

**BUILT TO MEASURE:  
RECONSTRUCTING AN ANCIENT MEASUREMENT  
SYSTEM FROM EXTANT ARCHITECTURE  
AT CASAS GRANDES**

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MA in Anthropology

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by  
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BUILT TO MEASURE:  
RECONSTRUCTING AN ANCIENT MEASUREMENT  
SYSTEM FROM EXTANT ARCHITECTURE  
AT CASAS GRANDES

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**ABSTRACT**

The standardization hypothesis purports that goods manufactured by specialists exhibit less variation than products manufactured by more generalized, household-level producers. V. Gordon Childe posited that as specialization increases in a society, mensuration systems grow more accurate as precision becomes a paramount concern. I apply both of these hypotheses to the extant architecture of Paquimé, the cultural center of the Casas Grandes region of Northern Mexico and the American Southwest, in order to determine if the grid-ded, planned nature of the site was the product of specialist architects and builders using a formalized unit of measure. Statistical analysis of three architectural features at Paquimé – the Mound of the Cross, the I-shaped ballcourt and the assemblage of rooms designated Unit 12 – shows that a clear unit of measure of approximately 70 cm can be identified at the site. I therefore conclude that specialized production of architecture did indeed exist in the Casas Grades culture, reflecting a culture with substantial political complexity, and further possibly reflecting a diffusion of measurement systems from Mesoamerica.

# Chapter 1

## Introduction

“In physical science the first essential step in the direction of learning any subject is to find principles of numerical reckoning and practicable methods for measuring some quality connected with it. I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be.”

—The Rt. Hon. The Lord Kelvin [1824-1907]

The analysis of archaeological context to evaluate production specialization in a society has long been a standard practice in archaeology. Large lithic and ceramic assemblages can indicate the presence of specialized households or workshops devoted to the production of certain goods. However, in many archaeological sites context has been disturbed through the actions of human and environmental agitation, complicating any analysis of the organization of production. The use of artifactual measurement as a proxy to evaluate the level of specialization has proven useful in this area, however, and can be applicable even in cases where archaeologists are limited to pothunted and disturbed materials (VanPool and Leonard 2002). I build on this previous research here to establish and evaluate a method to investigate specialization using only architectural remains.



To develop this method, I examine the extant architecture of Paquimé, a large pre-Columbian settlement in northern Chihuahua, Mexico. The site is rich in artifacts, and previous studies of these artifacts have indicated that specialized production was certainly present at the site. The site also boasts much extant adobe architecture that was thoroughly and systematically recorded and measured, making it an ideal specimen for this research. Hypothesizing that the pre-Columbian settlement of Paquimé in Southwestern North America was the product of architectural specialists (given the vast size and overall architectural complexity of the site) I use mathematical analysis to determine if a base unit of measure was used in the construction of the site, based on both inductive and deductive logic, and apply that method to three key architectural features to determine if a such a unit was employed in their construction. This method will therefore provide a further means of evaluating specialization, in addition to providing supporting evidence for studies of specialization that have already been performed on material goods.

# Chapter 2

## Definitions and Models

In this thesis I will be referencing a number of anthropological terms and theories, some of which require explication. In this section I introduce and define each of these.

### 2.1 Specialization

Specialization arises in a society when individual producers begin to devote themselves either part-time or full-time to the production of goods and services intended for consumption by other individuals or segments outside of their immediate household (Muller 1987). By utilizing their time in this manner, producers are no longer focusing all their time and attention on providing for their own family's economic needs, but instead enter into an economic system of increased inter-household integration. This advances a condition of mutual dependence between these specialized producers and the greater population they serve.

Specialization can be present in simple hunter-gatherer societies, but becomes increasingly important in middle-range societies as social differentiation increases. As specialization becomes more prevalent in a society, both the size and complexity of the interrelated corporate workgroups increases (Earle 1987). Additionally, widespread specialized

production will lead to both differential access to resources and the emergence of formal exchange networks, which suggests the development of stratified social classes, leaders and complex social organization (Brumfiel and Earle 1987, VanPool and Leonard 2002). This apparent correlation between the evolution of specialization in production and an increase in societal complexity has long concerned archaeologists, and still plays an important role in current research on the organization and development of political and social systems (Stark 1991; see also Brumfiel and Earle 1987; Clark and Parry 1990; Flannery 1972; Muller 1987).

The organization of specialized production can occur on a wide range of levels, from individual households to large elite- (or state-) sponsored workshops to entire communities (Costin and Hagstrum 1995; Stark 1991). Further, specialized production is usually defined as one of two types: independent specialization or attached specialization. In the former, producers provide goods for the general population (subject to economic, political and social demands). In the latter, producers provide goods or services for elites or government institutions, a form of patron and client system (Brumfiel and Earle 1987). Both types of specialization are likely to be found in any complex society, as independent specialists tend to produce goods for general consumption, while attached specialists produce wealth-based items and services, as well as high-prestige trade goods, weaponry and other military items (Arnold and Munns 1994).

As attached specialists are driven by patron-elites (Arnold and Munns 1994), they are rarely found in large numbers in middle-range cultures, as elites tend to have limited social and economic power in these societies. They typically lack the social power and concentration of resources needed to compel others to undertake such specialization. Researchers have attempted to differentiate between the two general types of specialists, typically using the distribution of resources and nature of the workshops (Costin 2001). In general, though, Minnis (1989) notes several key hallmarks of specialization in any given society: large-scale production, formalized production facilities (workshops), product stan-

standardization (discussed in the following section), centralized control of production (elites), stockpiles of large materials (storerooms) and large deposits of production waste (Minnis 1989:285; see also Feinman 1985).

## **2.2 Standardization Hypothesis**

The standardization hypothesis states that goods produced by specialist producers (either independent or attached) will exhibit a greater degree of homogeneity in metric and design characteristics than those produced by nonspecialists (Rice 1991). Mathematically, the standardization hypothesis states that goods produced by specialists should produce a lower coefficient of variation (the standard deviation of a dataset expressed as a percentage of the overall mean) than nonspecialist-derived goods (Crown 1995).

The standardization hypothesis has been used in archaeology as a method in ceramic analysis to determine whether ceramic goods were the outcome of mass production (and, therefore, specialized production) or the outcome of less intensive modes of production (e.g., household-level production) (Blackman et al. 1993). More recently, VanPool and Leonard (2002) have adopted the standardization hypothesis as a means to test for specialized production in other types of artifact assemblages, such as groundstone implements.

## **2.3 Mensuration and Social Complexity**

In *Man Makes Himself*, V. Gordon Childe asserts that a given society's system of mensuration is closely tied to sociopolitical complexity (1953:153). A deepening concern with industry and trade in a society, Childe purports, positively corresponds with increasing levels of formality in measurements (i.e., in terms of accuracy and precision). Childe ultimately defines three discrete stages in the evolution of measurement systems and describes the sociopolitical settings in which they are likely to occur.

In the first and simplest stage, mensuration consists of simple comparisons between objects. In this system, no numerical data are involved, and thus the measurement system is only capable of yielding simple binary answers: Either “yes, this will fit,” or “no, this will not fit.” Childe’s examples of this mensuration strategy include a comparison between a potential bowstring to a bow, and a potential haft to an axe-head. This type of measurement system occurs in societies where there is little to no formal industry; production occurs primarily on the individual or household scale.

In Childe’s second stage, increasing trade and industry within a society (i.e., production evolving from the intra-household level to inter-household level) necessitates the development of a more robust measurement system that is capable of yielding roughly similar measures between individuals. In response, Childe explains, such societies adopt “natural” measurement systems, wherein the units are based on easily observable and replicable objects. Since the human body serves as a readily accessible counting device, measurements at this stage can take the form of finger-widths, hand-spans, arm-lengths and similar body-units (Childe 1953:154). Notable at this stage is the ability of a measurement system to provide more than a binary answer; beyond the qualitative “yes” or “no,” quantitative information can be provided, such as “this measure is one unit too short” or “this measure is five units too large.”

In Childe’s third and ultimate stage, trade and industry have advanced to the point where replicability, accuracy and precision of measurements have all become paramount concerns. Measurement systems, therefore, must be robust and complex enough to allow for exact replicability between individuals. To meet this challenge, societies develop standardization within measurement systems. While a measurement may still be expressed in terms of natural measures, these measures are standardized to a specific object, such as a length of string or a wooden rod (the Imperial “foot” is as an excellent example) (Childe 1953:154).

It is important to note that even the most complex society will use all three stages of measurement depending on the particular behavioral context in which people find them-

selves. In our own culture we may, for example, use visual comparison to discern whether a box is too large to fit within the trunk of an automobile; we may then progress to using a natural measurement in an attempt to determine fit before giving up and using a tape measure to be certain. One may argue with the underlying cause of increased mensuration standardization, but Childe's (1953) framework provides a useful classification system for classifying mensuration strategies.

## 2.4 Historical Metrology

Scientific concern with ancient measurement systems dates to at least the 17th century, when Sir Isaac Newton pursued the mathematical study of ancient structures (Petrie 1879). In his *Dissertation on Cubits*, Newton established that ancient measures could be reconstructed via mathematical examination of dimensional ratios (Petrie 1879:107). Newton began with the assumption that ancient structures built on the cubit system were likely to be rounded to the nearest whole cubit, and from there was able to deconstruct the English Imperial metric equivalents of this ancient measure. Newton's study laid the intellectual foundations for the adoption of historical metrology, or the study of historic measurement systems, into anthropology some two centuries later by Sir William Matthew Flinders Petrie.

In his *On Metrology and Geometry in Ancient Remains*, Petrie contends that measurement systems are an important proxy for divining the capacities of the ancient mind. The more complex the measurement system, he argued, the more complex the mind behind it. Additionally, Petrie established that measurement systems could be used as a method to evaluate connections between ancient cultures in a manner similar to the study of languages (Petrie 1879:107). Cultures sharing similar measurement systems likely had some form of contact. Of greatest importance, however, is that Petrie provides a framework by which historical metrology can be performed. In Petrie's mind, when investigating the measurements of architectural remains, special attention needs to be paid to oft-repeated units and

ratios. It is improbable that a given dimension will continually recur by chance. Should such a measurement be located in architectural remains, and appear in halves or doubles, then the probability that this measure reflects a real historical unit of measure increases (Petrie 1879:107).

To guard against spurious units and coincidences in measurement, Petrie proposed two checks to ensure the validity of the apparent unit. First, if the average of a given set of measurements is the same as the suspected unit, then there is strong evidence that the unit is real and not coincidental. Second, “if several lengths have by chance so nearly simple relations between them as to appear the result of intention—it is highly likely that these relations will be all very exact; on the contrary more and more of these fallacious results will be found on looking at relations which are less and less exact; thus the fallacious relations being on average far less exact than the intentional relations, they will, as already noticed, have a far larger probable error” (Petrie 1879:109). In other words, objects that have consistent measurements such that one is half the size of another, a fourth the size of another, and twice as big as another likely reflect the use of a measurement system.

Petrie’s establishment of historical metrology has been applied to archaeological ruins spanning the Old World to recover ancient measurement systems, from ancient Mediterranean cultures (the Greek and Roman foot) to those employed by ancient Near Eastern cultures (such as the Assyrian foot) (Berriman 1953). However, while historical metrology has been widely employed in the Old World, there has been very little study of this type in New World archaeology. One notable exception is O’Brien and Christiansen’s study of the ancient Maya measurement system (1986), wherein the authors applied the methods of historical metrology to obtain a mean unit of measure likely employed by the great Mayan builders.

# Chapter 3

## Background

### 3.1 Ethnographic Accounts of New World Measurement Systems

Surprisingly, there have been few direct studies of New World measurement systems. I have only been able to locate a small handful of ethnologies wherein some consideration was made towards a study of measures and measurement systems (e.g. Barrett 1952; Birket-Smith 1953; da Silva 1962; De Laguna 1972; Densmore 1970; Emmons 1991; Ewers 1958; Jochelson 1933; Kluckhohn 1971; La Barre 1948; Lantis 1984; Nash 1970; Olson 1936; Ray 1938; Redfield and Rojas 1934; Rowe 1946; Stephen 1969; Talayesva 1942; Tschopik Jr. 1946; Villa Rojas 1969). In each of these references, measurements are expressed in terms of natural measures. For example, in his work *The Tlingit Indians*, George Thorton Emmons notes: “The Tlingit possessed no mechanical lineal measure. His rule was the human body, with the tip end of the second finger as the zero point” (Emmons 1991:192). Specific units of measure included the *Ka dlekh*, a measurement “from the tip of the second finger to its third joint,” and the *Ka kikee*, a measure “from the tip of the second finger to the middle of the body” (Emmons 1991:192).



Clark (2008) describes a very similar system in use among the Aztec. The basic Aztec measurement system consisted of codified units called “hands” (*maitl*), a measurement from outstretched fingertip to fingertip, and “hearts” (*yolloti*), a measure from outstretched fingertip to the center of the chest.

Ray (1938) reported that the Lower Chinook Indians used a system of rods cut to a specific length as dictated by a chief (who defines the measure in terms of “hands” and “spans”) to determine how to cut up whale carcasses for food distribution (Ray 1938:50). In this case, however, the chief determines the exact measure to be used that day for cutting the whale, yielding a measurement system that could easily fluctuate. This culture, therefore, uses a modified form of the second stage Childe’s classification that includes at least temporary standardized measurement implements typical of Childe’s third stage.

However, more complex measurement systems can be found in studies of the Inca culture, one of the most socially complex cultures in the New World. Rowe, for example, found that the Inca used a measurement system based on natural body measures, but that some of these measurements were standardized by wooden rods: “The largest measurement based on the human body was the fathom (*RIKRA*) of about 64 inches. . . a measuring stick (*COTA-K’ASPI*) of this length was kept as a legal check” (Rowe 1946:323). Given that the Incan empire was built upon trade and included highly complex architectural features, a robust and complex system of measurement was required given Childe’s arguments, and the Inca culture therefore reached the third stage of Childe’s hierarchy.

In general, the ethnographic and archaeological studies give the impression that most cultures in the New World likely used the first or second stage of Childe’s measurement system, while larger state-level societies seem to have advanced to the third stage.

### 3.2 The Casas Grandes Culture

The Casas Grandes culture emerged, flourished and declined between AD 600 and AD 1450 in the North American Southwest. The culture was named for the settlement of Casas Grandes (now commonly referred to as Paquimé to distinguish it from the Casas Grandes culture), which is situated along the west bank of the Rio Casas Grandes in Chihuahua, Mexico. At its peak, the area of Casas Grandes' cultural influence extended far beyond the settlement itself into Western Sonora and the Southwestern United States, including much of Southern New Mexico and Southwest Texas (Schaafsma and Riley 1999).

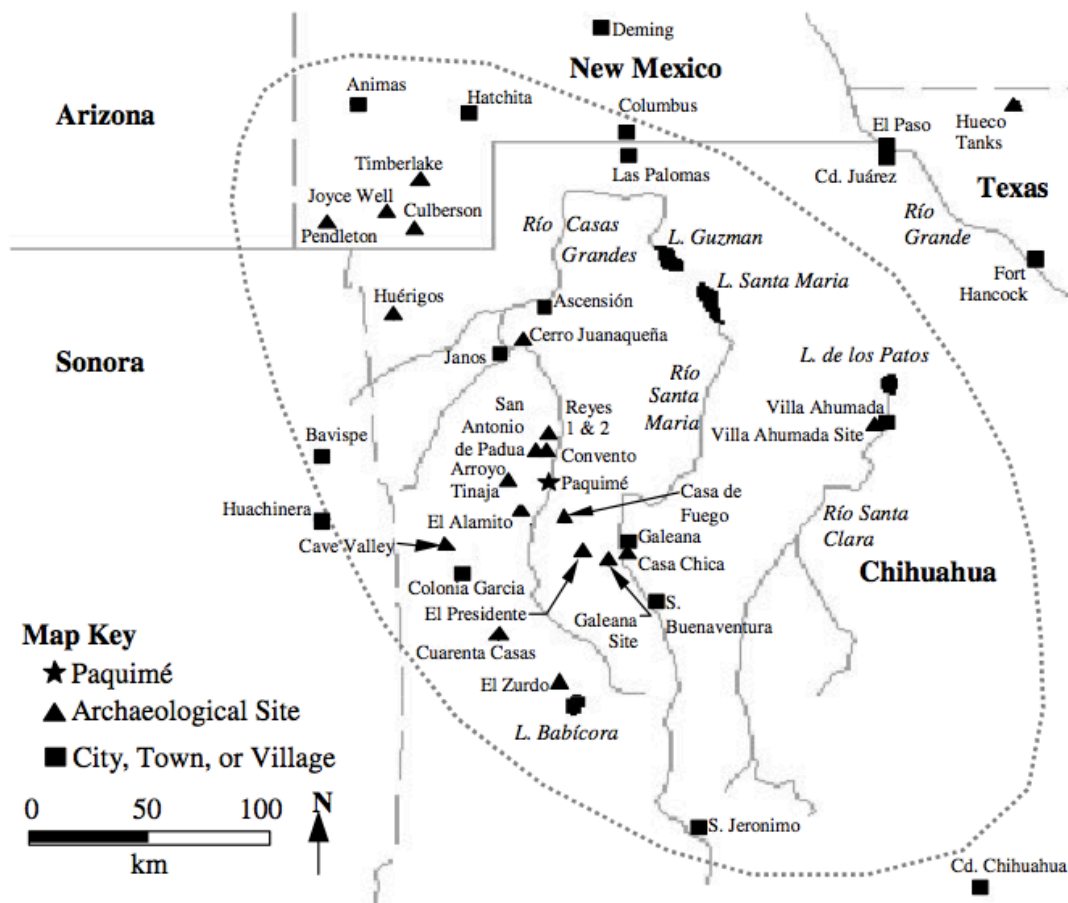


Figure 3.1: Image illustrating the known extents of the Casas Grandes culture. As defined by Brand (1943, in [Schaafsma and Riley 1999:Figure 1:8].) Courtesy of Marcel Harmon (Harmon 2005).

While the Casas Grandes region saw a long history of occupation from the PaleoIndian through the Archaic periods, the unique characteristics that comprised the Casas Grandes culture came together during the Ceramic period. Charles Di Peso, who partially excavated Paquimé as part of the Joint Casas Grandes Project in 1958, divided the Casas Grandes culture into three distinct cultural phases: the Viejo (old) phase, the Medio (medial) phase and the Tardío (late) phase (Minnis and Whalen 2004).

Prior to the Viejo phase, settlers in this region lived a largely nomadic lifestyle based upon a hunter-gatherer subsistence pattern. The Viejo phase, however, saw the transition of these nomadic hunter-gatherers to maize agriculturalists. As a natural consequence of an agricultural subsistence regime, settlers began to concentrate in small, widely dispersed villages. These villages largely consisted of groupings of small pithouses near agricultural fields (Stewart et al. 2005). A lively ceramic tradition took hold, transitioning from simple plainwares at the beginning of the Viejo phase to complex, geometrically decorated ceramics towards the end of the phase (Larkin et al. 2004). In addition, the Viejo phase is marked by an increase in the complexity of inhumation rituals as the phase progressed, with complex burials with multiple artifacts supplanting simpler burials with fewer grave goods (Rakita 2009). Finally, the Viejo period saw the beginnings of trade of various imported goods, including shell beads, copper artifacts and turquoise jewelry (Whalen and Minnis 2003).

The most recognizable traits of what today is considered the Casas Grandes culture developed during the Medio period. During this time, the settlement of Paquimé was vastly enlarged and elaborated as it grew to become a center for religion and trade (Di Peso 1974). A number of new cultural traits were established, including Scarlet Macaw and turkey husbandry, the production of polychrome ceramics featuring geometric and figural designs and the hoarding of trade goods, including copper, turquoise, shell and groundstone artifacts. Upon excavation, vast storerooms of these goods were unearthed, an observation that has led to many hypotheses regarding the nature of these caches. Following Fish and Fish's

(1999) proposal that Paquimé was a pilgrimage center, VanPool et al. (2005) surmise that these caches were offerings made by pilgrims visiting the settlement, which would appear to strengthen the argument that Paquimé served as a religious center.

Di Peso divides the Medio phase into three sub-phases: The Buena Fé phase, the Paquimé phase and the Diablo phase. In the first of these, a number of room-blocks were built over old pithouse structures. While these room-blocks grew to be fairly large, they seemed to be largely independent of each other, with their own plazas and ceremonial structures. However, in the Paquimé phase, these individual room-blocks were combined to form a larger settlement, and communal, ceremonial structures were built (Wilcox 1999). Power seems to be concentrated during this phase into a central ruling authority, as a building project of this scale requires some form of direction. Other settlements near Paquimé also appear to undergo at least some form of reconstruction during this time period (Di Peso 1974). Macaw and turkey husbandry also seems to be increasingly important, as a large number of cages and burials were excavated. Finally, the Diablo phase saw a heavy decline in new construction in favor of light remodeling of preexisting structures. From here, the Casas Grandes civilization appears to slowly decline until the ultimate abandonment and subsequent burning of Paquimé.

Post-abandonment, the Casas Grandes culture entered into the Tardío phase, which saw the further decline of the Casas Grandes occupation. Populations appeared to largely abandon both Paquimé and its outlying settlements, with the occupants possibly reverting to a hunter/gatherer form of subsistence.

### **3.3 Architecture at Paquimé**

Paquimé is one of the most architecturally extensive settlements in the American Southwest. The site is a mixture of single- and multi-story adobe structures, many of which are joined into a large single structure comprised of contiguous room-blocks and enclosed

plazas. Surrounding the main central structure are several freestanding ceremonial edifices. In its basic layout, the architectural construction of Paquimé appears to mirror, at least in part, the Classic Hohokam construction aesthetic: large, conjoined housing compounds with multiple levels, ground-level entryways, and enclosed plazas (Bagwell 2006). In contrast to the Hohokam style, however, the interiors of Paquimé structures were very complex, possessing a large number of interior rooms. There is evidence of extensive remodeling throughout the settlement's history, perhaps indicating that several of these rooms were repurposed over time.

Casas Grandes architecture does exhibit several unusual features. Chief among these is the nature of the adobe walls: poured (or puddled) adobe, rather than the more traditional adobe brick style. To create these walls, the builders would have needed to construct large wooden forms, into which the adobe matrix was poured and allowed to dry before successive rows were laid down. These walls were also, on average, much more substantial than they needed to be from a purely architectural standpoint. Whalen and Minnis (2001) contend that in some cases the walls are two to three times thicker than necessary and comprise what they call an "Architecture of Power" – construction on a scale intended to awe and impress.

Surrounding the primary settlement are several ceremonial structures. At least two of these structures are mounds seemingly built as effigies of animals. These include the Mound of the Serpent, a structure designed to resemble an elongated snake and the House of the Bird, a structure that Di Peso believed represented a decapitated macaw, which was of regional religious significance. Perhaps the most clearly ritualistic structures are the two I-shaped ballcourts, the T-shaped ballcourt and the walk-in well (Harmon 2008; VanPool et al. 2008). The northern I-shaped ballcourt is a large, freestanding structure attached to an elevated platform, whereas the T-shaped ballcourt is within a room block with limited public access (Harmon 2006). The T-shaped ballcourt appears to be associated with human sacrifice (Rakita 2009). The walk-in well is a subterranean water source located in the heart

of the community. It had limited access through a two-story flight of stairs down into the well (Di Peso 1974).

Several advanced engineering principles were incorporated into Paquimé. For one, it had a complex water-management system. Canals brought water into the settlement from warm springs in the hills near the city. Water moved down these hills in a terracing system before entering canals that ran through the settlement. These canals routed water into the structures of the city through channels carved in the floors of the rooms. The large walk-in well provided a second, independent source of water from the local water table. Finally, a system of drains diverted excess water and runoff towards holding cisterns for future use (Hodgson 2002).

Paquimé also possessed an underfloor or floor-level venting system, which would have allowed fresh air to more easily circulate through the structures of the complex. Many of the interior rooms of the site are deep enough into the structure that air would be stagnant without such a venting system. They may also have played a role in smoke mitigation, since these deeper interior rooms would have had no source of natural light, and thus would have had to be lit by fire.

### **3.4 Specialization at Paquimé**

There have been several studies of specialization at Paquimé. Minnis (1988) identified specialization in four separate goods: shell tradegoods, macaws, turkeys and agave products. Minnis reports that a voluminous amount of shell goods were excavated at Paquimé, with the majority of these goods found cached in two storerooms. This central caching of goods, coupled with the presence of at least two small-scale workshops involved in shell good production, led him to conclude (at least tentatively) that a super-household method of production existed for this good, and was thus specialized. There is some question as to whether the shell goods found at Paquimé were locally created or simply a repository of

traded goods from other locations. However, Bradley (1992) found that overall shell diversity in the American Southwest increased during the time Casas Grandes was occupied and declined following the occupation timeline, a passive indicator for the production of shell goods at the site. Bradley also points to an extensive trading network in place for shell goods, which involved Paquimé, further indicating shell production specialization.

Minnis further claimed specialization in the husbandry of macaws and turkeys at Paquimé. Both of these exhibit large-scale production, though they may have been organized on different levels of production. Turkeys, for example, were largely the product of a very centralized production regime, with the majority of turkey pens centralized into very specific areas. Macaws, on the other hand, may have been a less centralized good as macaw pens were spread throughout the site, rather than centrally located like turkeys. However, Bradley (1992) found that Macaw-based goods followed a very similar distribution pattern as shell, indicative of an intensive (and thus specialized) trade good. In addition, the sheer number of macaw specimens (over 500) excavated (Minnis et al. 1993) coupled with the fact that the bird was not native to the region and had to be imported from southern Mexico and Central America (Creel and McKusick 1994), tacitly improves the argument for specialized production.

Minnis also identified several centralized roasting pits for agave products. Based on the large size of these pit ovens, as well as their "centralized" location in the northern part of the site, Minnis identified them as evidence for centralized specialized production.

In another study, VanPool and Leonard (2002) identified and evaluated the degree of production specialization in two different forms of metates found at Paquimé: a square-cornered version and a round-cornered version. They measured various dimensional characteristics of both types of metates and obtained values of the coefficient of variation for each metric. They concluded that the square-cornered variety of metate had a lower coefficient of variation (c.v.) in every metric, leading them to conclude that there was a higher degree of standardization in the square-cornered metate type than in the round-cornered type.

Given that a much higher number of the square-cornered type relative to the round-cornered type were excavated from the site, and many of these were found in large storeroom caches, these metate types were likely produced by specialists and stored for later use and/or trade.

Finally, Bagwell (2006) examined the organization of production for architecture at Paquimé and other Casas Grandes settlements. Compared to other sites in the region, Paquimé exhibited the lowest overall coefficients of variation in architectural features such as wall thickness and certain doorway widths. Based upon this and other architectural data, Bagwell concluded that Paquimé appeared to be more specialized in architectural production than its neighbors.



# Chapter 4

## Methods and Analysis

### 4.1 Premises

As previously discussed, the vast majority of metrological studies have been conducted in the Old World, where there is a rich, historical literary tradition that provides important clues for the reconstruction of measurement systems. In the New World, metrological studies have been largely confined to those civilizations that had a great deal of contact with the Spanish, who in early ethnographies provided information on native measurement systems and their Spanish equivalents. Paquimé, however, reached its apex, decline and subsequent abandonment well prior to the arrival of the Spanish. As a result, all attempts to recreate a mensuration system for the Casas Grandes culture must be based entirely in mathematical analysis with no literary clues to help confirm any possible measurement systems I may derive.

Consequently, I will evaluate two premises regarding the Casas Grandes numbering system. The first of these is that a true system of numbering existed at Paquimé. This premise builds from the sheer amount of trade goods at Paquimé. As Childe pointed out, trade on that scale necessitates some form of measuring system by which quantities of goods

can be determined. This of course does not necessitate the use of a consistent measurement system in architecture, but it seems parsimonious to suggest a formalized measurement system would be used in that context, if it were present.

The second premise extends the first, and states that any numbering system in use would likely be a vigesimal (base-20) numeration system, rather than a decimal (base-10) system. In a base-20 system, there are twenty distinct numerals used for counting, where a base-10 system uses only ten distinct numerals. In a vigesimal system, numbers are reckoned as powers of 20, while a decimal system reckons numbers as powers of 10. As an example, the numeral “42” in decimal notation is  $(10 \times 4 + 2)$ . In vigesimal notation, this would be  $(20 \times 2 + 2)$ . As with a decimal system, a vigesimal system could be considered a “natural system”. Whereas a decimal system can be easily counted on fingers, a vigesimal system can be easily counted on fingers and toes.

The premise that a vigesimal system is in use is predicated on the presence of a base-20 numbering system among some Mesoamerican groups and the unambiguous Mesoamerican influences in other aspects of the Casas Grandes culture.

## **4.2 Analytical Methods**

I employ both an inductive and deductive approach to derive a base unit of measure. The inductive method consisted of working from ceremonial architectural features previously identified as specialized (or, at least, semi-specialized) and dividing their measurements by simple fractions to detect possible base units of measure, while the deductive approach applies this derived base unit of measure to other architectural features to determine if the unit is real or a coincidence of mathematics. If the derived unit identified by the inductive method is indeed real, it should be evident in other architectural features of the site.

### 4.3 Sample

The initial inductive approach focuses on metric data from the Mound of the Cross and the I-shaped ballcourt at Paquimé, supplemented by other Medio period ballcourts from throughout the Casas Grandes region. I will then evaluate the inductively derived unit using architectural information from an assemblage of rooms at Paquimé (designated by Di Peso as Unit 12). Each of these features was chosen on the merits of prior investigations: Mora-Echeverría's analysis of proportionality in the construction of the Mound of the Cross (Mora-Echeverría 1984), Marcel Harmon's investigation of Casas Grandes ballcourts (Harmon 2005), and Elizabeth Bagwell's investigation of architectural specialization in the Casas Grandes region (Bagwell 2006). The ballcourt and the Mound of the Cross were chosen based on their status as the most ostentatious examples of ceremonial architecture at Paquimé in conjunction to their visually symmetrical form. Following arguments by Di Peso (1974), VanPool and VanPool (2007) propose that the Mound of the Cross was reflective of the ruling elite of Paquimé. If there truly is specialist architecture controlled by the ruling elite class, it should be manifest in this structure, making it a good candidate upon which to test my hypothesis. Unit 12 was identified by Bagwell (2006) as the single most likely example of specialized domestic architectural production at Paquimé. Should a unit of measure be present in non-ceremonial architecture, it will therefore be most visible in this unit. All metric data used in this thesis were obtained from tables published in Vols. 3 and 4 of Di Peso's Casas Grandes excavation report (Di Peso 1974).

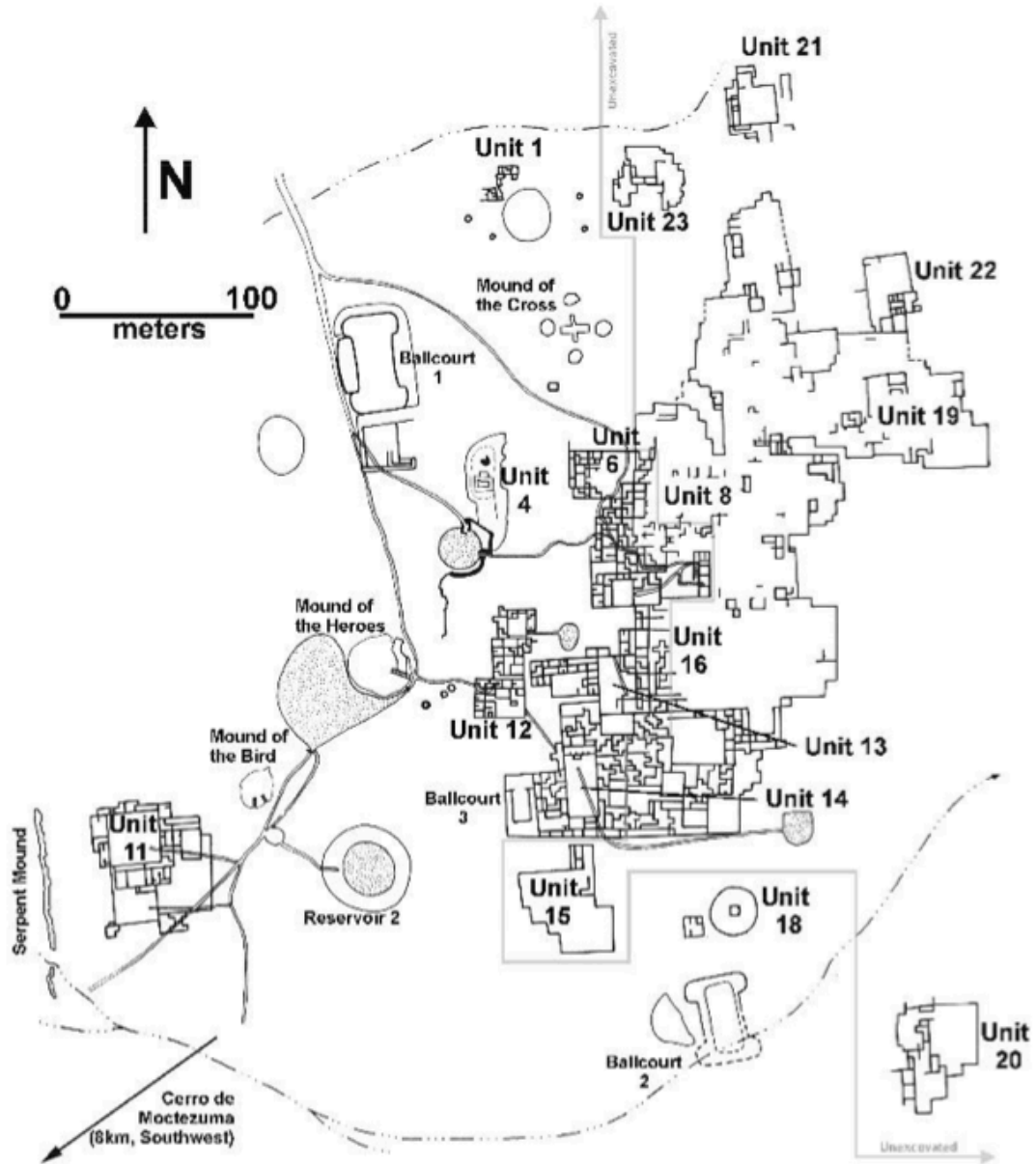


Figure 4.1: Plan view of Paquimé, illustrating the Mound of the Cross, the I-shaped ballcourt (as Ballcourt 1) and Unit 12. Courtesy of Gordon F.M. Rakita (Rakita 2009).

## 4.4 Analysis

Before I embark on a mathematical analysis of each of these three features, I should include a note on data precision. All of the measurements taken by Di Peso are rounded to the near-

est whole centimeter. As such, any unit I may derive is limited in precision by the original data. Furthermore, the measurements taken by Di Peso are subject to some degree of error. Adobe structures, especially in hot environments, are subject to melting and subsidence over time, introducing error into any measurements taken since the original construction. Consequently, this limits the ultimate precision of any unit that may be derived.

#### 4.4.1 The Mound of the Cross

Analysis began with a metric investigation of the Mound of the Cross, perhaps the most defining architectural feature of Paquimé. No other archaeological site in the region has a similar structure, and its almost exact orientation with the cardinal directions indicates that some care and planning went into its construction. Furthermore, as Mora-Echeverría has shown, the Mound of the Cross also exhibits a striking degree of geometric proportionality.

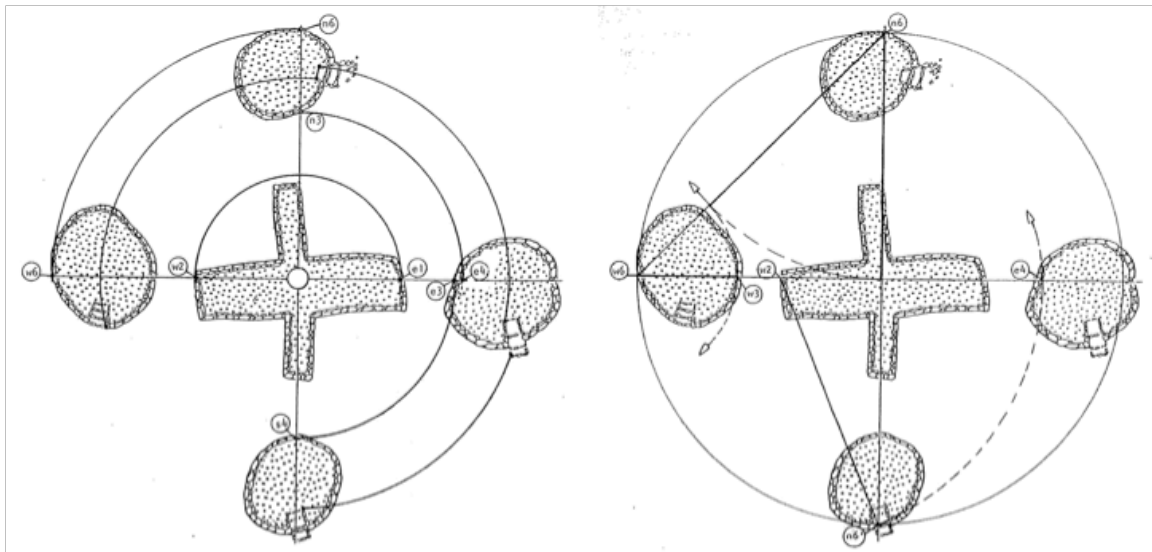


Figure 4.2: This image illustrates the geometric proportionality of the Mound of the Cross. Adapted from Mora-Echeverría 1984:Figure 7:16 and 1984:Figure 10:18.

The Mound of the Cross is composed of a raised cross-shaped central structure with round, flat-topped platforms slightly separated from the main cross-shaped structure and placed at the cardinal points off each arm of the cross. The cross and the mounds are con-

structed of an outer layer of carefully fitted medium-sized stones and are filled with smaller stones, earth and general rubble fill. The central cross-shaped structure averages a (reconstructed) height of approximately 67 cm above the surrounding area, while the mounds average a height of 97 cm. In addition, each mound has a small staircase integrated into the structure leading to the top of the structure. Taken as a whole, the feature spans some 3,635 cm on the north-south axis and 3,718 cm on the east-west axis.

To begin my analysis, I focused at the central cross of the structure. Assuming a base-20 numbering system, I divided the 1,410 cm length of the north-south axis of the cross by 20 to achieve a base unit of 70.5 cm. Similarly, I divided the 1,513 cm length of the east-west axis of the cross by 20 to achieve a unit of 75.7 cm. Each of the four mounds also appears to be roughly half the size of the central cross. Accordingly, dividing the maximum width of the northern mound by 10 yields a unit of 70.6 cm, and the southern mound yields a unit of 71.0 cm. The eastern and western mounds are significantly larger, with the eastern mound yielding a unit of 85.5 cm and the western mound yielding a unit of 87.0 cm. Curiously, both the eastern and western arms of the cross and the eastern and western mounds are larger and seemingly less standardized than their northern and southern counterparts. This may have some ritualistic meaning but could also reflect some oddity in the excavation or an artifact of the preservation and reconstruction work performed on the mounds, though such an investigation is beyond the scope of this thesis. The north-south features appear to reflect a unit between 70 and 71 cm.

#### **4.4.2 The I-Shaped Ballcourt**

Having established basic proportionality in the Mound of the Cross, I next turn to an investigation of the northern I-shaped ballcourt. This structure is located in the northwest corner of the site and consists of an excavated playing field in an “I” shape. An attached multitiered platform mound is located at the southern end of the field, and functioned as a raised platform from which the playing field could be easily viewed. The playing field

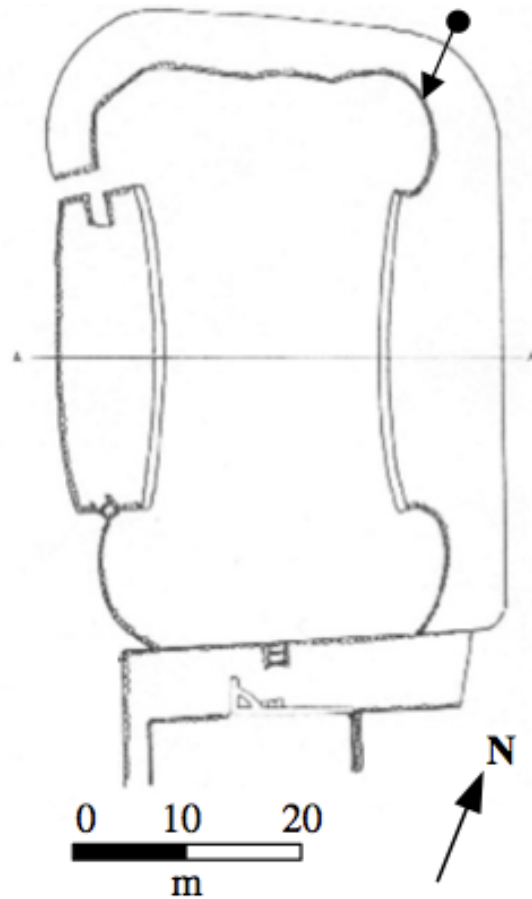


Figure 4.3: Plan of the northern I-Shaped ballcourt. Courtesy of Marcel Harmon (Harmon 2005).

itself is comprised of tightly compacted river mud and is bounded by a mixture of masonry and earthen embankments. Taken collectively, this feature spans some 8,800 cm on the north-south axis, and 4,000 cm in width on the east-west axis (Harmon 2005).

For the purposes of this analysis, only the playing field of the ball court is considered. At 2,880 cm long, the ball court is a bit over twice as long as the north-south axis of the Mound of the Cross. Dividing the north-south axis of the field by 20 produces a base unit of 144 cm, which is slightly more than twice the 70 to 71 cm unit derived from the Mound of the Cross. Dividing the court by 40 (two sets of 20) produces a base unit of 72.0 cm, which again is strikingly similar to the units derived from the north-south axis of the central structure and northern and southern mounds at the Mound of the Cross. In Mesoamerican ballgames,

the center marker is ritually significant (Harmon 2008), and it does seem reasonable that it served as a base point from which measurements were taken. Twenty units on either side of its center is consistent with the symmetry at the Mound of the Cross. Furthermore, Dividing the east-west axis of the court by 30 units (as it is roughly  $\frac{2}{3}$  as wide as the north-south axis is long) yields a unit of 66.7 cm, which is also close to the 70 to 71 cm unit found at the Mound of the Cross.

Marcel Harmon has previously performed a detailed metric analysis of Casas Grandes ball courts, ultimately concluding that (1) the I-shaped ball court and its contemporaries across the region were a product of the Medio period of occupation, and (2) that their highly standardized form reflects the transmission of a uniform ritual structure, as opposed to the incidental mimicry of independent invention (homologous, rather than analogous traits). Harmon identified and investigated a total of six I-shaped ballcourts in the Casas Grandes region, including the two ballcourts at Paquimé. Taken collectively, his measurements show a strong degree of standardization in the north-south axis of these ballcourts, with an average of 2,722 cm in length ( $\sigma$  325 cm, c.v. 11.9%). The east-west axis exhibits far more variation, with an average width of 1,713 cm,  $\sigma$  of 331 cm and a c.v. of 19.3%.

Given the difference in the apparent standardization in the north-south and east-west axes of these ball courts, I propose that the north-south dimensions were considered of paramount importance and are thus the most likely to be standardized using a consistent unit of measure. I divided the north-south axes of the other six ball courts by the same ratio of 40 that proved useful for the ball court of Paquimé, which again produced similar base units: 71.5 cm, 75.0 cm, 70.0 cm, 71.3 cm and 65.8 cm. One ball court seems to be an outlier with a base unit of 50.8 cm. Again, this clustering around 70 to 71 cm seems too consistent to be a mathematical coincidence.

I believe I have provided ample evidence for my first premise; the mounds being half the size of the central axis of the Mound of the Cross and the ball courts being double the length of the central axis shows a degree of proportionality that is reflective of the use of



a measurement system. I thus conclude that a consistent unit of roughly 70 to 71 cm is reflected in the north-south measurements of the I-shaped ballcourts and the Mound of the Cross, suggesting that it will be generally associated with architecture created for or by the leadership elite of Paquimé.

#### **4.4.3 Unit 12**

While architectural specialists may have been employed to construct elite architecture, they may not have been employed to construct the smaller units, which would likely use a more individualistic or household level of production. As a result, I wish to evaluate whether it is also present in more domestic forms of architecture. If the unit is present here, then it was likely that architectural specialists served an expanded role in the construction of Paquimé, which may provide insight into the degree of control the elites had over the construction of the site as a whole. To evaluate this hypothesis, I chose to look at wall dimensions from the square-shaped rooms of Unit 12, a feature consisting of 36 contiguous, single-story rooms of adobe construction, four plazas and several macaw breeding boxes (Bagwell 2006). Unit 12 is well suited for this analysis as it a discrete feature, set slightly apart from the main construction, and has been previously identified by Bagwell (2006) as the likely product of specialized builders.

The underlying premise of the deductive evaluation of the base unit of measure is that it should be reflected in domestic architecture such that wall lengths should be close to a whole unit. Thus, walls should be built to 10, 11, 12 or so on whole units. If there is a unit of measurement, then dividing the wall lengths by this number should produce significantly more whole (or nearly whole) values relative to a random number. For example, if the base unit of measurement of 70 or 71 cm is reflected in the architecture of Unit 12, then dividing the wall lengths by those values will produce more integers ending in .0 or close to it, than dividing the wall lengths by a random number such as 58 cm. For this evaluation, I divided the wall lengths by numbers from 60 cm to 80 cm in one-half centimeter increments. If

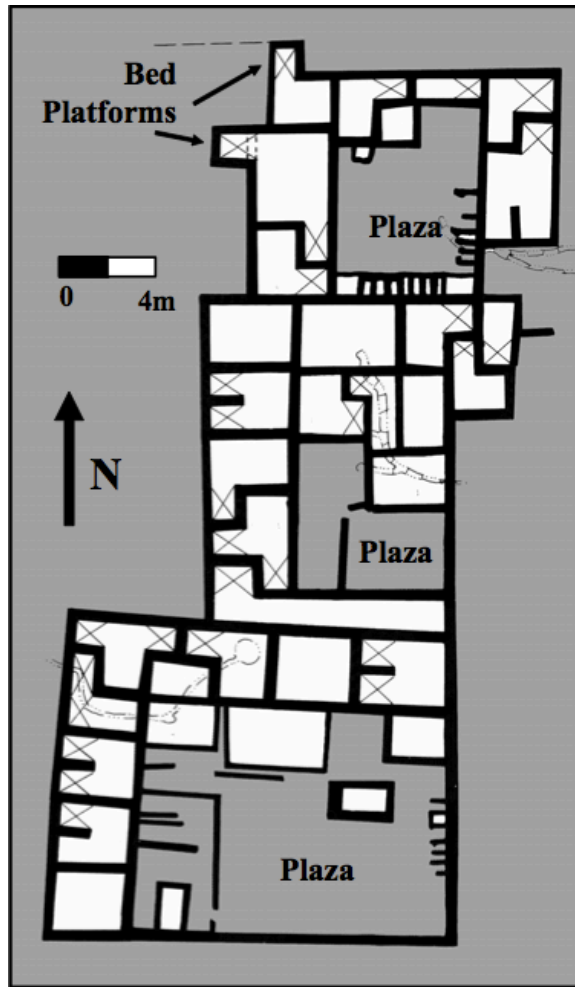


Figure 4.4: Plan detailing layout of the rooms of Unit 12. Measurements were taken from the 13 square-shaped rooms. After Di Peso 1974:5:524 and courtesy of Elizabeth Bagwell (Bagwell 2006).

standardization is indeed present and 70 to 71 cm is the unit of measure, I would expect for there to be more whole numbers in the data set divided by these units than other number. I would expect that whole unit to be reflected in the length of the walls, as it is convenient for builders to construct these walls in simple multiples of the base unit. For this analysis, I consider a unit be a whole number if it is within 1/10 of a whole unit (e.g., 0.9, 1.0 and 1.1 would all be considered a whole number). To statistically evaluate the significance, I took the average frequency of whole numbers across this entire range. I then averaged the number of fits, and constructed confidence intervals using the t-distribution. The average

number of fits is 16.8 whole numbers, with a standard deviation of 3.7 whole numbers. For the t-distribution, the t value for an  $\alpha$  of 0.05 and 40 degrees of freedom is 2.0. The upper confidence interval is 24.1 whole numbers, while the lower confidence interval is 9.5 whole numbers. The null hypothesis is that the observed frequency of whole numbers is equal to the average of all the whole numbers. Any number outside of these confidence intervals either has more or fewer whole numbers than would be expected by chance. Only one measurement exceeded the confidence limits – 70.0 cm. As a result, I reject the null hypothesis and conclude that a unit of measure of approximately 70 cm exists at Paquimé.

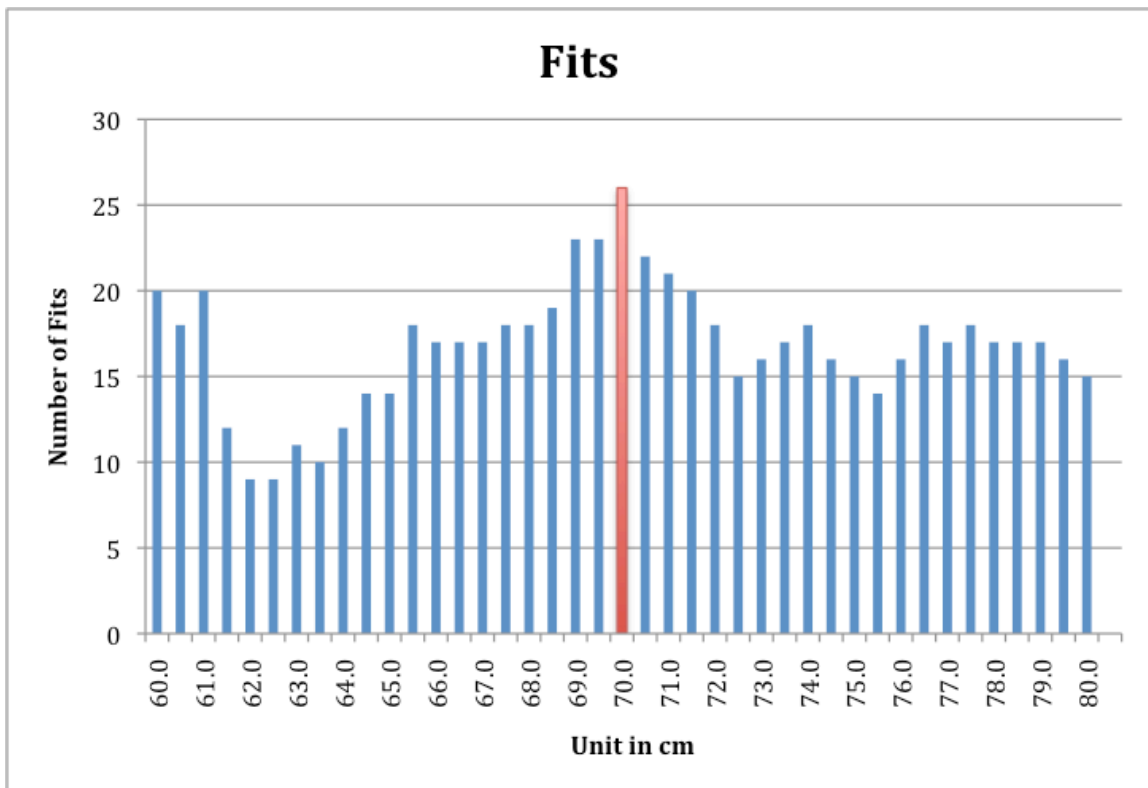


Figure 4.5: Number of fits per 0.5cm unit. More than 24 fits is statistically significant.

# Chapter 5

## Results and Discussion

My analysis has shown that there is indeed a unit of measure of approximately 70 cm employed by the builders of Paquimé. That this unit was arrived at inductively then reproduced deductively using different architectural features of very different structures provides support for its veracity, and the unit's persistence is particularly convincing given the vagaries of adobe construction. Moreover, I doubled and halved the proposed 70 cm unit and again examined the number of fits. A unit of 35 cm yielded only 17 fits, and a unit of 140 cm yielded only 18 fits. Neither value proves statistically significant via a t-test, and indicates that the true unit is indeed 70 cm in size. The presence of this unit of measure suggests that there is a high level of standardization and, consequently, specialization present in the architecture of Paquimé. It is likely, therefore, that the settlement was constructed by specialist architects under the control of ruling elites. Moreover, this architectural data supplements and strengthens arguments for specialized production based on studies of material remains found at the site (e.g., Minnis 1988; Vanpool and Leonard 2002).

The unit also proves rather interesting when compared to Mesoamerican metric studies. As O'Brien and Christiansen (1986) found, the Late Classic Mayas used a unit of 147 +/- 5 cm to construct their ritual architecture, a unit that is quite close to two of my Casas Grandes units. This unit is also close to two units of linear measure in use among the Aztec: *A tlacxiti*

(“step”) was a measure of 69.65 cm, and the *ciacatl* (“armpit”) was 72.0 cm (Clarke 2010). These similarities in measurement may help strengthen the argument for strong Aztatlán cultural influence during the Medio period of occupation at Paquimé. Following the work of Di Peso (1974) and Kelley et al. (1999), VanPool et al. (2008) found a strong similarity in trade goods between traditional Aztatlán settlements and Casas Grandes. They further argued that the presence and morphology of the I-shaped ballcourts bear striking similarities to the Aztatlán ballcourt tradition; a sentiment established more fully by Harmon (2005), who identified these ballcourts as homologous (rather than analogous) traits and therefore a product of cultural transmission. These similarities may indicate a greater transmission of Aztatlán cultural traits than has previously been recognized.

# Chapter 6

## Conclusions and Recommendations

### 6.1 Conclusions

The overall goal of this thesis was to evaluate the possibility of using architecture as a proxy for evaluating the degree of specialization in a society. I believe I have succeeded in that regard, as my detection of a base unit of measure shows that standardization in architectural measurement was present at Paquimé. As discussed earlier in this paper, high levels of standardization are indicative of specialized production within a society.

What remains unclear is the level of mensuration complexity that the Casas Grandes culture maintained. As the 70 cm unit appears in multiple contexts at Paquimé, evidence is strong that this culture reached the third stage of Childe's measurement hierarchy. However, I must concede the possibility that this measure may indicate a convenient natural measure in use during the construction of the site, rather than a true standardized measurement. However, my findings that the North-South axes of ceremonial architecture are far more standardized than the East-West axes provide support for the existence of a unit of measure and thus a culture that had likely reached Childe's third stage of complexity.

The methodology I have outlined here has shown that cultural progression and organiza-

tion of production can be derived solely from architectural remains, an analytical technique that may prove especially useful at settlements where cultural material has been robbed through either human or environmental causes. Furthermore, it may provide an additional line of evidence to corroborate studies of specialization that focus on material goods such as pottery or weapons production.

In addition, the apparent similarities between the Casas Grandes unit of 70 cm to that of Mesoamerican cultures may be indicative of diffusion of a ceremonial measurement system from Western Mexico to Northern Chihuahua. VanPool et al. (2008) has identified a number of traits shared between the two regions, and this may serve as an additional line of evidence to support some forms of cultural transmission.

## **6.2 Recommendations**

It would be interesting to expand this analysis to all known archaeological settlements thought to be of the Casas Grandes culture to evaluate whether this unit is present in all cases. I would hypothesize that the unit would be readily apparent in what Whalen and Minnis termed the “core zone” of Casas Grandes – the 30 or so km immediately surrounding the site of Paquimé – but will dwindle in appearance and ultimately disappear in the periphery sites.

Additionally, this type of metric analysis may be useful to evaluate Stephen Lekson’s theory of cultural relatedness between the Casas Grandes residents, the settlers of Chaco Canyon and the settlers of the Aztec site in New Mexico (Lekson 1999). Should this measure be in place at these other sites, it would serve as an additional line of evidence supporting that theory.

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