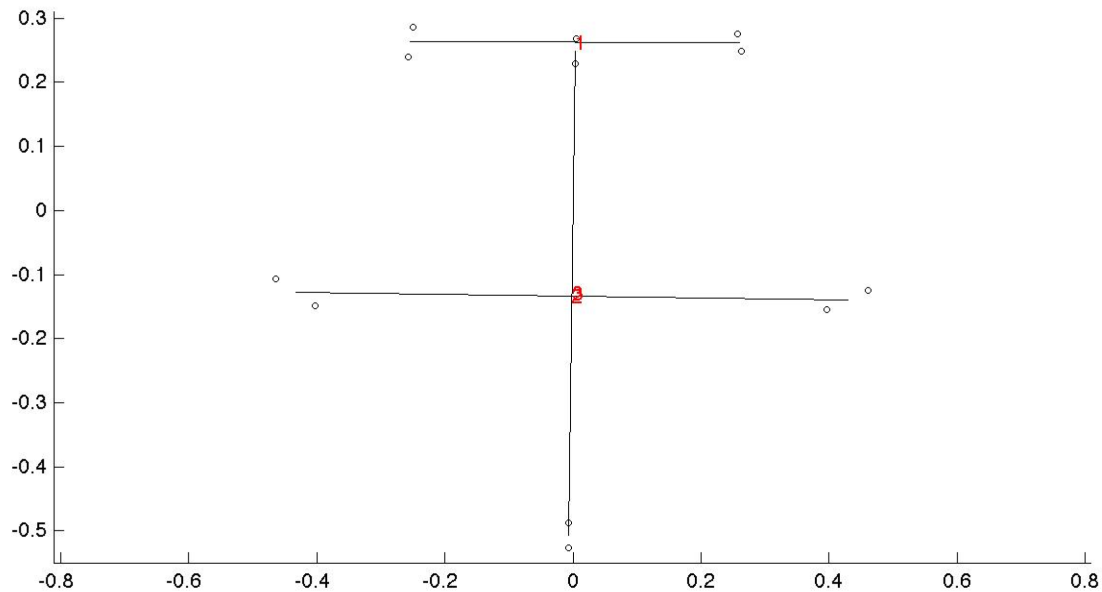


Figure 9. Viejo TMorphGen Results

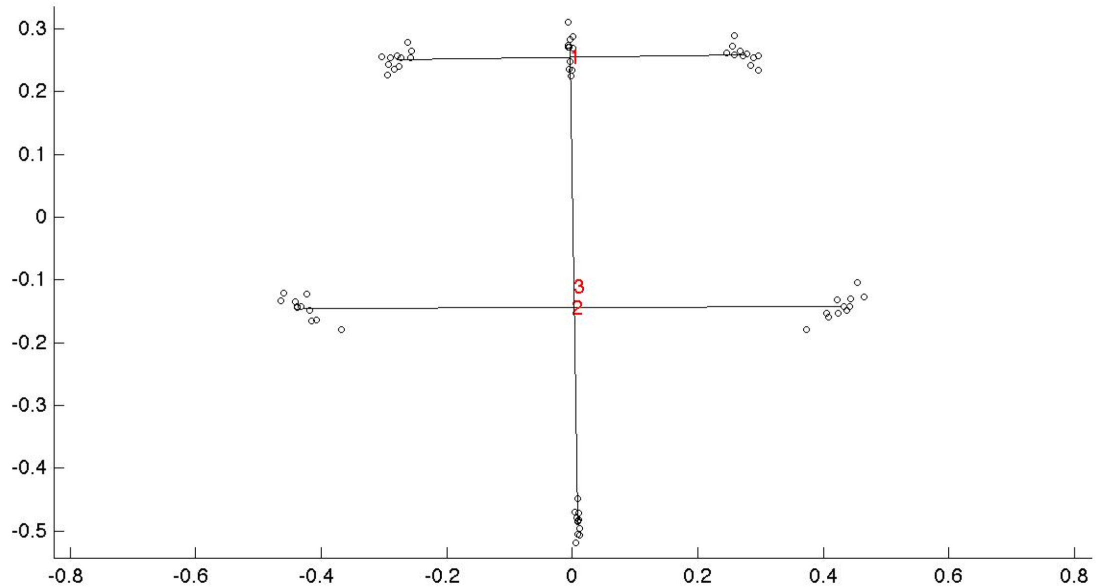


Figure 10. Villa Ahumada TMorphGen Results

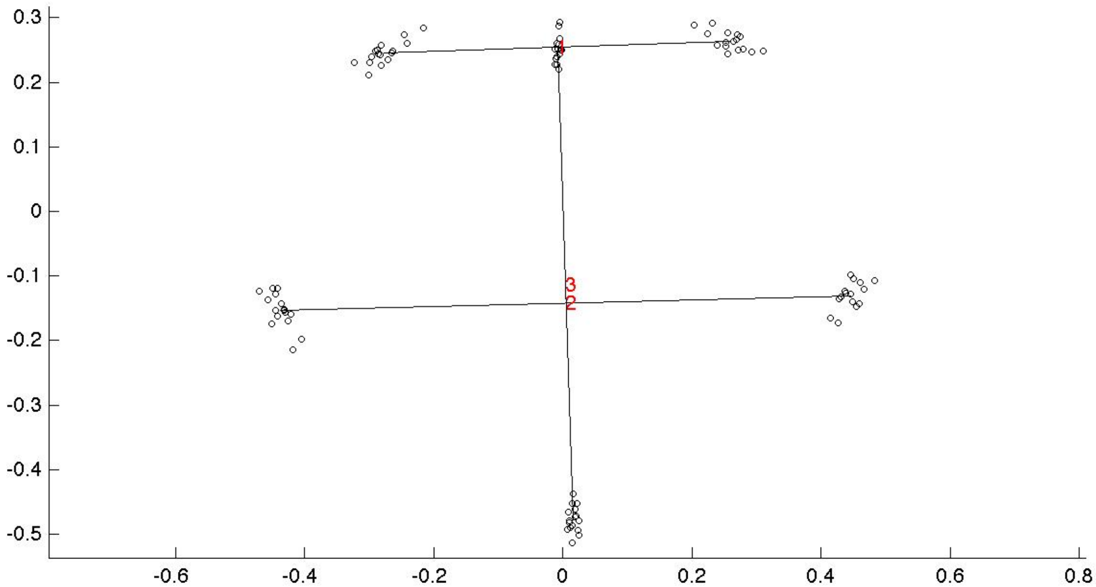


Table 1. Rim Diameter Data by Type, Lowest to Highest CV*

Type and Sample Size	Average (cm)	Range (cm)	Standard Deviation (cm)	Corrected CV*
Babicora (n=20)	11.4	5	1.4	12
Ramos (n=20)	11.6	5.9	1.4	12
Carretas (n=10)	10.3	4.7	1.5	14.7
Villa Ahumada (n=16)	10.3	9.6	1.6	15.6
Viejo (n=11)	9.5	5.9	1.8	19.4
Types with Small Sample Sizes				
Corralitos (n=4)	10	3.2	1.3	14.2
Santa Ana (n=2)	13.1	2.4	1.7	14.6
Dublan (n=6)	9.5	5.3	1.9	20.9

Table 2. Vessel Body Width Data by Type, Lowest to Highest CV*

Type and Sample Size	Average (cm)	Range (cm)	Standard Deviation (cm)	Corrected CV*
Ramos (n=20)	20.3	7.6	2.3	11.7
Babicora (n=20)	19.8	10.1	2.7	13.6
Carretas (n=10)	16.9	8.3	2.4	14.7
Villa Ahumada (n=16)	17.1	10	3	17.7
Viejo (n=11)	14.6	8.7	2.9	19.9
Types with Small Sample Sizes				
Corralitos (n=4)	15.5	5.9	2.6	17.6
Santa Ana (n=2)	22.1	6.5	4.6	23.5
Dublan (n=6)	15.1	10.6	3.7	25.8

Table 3. Vessel Height Data by Type, Lowest to Highest CV*

Type and Sample Size	Average (cm)	Range (cm)	Standard Deviation (cm)	Corrected CV*
Ramos (n=20)	18.8	7	2.2	11.7
Babicora (n=20)	17.1	9.1	2.22	13.1
Viejo (n=11)	12.8	7.9	2.4	18.8
Villa Ahumada (n=16)	14.25	10	3.4	24
Carretas (n=10)	14.4	11.3	3.5	24.8
Types with Small Sample Sizes				
Santa Ana (n=2)	19.1	1	0.7	4.2
Corralitos (n=4)	12.5	2.7	1.2	10.1
Dublan (n=6)	12.6	8.9	3.1	25.5

Based on common ceramic measurements, Ramos and Babicora have substantially less size variation than other types, including the least amount of variation in vessel body width, rim diameter, and vessel height. Santa Ana and Corralitos also have low variation, but these results could be due to small sample sizes. The other pottery types are similar to the Viejo period pottery, suggesting that

Ramos and Babicora were produced by specialists above the household level, while the other pottery was made by generalists operating at the household level.

The metric data considered above only reflects size, as opposed to shape data. To also examine shape data, I calculated CVs for each ceramic type based on the relative location of the secondary landmark data, as opposed to linear measurements between set points (i.e., how close are the landmark 1 measurements to each other, the landmark 2 measurements to each other, and so forth). This information includes both shape and size (Table 4). The software allows this comparison by calculating both an average and standard deviation as part of the "Simple Statistics" option based on their distance from the centroid, but these values correlate to the number of landmarks considered (e.g., an average based on 7 landmarks is expected to be larger than one based on 6 landmarks for no other reason than the increased number of landmarks). As a result, the CVs cannot be directly compared to a demarcating cut-off such as 10%, simply because values above and below 10% can be obtained from the same data by simply changing the number of landmarks considered. Put another way, the fact that the CVs presented in Table 4 seem roughly comparable to those considered above does simply reflect that I used 6 landmarks. If I had measured 9, 50, or 100 landmarks instead, the CVs would be considerably smaller, depending on the number of landmarks. Still, general trends in relative CV values will reflect differences in the relative standardization of pottery types.

Table 4. Secondary Landmark Corrected Coefficients of Variation

Type and Sample Size	Standard Deviation Centroid Size	Mean Centroid Size	Corrected CV*
Ramos (n=20)	2.5	24.2	10.5
Babicora (n=20)	2.7	22.5	12.2
Viejo (n=11)	3.1	17.1	18.5
Carretas (n=10)	3.5	19.3	18.6
Villa Ahumada (n=16)	3.9	19.4	20.4
Types with Small Sample Sizes			
Santa Ana (n=2)	2.8	25.4	12.4
Corralitos (n=4)	2.2	17.2	13.6
Dublan (n=6)	4.1	17.2	24.8

Again, Ramos and Babicora produce CVs substantially smaller than the other pottery types, which correspond well with the Viejo period pottery made by generalized producers. This means that Ramos and Babicora are more standardized than the other types when both *size* and *shape* are considered at the same time.

The CoordGen Simple Statistics feature also produces a measure that gives statistical information that has removed size using Procrustes superimposition, reflecting *only* differences in shape. As mentioned, during Procrustes superimposition, the set of landmark coordinates for each specimen are centered at their origin, or centroid. The program then places each object at the same spot and the landmarks are rotated so as to minimize size variation (Zelditch et al. 2012).

CoordGen produces shape variances, separated by type, which provides a way to assess shape variation with size data removed. These values do not correlate with the number of landmarks, but they also do not provide a mean value, making it impossible to calculate CVs. For this portion of the analysis, I input secondary and tertiary landmark data for a total of 96 landmarks, which capture the entire perimeter of each pot (Figures 11-18). Though they are difficult to see due to overlapping, the average for each sliding landmark is marked as a triangle.

Figure 11. Babicora SLM (sliding landmark) Procrustes Superimposition

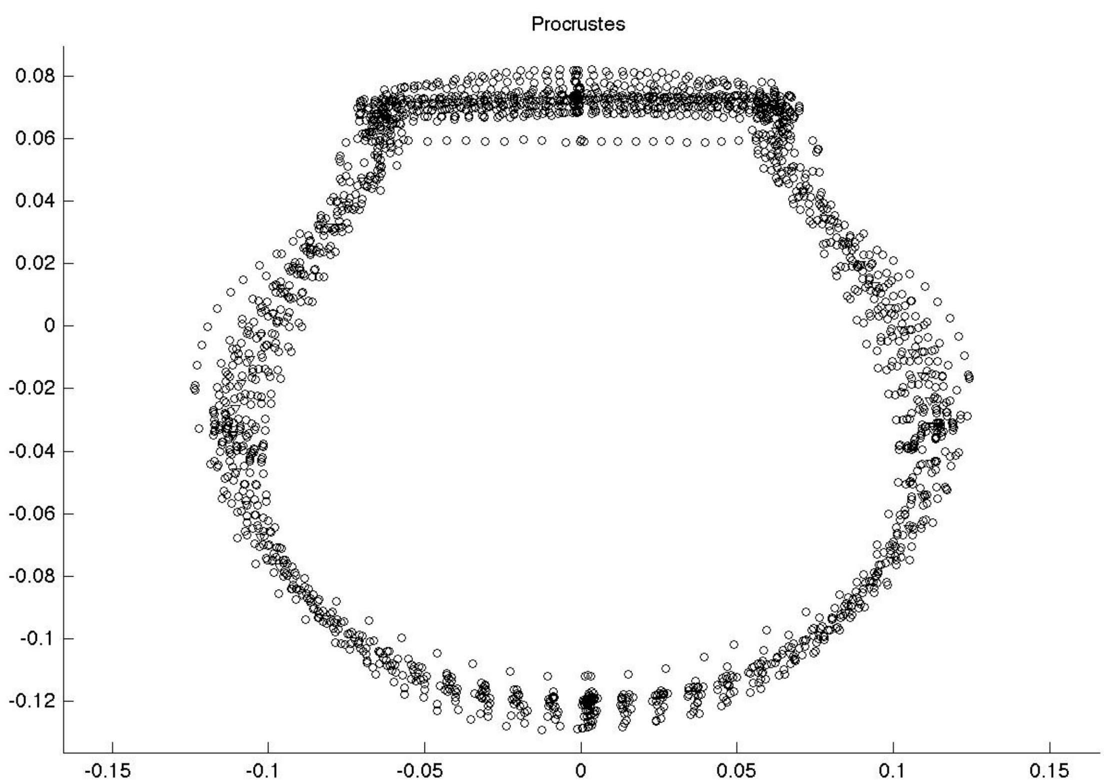


Figure 12. Carretas SLM Procrustes Superimposition

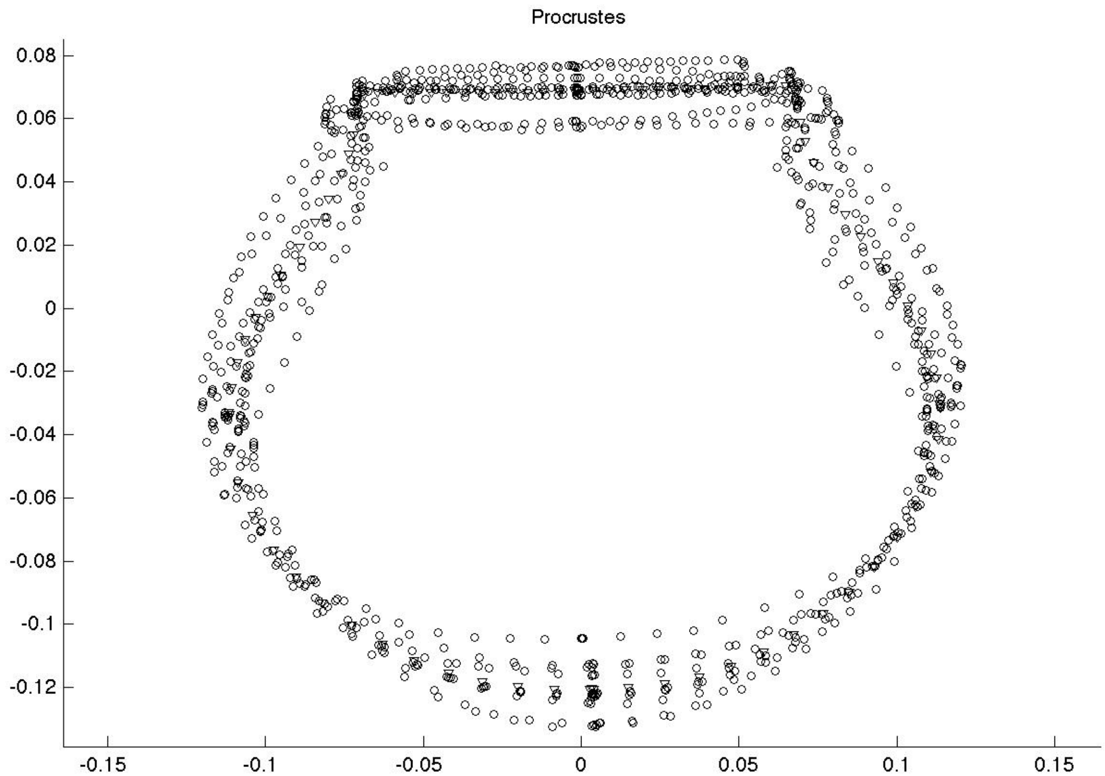


Figure 13. Corralitos SLM Procrustes Superimposition

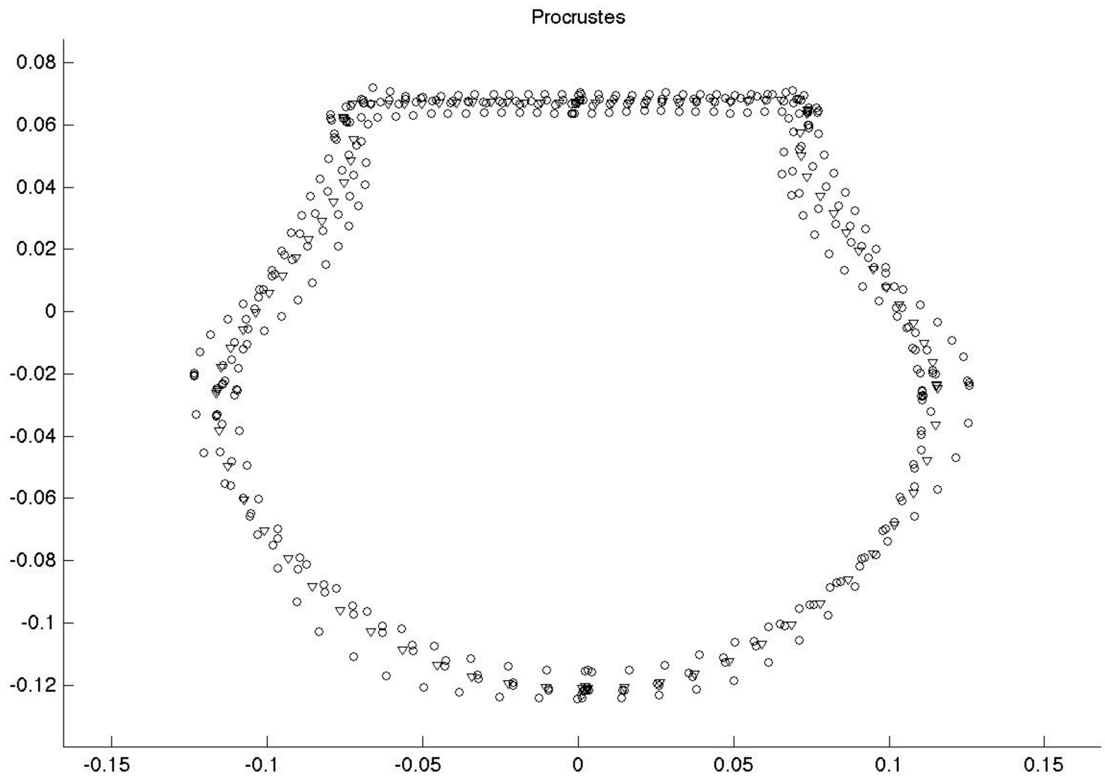


Figure 14. Dublan SLM Procrustes Superimposition

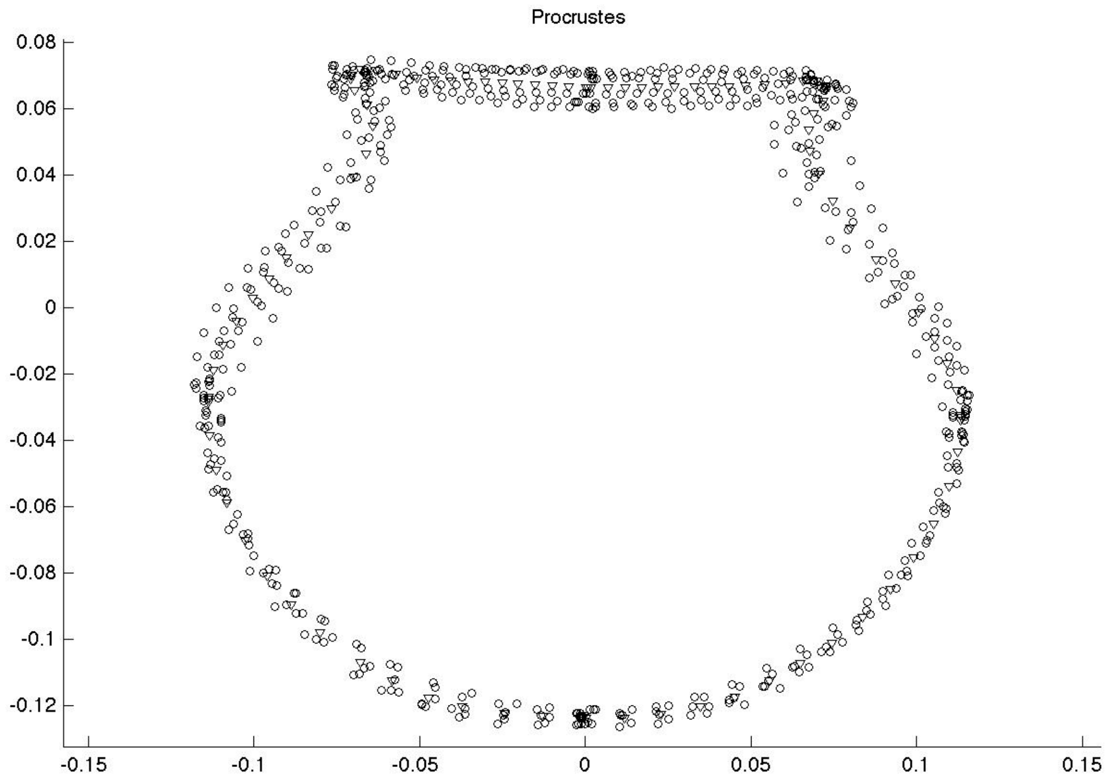


Figure 15. Ramos SLM Procrustes Superimposition

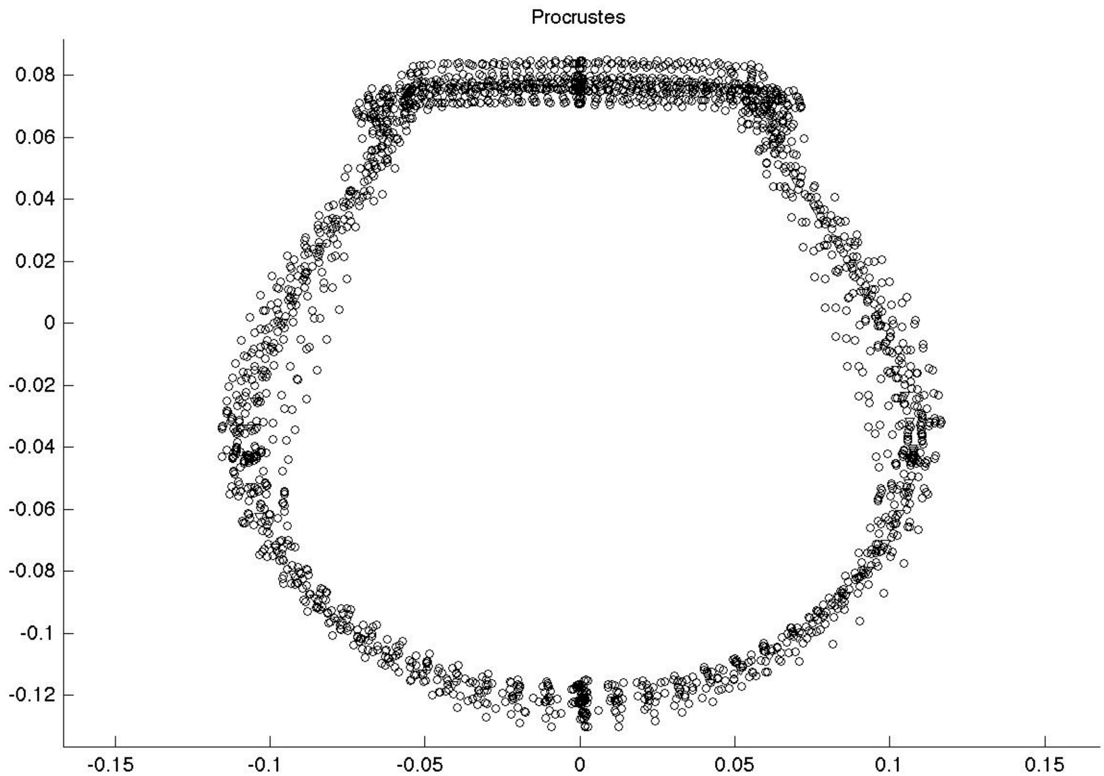


Figure 16. Santa Ana SLM Procrustes Superimposition

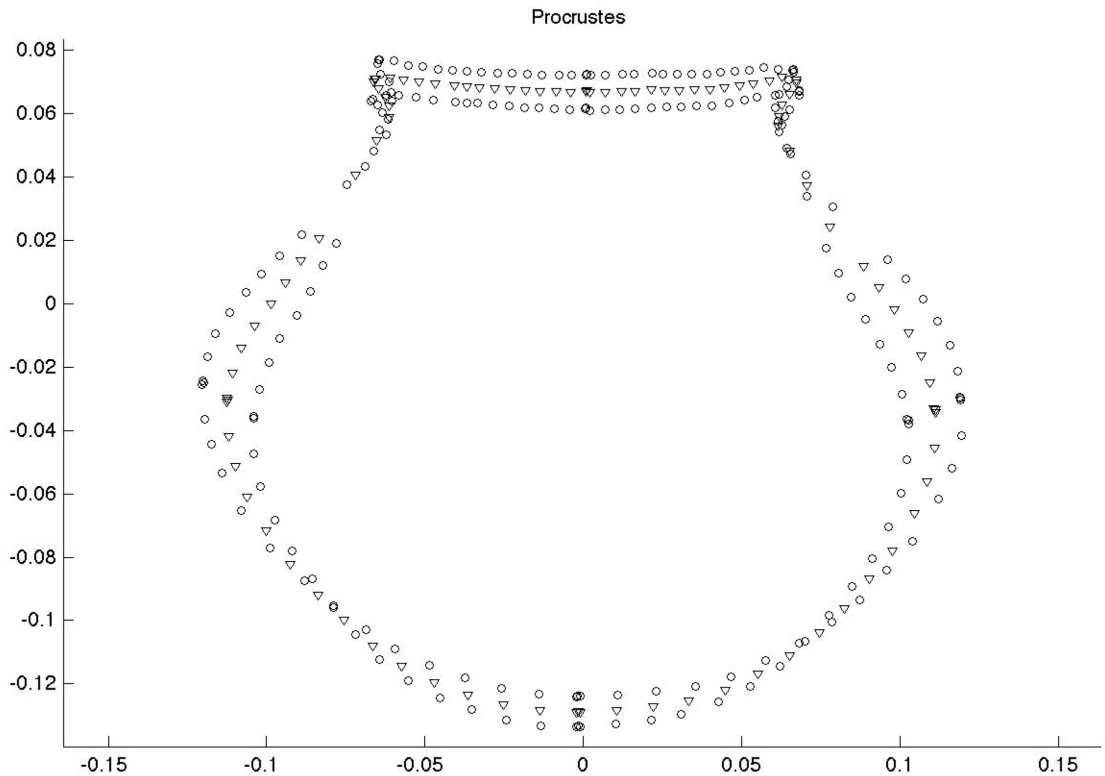


Figure 17. Viejo SLM Procrustes Superimposition

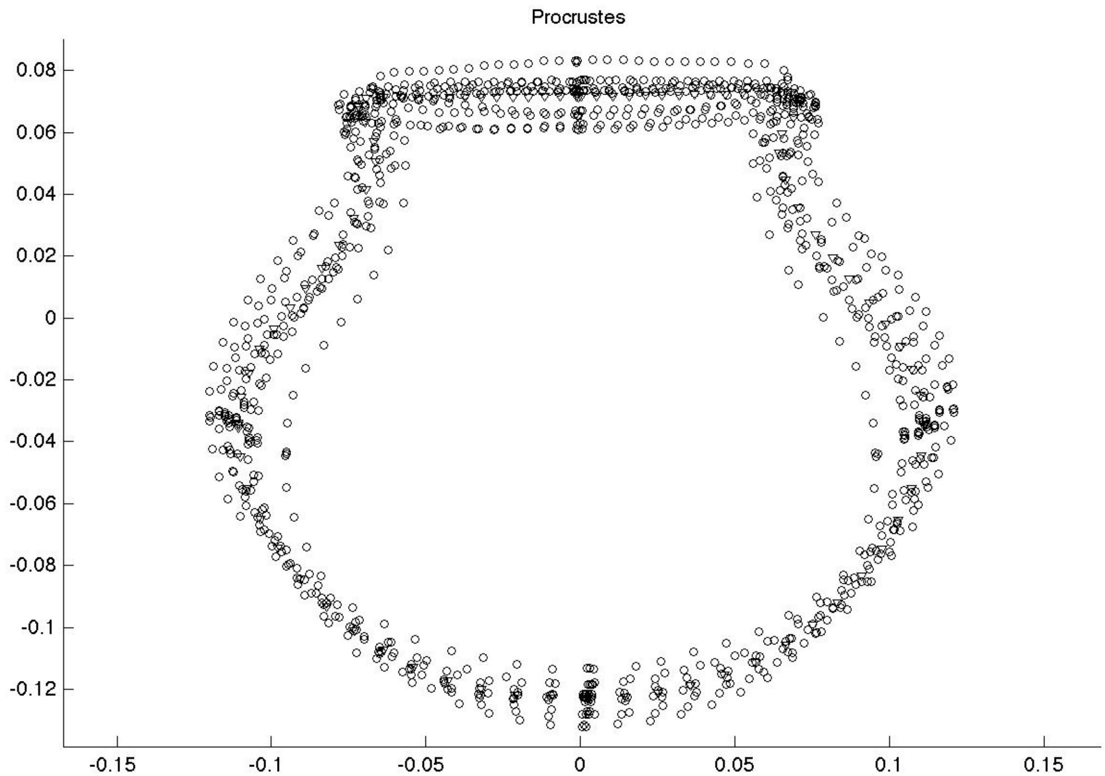


Figure 18. Villa Ahumada SLM Procrustes Superimposition

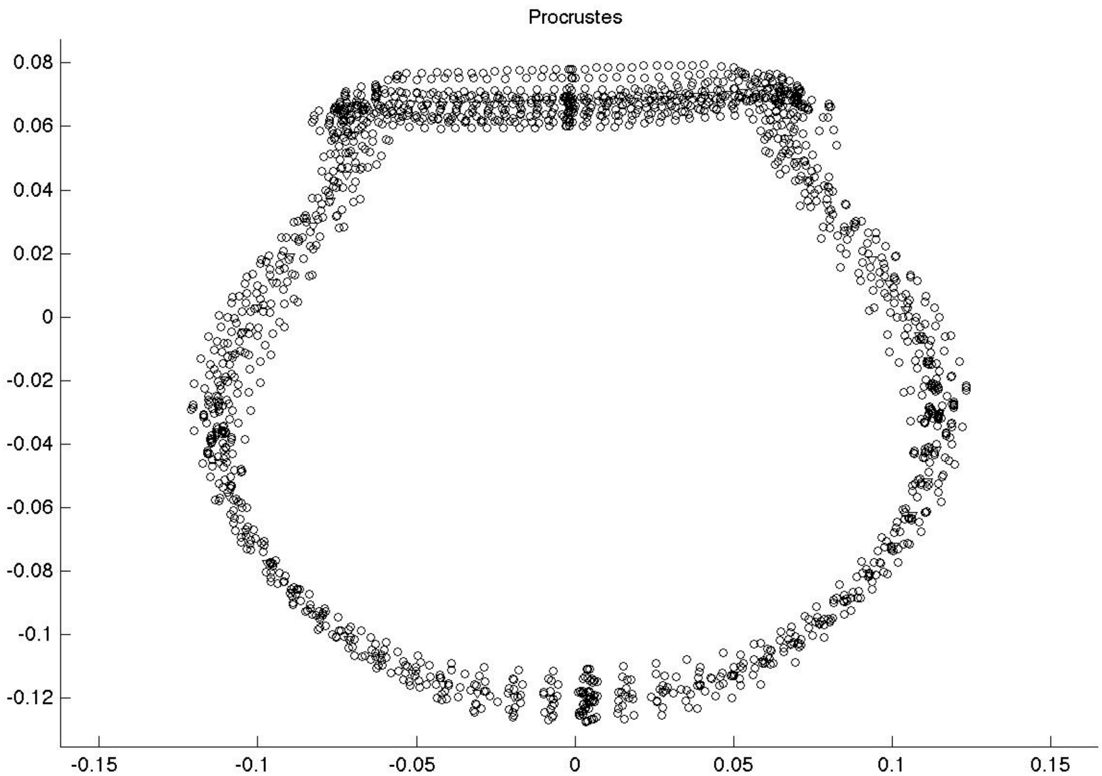


Table 5. Shape Variances

Type and Sample Size	Variance
Corralitos (n=4)	0.003
Dublan (n=6)	0.003
Babicora (n=20)	0.004
Villa Ahumada (n=16)	0.004
Ramos (n=20)	0.005
Viejo (n=11)	0.005
Carretas (n=10)	0.007
Santa Ana (n=2)	0.008

There are no known boundaries or standard markers by which to determine levels of standardization and specialization for ceramics based on perimeter shape, but the values do not show intuitively identifiable breaks like the other values above (Tables 1-4). The fact that Viejo pottery and Villa Ahumada Polychrome are comparable to the rest of the sample in the variation reflected in their shapes when these types were highly variable in other measures indicates that the increased variation evident in Tables 1-4 really correspond to variation in size, not actual shape. Put another way, the reason that Babicora and Ramos Polychrome have lower corrected CVs is because they are more similar in size, not because they are more symmetrical or otherwise more consistently shaped. The variances then, demonstrate that ceramics within the Casas world were likely constructed with similar shaping methods for a substantial amount of time. The values also show that, with the programs and statistics used, size might be a better indicator of standardization and specialization.

Chapter 4

Discussion

In her analysis of Salado polychrome, Crown (1995) suggests that decreasing coefficients of variation can indicate specialization even when they are above the 10% cutoff, which some have suggested is likely excessively conservative and prone to misclassifying some of the assemblages produced by specialists (VanPool and Leonard 2011:715). With this in mind, Babicora, with a secondary LM CV of (12.2), and Ramos, with a secondary LM CV of (10.5), were meaningfully more standardized. Results from TMorphGen, which essentially mimic common measurements of whole ceramic vessels, lead to the same conclusions. Ramos had CVs for rim diameter (12), vessel body width (11.7) and height (11.7) substantially lower than other types in the sample. Babicora CVs for rim diameter (12), vessel body width (13.6) and height (13.1), also show less variation. Shape variances are average for both when compared to the rest of the sample (Babicora: 0.004 and Ramos: 0.005).

In an analysis of decoration and design execution, Sprehn (2003) suggested that nearly all forms of Ramos and Babicora large ovoid jars were produced by specialists. Christine VanPool (personal communication 2016) and others (Sprehn 2003) note that distinctions between the two types reflect differences in the skill of their decoration, given that their iconography and symbolism are consistent. Babicora vessels display less labor investment and skill in decoration than Ramos (Sprehn 2003). Additionally, some researchers argue the two are primarily produced in different areas. Ramos was primarily produced in and around Paquimé at the height of the Medio period, while Babicora was made earlier and to the south (Sprehn 2003).

What the above suggest is differing levels of specialization. Costin and Hagstrum (1995) distinguish between attached and independent specialists. Attached specialists produced politically and socially symbolic goods for some form of elites. Independent specialists craft utilitarian goods for the household level (Costin and Hagstrum 1995). Babicora Polychrome has low levels of variation in all measures that indicate, in terms of shape and size, that it was produced by specialists. Its decorative aspects demonstrate lower levels of investment and less skill relative to Ramos, however, suggesting that Babicora was made by independent specialists who were skilled in standardizing the pots in terms of size and shape, but not in decoration. If the vessels were produced for utilitarian purposes, decorative aspects were likely less important.

Ramos Polychrome displays even lower levels of variation with the addition of high skill in decoration, according to Sprehn (2003). Many suggest Ramos pots were primarily created near Paquimé. A large aboveground pueblo that served as the region's religious, political, and economic capital likely attracted the best potters and other artisans in the area. The evidence of this study, when added to previous research (Sprehn 2003), indicates that Ramos was made by attached specialists. As such, the potters were actively sponsored by elites to produce vessels not only fine in terms of shape and size, but also in decoration that was used to convey politically and/or socially important messages. Analyses of effigy vessels also support this conclusion. Ramos effigies were, in many ways, more finely constructed than those of other types (Sprehn 2003). Study of the individuals depicted in Ramos effigies also shows distinctive imagery and clothing that would have been impractical in a utilitarian sense (Christine VanPool personal communication 2016).

With high CVs in terms of secondary LMs (18.5), rim diameter (19.4), vessel width (19.9) and height (18.8), Viejo pots serve as an excellent example of household production. They were created earlier than other Casas Grandes types in this study's sample. Additionally, Viejo period sites were occupied by small groups of people. Pottery of the time was certainly made for the household level and was not as finely decorated. Carretas, Corralitos, Dublan and Santa Ana polychromes were also produced by generalists, as indicated by high levels of variation in the above measures.

Sprehn (2003) also found that large ovoid Villa Ahumada pots were produced by specialists. Geometric morphometric results disagree, as Villa Ahumada has high secondary LM (20.4), vessel body width (17.7) and height (24) CVs, and average rim diameter (15.6) and shape (0.004) measures for the sample. Aspects of Villa Ahumada decoration might indicate some degree of specialization above the household level, but measures of shape and size for this sample do not.

A number of photographic aspects could affect landmark placement. Six pots in the sample were cracked, which resulted in small missing pieces of the rim. The curves were placed to include the crack instead of extrapolating to guess at the original rim shape. This contributed slightly to variation, but its effects are swamped by the high number of sliding landmarks, and did not change any of the results reported in Tables 1-5. Additionally, pots with flared handles near the rim were excluded from the analysis. In an initial view of the data, these caused considerable variation because handles were not present on most of the vessels.

In the final data cleanup, two pots were removed from the Villa Ahumada sample. One had a flawed scale that significantly skewed rim, vessel body and height measurements. The 4.6cm diameter rim, for example, was half to one-third that of other Villa Ahumada vessels. The other omitted pot was unique in both decoration and form. Its neck was longer and narrower than all other ovoid pots included in the study. It was also decorated on the bottom, another rarity for the ceramic type. Because of these relative oddities, it too was removed. Excluding these two pots lowered Villa Ahumada CVs by roughly 3% in all measures, but Villa Ahumada remained one of the most variable types in terms of both shape and size.

Lighting during the photographic process is highly important. Plate 5 displays a shaded area at the bottom of the pot, which made landmark placement for that portion very difficult. The object mount or stand is also paramount. Some of the images in this sample displayed ceramics placed on stands in a way that somewhat obscured base shape. Background color can also affect landmark placement. Some vessels had black paint near the perimeter and the photographs were taken with a dark background. This made recording those areas difficult, though using the zoom feature in tpsDIG2 helped. While not used in all analyses, the inclusion of a scale in each photo is necessary for some calculations.

Plate 5. Ramos Pot with Shading

Courtesy of El Paso Museum of Archaeology, photograph by Christine VanPool

It is also important to acknowledge the influence of overall sample size. If items were specialized, they would have been mass-produced at various levels. A sample of 89 might give an inadequate picture of ceramic shape and size. However, we typically deal with small samples in anthropology and archaeology. It is hoped that nearly 100 complete pots is a sufficient number to draw conclusions about overall trends in Casas Grandes wares.

Chapter 5

Conclusions

In an assessment of Casas Grandes ceramics using 2-D geometric morphometrics, I find that Babicora and Ramos polychromes are standardized at different levels. With low levels of variation that are slightly above standard markers for recognizing specialization, Babicora Polychrome was likely produced by independent specialists. Goods crafted at this level are finely made, but are primarily for utilitarian purposes (Costin and Hagstrum 1995). This conclusion agrees with Sprehn (2003) and others who found less elaborate and not as finely decorated forms on Babicora pots. Babicora potters were in a less populated area with less wealth and, as a result, likely did not focus on outer ceramic designs. With even lower levels of shape and size variation, Ramos Polychrome was produced by attached specialists. Items produced at this level are not only finely made, but are made through the sponsorship of elites, and convey political and symbolic messages (Costin and Hagstrum 1995). Sprehn (2003) and others (Rakita and Cruz 2015; Whalen and Minnis 2009) have demonstrated the high degree of craftsmanship of Ramos vessels, especially in terms of decoration. The results of this study add shape and size data that agree.

The conclusion that Babicora and Ramos ceramics were the products of craft specialists has important implications for the socio-economic structure of Paquimé and the greater Casas Grandes system. Fitting Ramos with the specialized productions of shell products, agave resources, metates, and controlled macaw and turkey husbandry, the number of items and distribution distances of the specialized goods are unique in the Southwest. These aspects point to an incipient elite with greater access to resources and a sociopolitical system of high differentiation. During the Medio period, social hierarchies, political, and religious authority, were present and important organizing principles of Paquimé and the greater Casas Grandes region, as noted by Di Peso (1974), Minnis (1988), Rakita and Raymond (2003), Sprehn (2003), and VanPool and Leonard (2002).

This study can also serve as a methodological outline. No previous research was conducted with this approach. While some authors used geometric morphometrics to examine ceramics (Selden 2014; Wilczek et al. 2013) they did not specifically outline a system for landmark placement. Others used 3-D morphometric data (Selden et al. 2014), which have a great deal of utility, but suffer from difficulties in translating three-dimensional data onto a two-dimensional medium. Equipment needed is also very expensive. It is hoped that this paper and others serve to demonstrate that 2-D geometric morphometrics should become a standard part of the analysis of ceramic archaeological assemblages; especially museum collections, as for this study, complete pots were required. The use of geometric morphometrics as a means for quickly, reliably and non-invasively assessing archaeological materials is an increasing trend, one that will hopefully continue to the point of standard analytical practice.

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