

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/256475170>

Measuring time, population, and residential mobility from the surface at San Marcos Pueblo, North Central New Mexico. *American Antiquity*, 74(3), 505–530.

Article in *American Antiquity* · July 2009

DOI: 10.1017/S0002731600048733

CITATIONS

16

READS

178

3 authors:



Ann F. Ramenofsky

University of New Mexico

11 PUBLICATIONS 309 CITATIONS

SEE PROFILE



Fraser Neiman

University of Virginia

20 PUBLICATIONS 855 CITATIONS

SEE PROFILE



Christopher D Pierce

Portland State University

65 PUBLICATIONS 430 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Applications of semantic technology to healthcare data management [View project](#)



Malibu Creek Archaeological Project [View project](#)

MEASURING TIME, POPULATION, AND RESIDENTIAL MOBILITY FROM THE SURFACE AT SAN MARCOS PUEBLO, NORTH CENTRAL NEW MEXICO

Ann F. Ramenofsky, Fraser Neiman, and Christopher D. Pierce

To understand the effects of European contact on the organization, size, and mobility of Pueblo populations in the Southwest requires detailed knowledge of the occupational histories of the aggregated settlements that typify the late prehistoric and early historic record. Unfortunately, such understanding is generally lacking because the methods used to document occupational histories of settlements tend to either obscure fine-grained temporal distinctions or necessitate costly, and politically objectionable, large-scale excavations. To overcome these difficulties, we use surface expressions to analyze the occupational and population history of San Marcos Pueblo (LA98), an aggregated, late prehistoric site in the Galisteo Basin of New Mexico that persisted to the Pueblo Revolt of 1680. Field methods include detailed mapping of the settlement and systematic surface collections of middens. Frequency seriation, correspondence analysis, and mean ceramic dates of decorated ceramic rims comprise our principal analytic methods and demonstrate that the pueblo was abandoned four times before 1680. Causes of abandonment are discussed. Relative scale measures of population show demographic fluctuations with maximum aggregation during the fifteenth century. Despite demographic pulses, the pueblo remained vital until the terminal abandonment.

Para entender los efectos del contacto europeo en la organización, el tamaño y la movilidad de las poblaciones amerindias "Pueblo" en el suroeste de los Estados Unidos de América, se necesita un conocimiento detallado de las historias de ocupación de los poblados de agregación que caracterizan los registros tardi prehistórico y histórico temprano. Desgraciadamente, tal conocimiento falta generalmente porque los métodos empleados para documentar las historias de la ocupación los yacimientos tienden a oscurecer las distinciones temporales finas o requieren excavaciones grandes y costosas o políticamente difíciles. Para superar estas dificultades, empleamos las evidencias en superficie para analizar la historia de ocupación y de población del Pueblo de San Marcos (LA 98), un gran poblado de agregación tardi- prehistórica en la Cuenca de Galisteo de Nuevo Mexico que continuó hasta la Revuelta de los Indios Pueblo en 1680. Los métodos del trabajo de campo incluyeron la cartografía detallada del yacimiento y la recogida sistemática de colecciones de superficie en las zonas de basurero. La seriación de frecuencias, el análisis de correspondencia y los promedios de las fechas cerámicas de los bordes decoradas componen nuestros métodos analíticos principales y demuestran que el pueblo fué abandonados cuatro veces antes de 1680. Se discuten las causas del abandono. Las medidas del tamaño relativo de la población demuestran la existencia de fluctuaciones demográficas, con una máxima agregación durante el siglo XV. A pesar de las pulsaciones demográficas, el pueblo siguió siendo vital hasta su abandono final.

Large, architecturally complex sites are the hallmark of the late prehistoric-historic transition in central and northern New Mexico, as well as across much of the Southwest. These sites represent persistent places (Schlanger 1992) that witnessed extensive and intensive use over long periods of time. Their size often dwarfed the largest of the earlier aggregated pueblos on the Colorado Plateau (Adler et al. 1996), with room counts rang-

ing from 300 to more than 1,500 (Adams and Duff 2004). These settlements are composed of the remnants of single or multistory room blocks made of stone masonry and/or adobe, as well as extramural features including ramadas, kivas, plazas, and deep middens. In some cases, their internal structure appears amorphous, a series of room blocks scattered across an area and lacking an ordered arrangement. In other cases, the room blocks are aligned

Ann F. Ramenofsky ■ Department of Anthropology, University of New Mexico, Albuquerque, NM 87131 (aramenof@unm.edu).

Fraser D. Neiman ■ Department of Archaeology, Monticello, Box 316, Charlottesville, Va, 22902 (fneiman@monticello.org)

Christopher D. Pierce ■ Web Data Works, 2733 Endicott Road, Shaker Heights, OH 44120 (chrisdpierce@hotmail.com).

American Antiquity 74(3), 2009, pp. XX-XX
Copyright ©2009 by the Society for American Archaeology

with one another, forming enclosed plazas (Bernardini 1998; Potter 1998). Both architectural patterns may be present at the same place.

The size, architectural complexity, and historical connection with early modern Pueblo peoples make these settlements essential to all discussions of place use history, settlement patterns, and population dynamics across the late prehistoric and early historic transition. The very characteristics that distinguish them, however, pose significant methodological challenges for reconstructing their occupational histories. Excavation is the traditional method employed for reconstructing the occupational history of these sites. Excavation provides wood samples used in estimating the age of construction events (through radiocarbon or tree-rings), as well as measurements of room size and function. The latter estimates are employed as proxies for creating numerical estimates of population size. Excavations also may recover stratigraphic sequences, as well as decorated ceramics or other temporal indicators, helpful for constructing chronologies of place use and abandonment.

These important contributions notwithstanding, excavation has several limitations. It is an onerous task at large sites, requiring years of sustained field and laboratory investigations and substantial amounts of money. In addition, given the current emphasis on preservation of archaeological deposits, excavation of these aggregated settlements is seen as politically objectionable, if not impossible. These problems in part explain why the major excavations at large late sites, notably native communities with missions, occurred in the early decades of the twentieth century (Cordell 1997; Ramenofsky and Feathers 2002). Since World War II, only a handful of reported excavations of aggregated settlements from late prehistoric New Mexico have occurred: Pot Creek (Crown 1991; Crown and Kohler 1994), Arroyo Hondo (Creamer 1993), Tijeras (Cordell 1980), Pueblo Pardo (Toulouse and Stevenson 1960), Pa'ako (Lambert 1954; Lycett 2002), and Pueblo Blanco (Creamer et al. 2002).

Unfortunately, most of these large places were abandoned well before the sixteenth century and the onset of documented history. Thus, modern archaeological knowledge of occupational histories or population dynamics across the late prehistoric-historic transition is extremely limited.

Despite their obvious significance, the late aggregated settlements tend to stand outside much of the current Southwestern research on settlement aggregation and dispersion, or persistence and change of Pueblo populations. For instance, the assumption of what it means to be sedentary is shifting in the Southwest (Lekson 1990; Powell 1990; Varien 1999); the simple contrasts between sedentism and mobility or agriculture and foraging no longer hold. Sedentary agriculturalists were residentially mobile at a number of temporal scales. Sometimes they returned to previous residences; sometimes they did not.

This significant change in knowledge, however, has not been integrated into archaeological understanding of the protohistoric aggregated settlements. They are assumed to represent deeply sedentary populations (Lekson 1990) who stayed put and grew incrementally over time. Because of this assumption, the terminal abandonment of these settlements during the Pueblo Revolt has been interpreted as representing significant population decline from introduced infectious diseases. That decline, in turn, is considered causal in changing the sociopolitical structure of early modern Pueblo populations (Cordell and Plog 1979; Haas and Creamer 1992; Lightfoot and Upham 1989; Upham 1982; Wilcox 1981).

Here, we evaluate the nature of sedentism and population dynamics of protohistoric Puebloan aggregated settlements by reconstructing the place-use history of San Marcos Pueblo (LA98), one of eight aggregated settlements located at the western edge of the Galisteo Basin (Figure 1). San Marcos, currently a preserve owned by the Archaeological Conservancy, is approximately 24 hectares. During its long use life that spanned the fourteenth through the seventeenth centuries, it was a significant community in the region. The pueblo is situated 5 km from the Cerrillos Hills, the principal source of turquoise and galena. Cerrillos Hills Galena was the primary flux in San Marcos glaze-paint ceramics (Habicht-Mauche et al. 2000), and the community was an important node of ceramic glaze-paint production, social interaction, and regional trade throughout the protohistoric period (Herhahn 2006; Huntley and Kintigh 2004; Nelson and Habicht-Mauche 2006; Shepard 1942; Warren 1976). Historical references to San Marcos appear routinely after 1582 and always in ref-

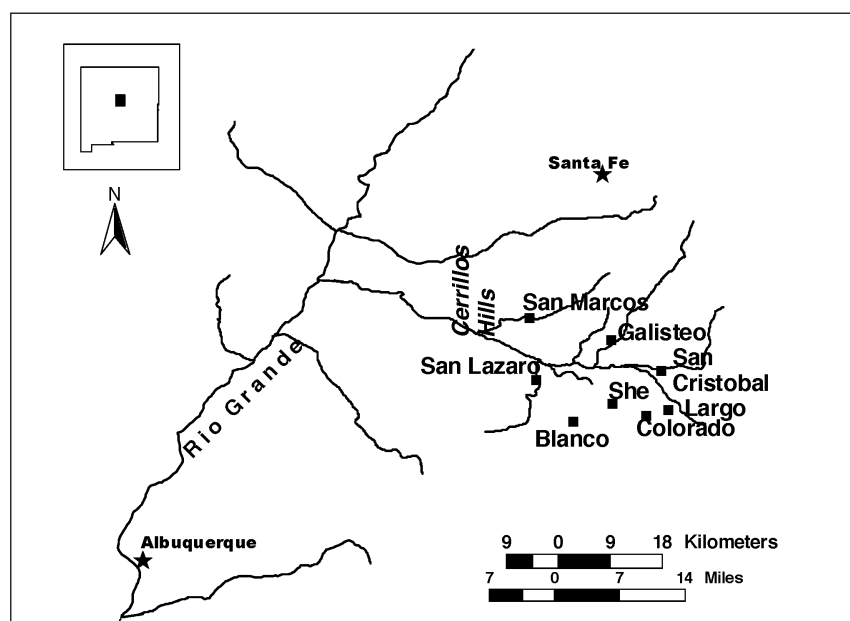


Figure 1. Galisteo Basin Pueblos.

erence to the metallic minerals of the Cerrillos Hills (Ramenofsky et al. 2008). In the 1630s, the Franciscans established San Marcos as a *doctrina* (Hodge et al. 1945). Until 1680, one priest was in residence at the pueblo.

In building this occupational history we employ a set of concepts and noninvasive methods most often used on regional scales, but are also suitable for reconstructing the use and population history of individual large settlements. The fieldwork focused spatially on the locations, documentation, and artifact collections of middens because they are rich repositories of temporal indicators. Our temporal constructions rely on frequency seriation and correspondence analysis of decorated ceramics, as well as mean ceramic dates.

Our analysis of surface evidence indicates dramatic fluctuations in the size of the native population at the pueblo. We use counts of ceramics deposited into middens as proxies for population size. The archaeological evidence is compelling and suggests that the San Marcoseños were not deeply sedentary. They practiced a form of residential mobility at the scale of centuries that involved both emigration from and return to the pueblo. This reconstruction contrasts with the received wisdom regarding the nature of sedentism at protohistoric pueblos, and points to a robust and

far less costly strategy for reconstructing place use history at these large settlements.

Chronology and Tree-Ring Dating in Southwestern Archaeology

In the early decades of the twentieth century, Southwestern archaeologists applied frequency seriation to temporally order surface artifacts, primarily pot sherds (Kroeber 1916; Lyman and O'Brien 1999; Lyman et al. 1998; Spier 1917, 1918, 1919). The method, however, did not survive very long. At the first Pecos Conference, A. E. Douglass summarized his initial results of dendrochronological dating of archaeological villages (Kidder 1927). Given the potential precision of tree-ring dating, Southwestern archaeologists moved quickly to establish the method as their principal means to temporally order archaeological events (Nash 1999; Towner 2002). Frequency seriation all but ceased as a chronological tool in the Southwest throughout most of the twentieth century.

Initially, the fine temporal discrimination provided by tree-ring dates was used to supplement culture historical periodization, adding calendrical estimates to culture history units. However, as period-based chronologies became fixed in absolute time by tree-ring dates and, as dates from

numerous sites accumulated, dendrochronology came to be used as a stand-alone method for building temporal sequences. Traditional culture history units, by contrast, served mainly as monikers of the general time period of interest (e.g., Adams and Duff 2004; Adler 1996; Spielmann 1998). The precision of the tree-ring dates translated into new realms of investigation including documentation of rapid regional abandonments, migration, and settlement reconfigurations.

To use dendrochronology to reconstruct settlement histories of such long-lived pueblos as San Marcos typically requires excavation because excavation supplies tree-ring samples. Moreover, large samples of wood are preferred to counteract the problems of differential preservation and wood recycling. Large samples, in turn, mean extensive excavation. Thus, an association exists between the number of tree-ring dates and the duration of excavation projects. For instance, Pecos Pueblo, excavated for more than a decade, has approximately 90 tree-ring dates (Kidder 1958). San Marcos, by contrast, with a more limited excavation history, has a total tree-ring sample of 15. Eight of these dates are non-cutting; seven are cutting dates divided across the fourteenth and seventeenth centuries. Even if all the dendrochronological dates from San Marcos were cutting dates, this sample is too small to suggest the nature or the duration of settlement use.

Despite the high potential precision of dendrochronology for estimating the age of archaeological expressions, including occupational history of aggregated pueblos, the method is most successful where excavation is an option. As described above, excavation is not currently a viable approach for the ancestral aggregated pueblos. To reintegrate these obviously important sites into the discussion of occupational dynamics and population pulses across the historic baseline requires a different strategy that works within the current economic and political structure of the discipline.

Chronology and Surface Archaeology

Beginning in the 1970s, archaeologists developed a different orientation to regional surface expressions, variously known as the siteless or nonsite survey (Bintliff 2000; Dancey 1998; Dunnell and Dancey 1983; Ebert 1992; Foley 1981; Jones and Beck 1992; Sullivan 1998; Thomas 1975). Collec-

tively, these approaches view the surface as an independent research domain with interpretive or explanatory potential. The general approach is distributional. Artifacts rather than sites are the fundamental analytic unit. The change in analytic scale means that sites are simply high-density nodes in a variable landscape of artifacts.

At San Marcos, we implemented a surface perspective to work at the scale of site. Artifacts and their distributions across the surface, rather than room blocks, constituted the initial analytic units. Variations in the density and composition of surface artifact distributions facilitated defining other analytic units, namely middens, which became more useful for reconstructing occupation history.

There have been objections to the interpretive potential of surface archaeology (e.g., Odell and Cowen 1987; Simmons 1998), including the assumption that the surface is more disturbed than the subsurface and the absence of datable material on the surface. Neither objection is supportable. Although surface expressions are obviously affected by record formation processes, such processes are not limited to current surfaces. All buried surfaces were originally surficial and subject to many of the processes affecting current surfaces (Dunnell and Dancey 1983). Rather than automatically discounting surface distributions, they must be evaluated in the context of a particular research effort. Simply, there is no universal criterion of disturbance. The issue must be empirically assessed.

Additionally, although there are no dating methods explicitly designed to work with surface artifacts, it does not follow that surface distributions are temporally impoverished. In fact, a number of dating methods are well suited for estimating the age of surface artifacts (e.g., Beck 1999; Feathers 1997, 2000; Jones et al. 2003; Phillips et al. 1951). As in all temporal construction, multiple methods are useful for increasing the precision of age estimation of an archaeological event.

In this reconstruction, we employ frequency seriation, correspondence analysis, and mean ceramic dating. All three methods estimate the same event: the weighted average of the time period over which the assemblage accumulated. Weights are proportional to the rate at which artifacts are deposited at a given point during the duration of use. Because the three methods are complementary,

Table 1. Comparison of Kidder's and Mera's Glaze-Paint Types.

Kidder's glaze sequence (1936)	Mera's glaze sequence (1933)
Glaze I	Glaze A Red
	Glaze A Yellow
	Glaze A Polychrome
Glaze II	Glaze B Yellow
	Glaze B Polychrome
Glaze III	Glaze C Polychrome
Glaze IV	Glaze D Polychrome
Glaze V	Glaze E Polychrome
Glaze VI	Glaze F Red

they increase the likelihood of more completely elucidating the occupation history of San Marcos.

Frequency Seriation (FS)

FS is based on a simple model of how the relative frequencies of a suite of mutually exclusive types is distributed across temporally successive assemblages: (1) there is temporal overlap among types—subsets of types do not appear and then disappear synchronously; (2) the type frequencies follow unimodal or battleship-shaped curves over time (Dunnell 1970; Ford 1962). Types that meet these criteria have been traditionally defined as “historical types” (Kreiger 1944). Given a set of assemblages whose temporal order is unknown, the FS model suggests that the one-dimensional ordering of assemblages that most closely fits the model is likely to be chronological. Types, however, can demonstrate unimodal responses along other gradients, including geographical space or social status (Kruskal 1971). Hence, the conclusion that any particular seriation solution is a chronology must be evaluated against independent evidence.

Culture historians recognized two nonchronological factors that could cause departure from the unimodality assumption of the FS model (Dunnell 1970): time averaging (variability in the amount of time over which assemblages accumulate), or combining assemblages from different local-stylistic traditions into a single seriation. Tradition is used here in the cultural-historical sense to refer to continuity of people and the social learning among them. Recently, evolutionary archaeologists have capitalized on this condition to track learning lineages (e.g., Lipo 2001; O'Brien and Lyman 2003; Shennan 2003; Van Hoose 2008).

The FS model places a heavy burden on the identification of types that are historical in the sense

that they have unimodal distributions in time. The ceramic types we use have been thought to be historical for nearly a century (Kidder 1936; Mera 1933; Nelson 1916). Two decorated ceramic traditions dominate the late prehistoric and early historic periods in the central and northern Rio Grande Valley. The matte-painted black-on-white wares, initially defined by Amsden (Kidder and Amsden 1931) and Mera (1935), are earlier and the glaze-paint wares later (Kidder 1936; Mera 1940). Nelson's stratigraphic excavation in the Galisteo Basin (1916) showed convincingly that the glaze-paint wares replaced the matte-painted wares. Both wares are present in significant numbers at San Marcos Pueblo.

There are two typologies for the glaze-paint types (Table 1). Kidder's excavations at Pecos Pueblo defined the glaze-paint sequence, known as Glaze I-VI (Kidder 1936). Rim shape of decorated bowls was the fundamental criterion used to distinguish among types. With a larger sample of rims from many more locations along the Rio Grande, Mera redefined Kidder's sequence as Glazes A-F (Mera 1933, 1940), adding subtypes based on geographic location, as well as the number and color of slips. Because San Marcos is within the Rio Grande corridor, rim shape is coded using Mera's definitions, as are the identifications of red, yellow, and polychrome slips.

The final issue is variable time averaging. Because our assemblages are drawn from a single site, the probability that some of them may have been deposited on areas of the site previously abandoned may be a problem. However, whether the assemblages seriate is ultimately an empirical matter. Close examination of trial solutions makes it possible to evaluate the fit between the types and the model.

Correspondence Analysis (CA)

CA is a multivariate statistical technique (Clausen 1998) with a long history of archaeological application in Europe (Bech 1988; Bølviken et al. 1982; Madsen 1988; Nielsen 1988; Shennan 1997) and a shorter one in the North America (Duff 1996; Neiman and Alcock 1995; Scholnick 2003; Smith and Neiman 2007; Van Hoose 2008). There are multiple mathematical derivations leading to the same equations of CA (De Leeuw 1983; Gower 1990), but the one most relevant to chronological inference begins with the FS model (Hill 1974; Neiman and Alcock 1995; Smith and Neiman 2007).

FS assumes that type frequencies are unimodal response functions on a single underlying temporal gradient. It seems likely, however, that type abundance might be influenced simultaneously by synchronic variation along a second gradient, or a third, or fourth. CA can be seen as an attempt to accommodate this possibility by identifying any additional gradients and providing estimates of the locations of assemblages and points of maximum frequency of the types along each one. CA represents those estimates as assemblage and type scores on a set of axes. The score of each assemblage on each CA axis is proportional to the weighted average of the scores of the types that are represented in it, where the weights are the type frequencies. The CA axes are constructed, as in principle components analysis (PCA), so that the scores on successive axes account for the most variation, or "inertia," in the data and are uncorrelated with one another. Inertia values for each assemblage represent their distance from all assemblages, or the average midden. Also, as in PCA, the amount of variation accounted for by each CA axis offers an initial clue about whether it has identified a real gradient.

Parsing type-frequency variation into variation along several orthogonal gradients comes at a parametric price. We must make additional assumptions about the type-frequency response functions and the locations along the gradients from which our samples are derived: (1) type frequencies approximate Gaussian curves, each with its own mean and variance when plotted against the underlying gradient to which it responds; (2) the type tolerances, which control the spread of the types along each gradient, are roughly equal; (3) the spacings

of the type means, which coincide with the locations of type-frequency maxima along each gradient, are equal or drawn from a uniform distribution; and (4) the spacings of the locations of assemblage samples along the underlying gradient are also equal or drawn from a uniform distribution. Given these assumptions, analytical and simulation results show that the scores of the assemblages and types on the CA axes approximate maximum-likelihood estimates of their true locations on the underlying gradients. In addition, CA appears to have considerable robustness in the face of departures from the assumptions (ter Braak 1985; ter Braak and Prentice 1988).

Do the San Marcos assemblages meet these requirements? As with FS, the technique and the models behind it allow us to generate concrete expectations about the patterns we should see if they do (Neiman and Alcock 1995; Smith and Neiman 2007). If type frequencies respond to only a single underlying gradient, as specified in the FS model, then the CA Axis-1 scores will capture that gradient. Sorting the assemblages on those scores will yield the unimodal-response curves of the FS model. The type scores will give the order in which the type maxima occur, producing a seriation of types as well as assemblages.

The scores of the assemblages and the types on the second CA axis may be a quadratic function of their scores on the first, leading to an arch configuration when plotted. The appearance of the arch signals that type frequencies are determined by unimodal response functions to a gradient that is long enough to capture inflections in the curves. With a single underlying gradient long enough to produce an arch, the variation or inertia of both the Axis-1 and Axis-2 scores will be far greater than the inertias of the high-order axes. With a single, shorter gradient, only the first axis will have a high inertia. If a second, underlying gradient influences type frequencies, then a higher-order CA axis will also have high inertia associated with it.

Plots of the assemblage and type scores on the CA axes allow us to identify clustering in their locations along the underlying gradients. The separation between adjacent clusters on CA plots should also be reflected in jumps in the frequencies of one or more types between assemblages that are adjacent in the FS order. Clusters of assemblages from CA and jumps in type frequencies from

Table 2. Tree-Ring Cross-Dates for Black-on-White and Glaze-Paint types (Dates are A.D.).

Glaze Type	Kidder (1936)	Mera (1940) ^a	Breternitz (1966)	Warren (1979)	McKenna and Miles (1991) ^b
Santa Fe Black-on-White			1200–1350		1175–1350 (or early 1400s)
Wiyo Black-on-White			1300–1400		1300–1400
Galisteo Black-on-White			1300–1350		1300–1400
Glaze I/ Glaze A		1350–1450	1300–1425+	1315–1425	1315–1425
Glaze II/ Glaze B	1425–1475	1350–1450	1300–1450	1400–1450	1400–1450
Glaze III/ Glaze C	1475–1550	1425–1575	1400–1500	1425–1500	1425–1490
Glaze IV/ Glaze D	1550–1600	1475–1550	1425–1575	1490–1515	1490–1515
Glaze V/ Glaze E	1600–1700	1550–1600	1425–1600	1515–1600 1600–1700	1515–1650/1700
Glaze VI/ Glaze F		1600–1700		1650–1700	1625–1700

^aDates refer to Glaze periods, not glaze–paint types.^bPublished in Vint 2000.

FS are indicators of discontinuities in deposition and occupation.

Mean Ceramic Dates from Dendrochronological Cross-Dates

Our final chronological method, mean ceramic dating, combines the assumption from the FS model that type frequencies are unimodal responses to a single chronological gradient with the assumption from the CA model that the response functions are Gaussian and have equal variances. The mean-ceramic-date (MCD) method further assumes that we already know the means in calendar years of the Gaussian functions that describe the type frequencies. If the type-frequency curves are Gaussian, then their means can be estimated as the midpoints between the beginning and ending manufacturing dates of each type. South (1972, 1977) proposed an estimator for the MCD that was the weighted average of the manufacturing midpoints. In this solution, the weights were the frequencies of the ceramic types and the midpoints were estimated from the documented history of the manufacture of the types in early-modern Europe. Unlike FS and CA, MCDs offer no feedback on the fit of the MCD model to a particular dataset. Employing MCDs alone for chronological inference invites unnoticed errors. However, MCDs offer a useful way to summarize the implications for one or more assemblages of independently derived evidence on manufacturing dates of the types found in them. The results can then be used to evaluate FS and CA solutions.

Applying the MCD method in the Puebloan Southwest requires estimates of manufacturing

midpoints from dendrochronology (Christenson 1994). Caution is necessary because there is a tortuous inferential trail linking the target event to the dated event, especially when extrapolating to assemblages (e.g., Dean 1978; Schiffer 1987). Table 2 summarizes the dendrochronological estimates of production dates for Mera's rim shapes. There is broad agreement among authors on the chronological order of the types. In what follows, we construct manufacturing midpoints based on McKenna and Miles (1991) and reported in Vint (2000).

Investigating the Surface at San Marcos

Archaeological investigations at San Marcos Pueblo follow a pattern typical of many large, late settlements in the Southwest. Nels Nelson initiated archaeological fieldwork on the Galisteo Basin pueblos in the early twentieth century including San Marcos (Nelson 1912–1915, 1914). His planimetric map of the visible architecture at San Marcos identified 43 room blocks, three kivas, and a Spanish mission complex (Figure 2). Nelson also excavated test trenches across all room blocks. Despite the significant scale of the test excavations, only selected artifacts were saved (see Welker 1997 for ceramic summary). Descriptive notes are sparse, and there are no stratigraphic profiles or descriptions. Most recent investigators have undertaken more limited explorations of San Marcos (Creamer 1996; Creamer et al. 2002; Eddy et al. 1996; Haas and Creamer 1992; Ivey and Thomas 2005; Reed 1954; Thomas 2000; Welker 1997). Our surface

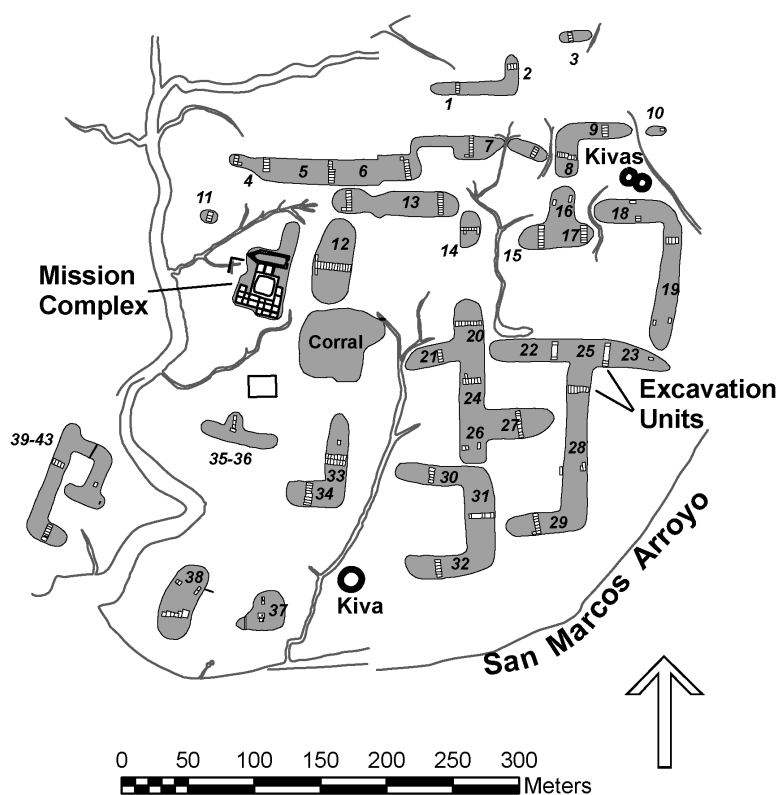


Figure 2. Nelson's 1914 planimetric map of San Marcos Pueblo.

data were collected as part of a large multiyear study of the entire pueblo (Pierce and Ramenofsky 2000; Ramenofsky 2001, 2003; Ramenofsky and Pierce 1998, 1999; Ramenofsky et al. 2008). Here we consider only that portion relating to the reconstruction of the occupation history.

UNM Surface Protocol

Sampling the surface for temporally sensitive artifacts was the first step in building a place-use history of San Marcos. To accomplish this goal we used a two-stage approach. In 1999 (Pierce and Ramenofsky 2000), the entire surface of the pueblo was systematically sampled at 20 m intervals. In each 1 m square unit, a shovel was used to scrape a thin layer (1–2 cm) of material from the surface that was dry screened and saved. Although substantially less than one percent of the area of San Marcos, these 371 units provided a reasonably clear picture of surficial artifact distributions. Artifacts occurred in low densities on room block mounds, but in discrete areas adjacent to nearly every room

block, artifact density increased greatly. Twenty such high-density locations were identified and defined as middens (Figure 3).

To increase the sample size of temporally sensitive artifacts from the middens, a second surface collection was conducted in 2000 (Ramenofsky 2001). This effort was enhanced by an unusually dry winter and spring, which greatly reduced vegetative growth. After defining midden boundaries more exactly, we established a collection grid consisting of 5 m square units over the accessible surface of each midden. This protocol resulted in a total of 1,055 sample units. Within each unit, all temporally sensitive artifacts were collected. The combined samples from both seasons of surface collection produced a total of 7,600 rim sherds. The temporally diagnostic glaze-paint bowl portion of the sample constituted approximately 50 percent of the total rim sherd sample.

Surface Formation Processes

The most significant issue regarding San Marcos

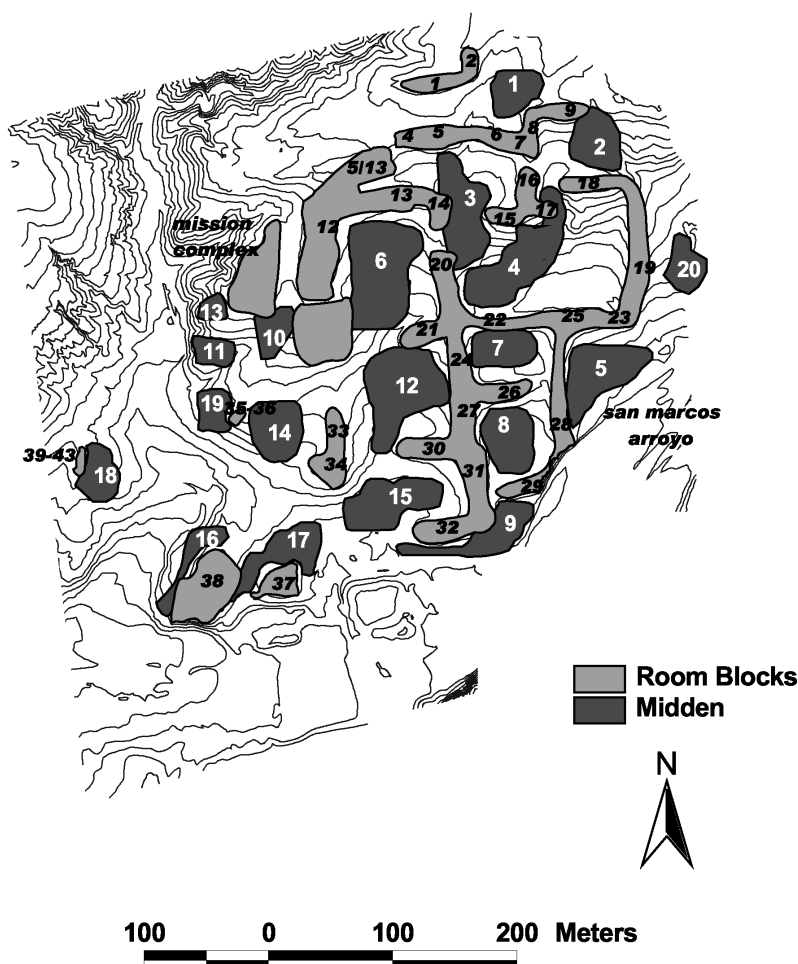


Figure 3. Middens and room blocks, San Marcos Pueblo.

surface expressions is the extent to which artifacts present on surfaces are representative in some understandable way of the range of artifacts deposited during the entire period of use of the trash dump. At San Marcos, two major processes can be identified that have likely exposed buried artifacts on the surface: erosion and bioturbation by gophers and people.

Erosional effects are closely linked to site topography. The room blocks and middens are situated on a small rise that gradually descends across two fill terraces and terminates at San Marcos arroyo on the south (Figure 4) (Hinz et al. 2008; Pinson 2008). The effect of this gradual descent is that the settlement is arranged in a series of tiers. From north to south, buildings are located on the two stream terrace surfaces and terminate on the flood-

plain of San Marcos arroyo. Sediments across the site are uniform, consisting of unconsolidated silty sand with gravel.

The topographic setting suggests downslope migration of sediments and artifacts. Because most middens are located in topographic lows relative to room blocks, the artifact record in these locations could be buried or enriched from those upslope. Complete burial has not occurred, but the extent of artifact displacement down slope is unknown.

Bioturbation is also important. Because of the dense vegetative cover and rich, friable soils of middens, burrowing rodents, especially pocket gophers (*Thomomys umbrinus*), have potentially modified all midden surfaces. Of the 1 m square surface-scraps units, approximately 22 percent of

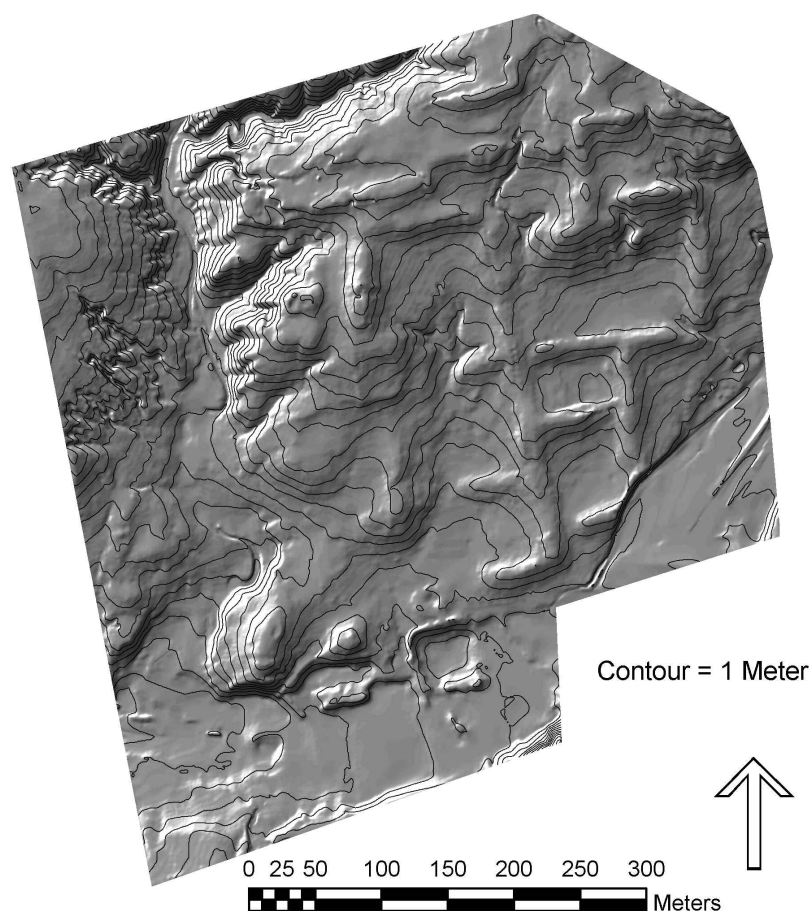


Figure 4. Digital terrain model of San Marcos Pueblo.

the midden units showed signs of active burrowing; 10 percent of non-midden units displayed comparable evidence. Although some of the burrows indicate the presence of large mammals such as rabbits, or hares, most are suggestive of pocket gophers or other fossorial animals. In general, the level of evidence for active burrowing is indicative of a thriving community of burrowing animals capable of producing substantial effects on the surface and subsurface record (Balek 2002; Morin 2006; Pierce 1992).

Pierce (1992) used his burrowing simulation program to evaluate the likely effects of sustained exposure to burrowing on the composition of surface artifact assemblages. The program is based on the burrowing behavior of the pocket gopher and the depth and size of burrows can vary by species (Wilkins and Roberts 2007). Consequently, the sim-

ulation results should be viewed as indicative of a general pattern of artifact movement from burrowing. Figure 5 shows the changes in the relative contributions to the surface of artifacts from different depth intervals over 700 years of burrowing exposure. Although artifacts originally deposited on or near the surface remain the most abundant throughout the period of simulated burrowing, contributions from deeper levels rise rapidly making up slightly less than 70 percent of the surface assemblage after only 300 years. The relative contribution to the surface of artifacts from different depth intervals decrease with increasing depth below the surface with artifacts buried below 70 cm never rising above 1 percent of the surface assemblage.

There is also evidence of cultural modification both during and following native abandonment.

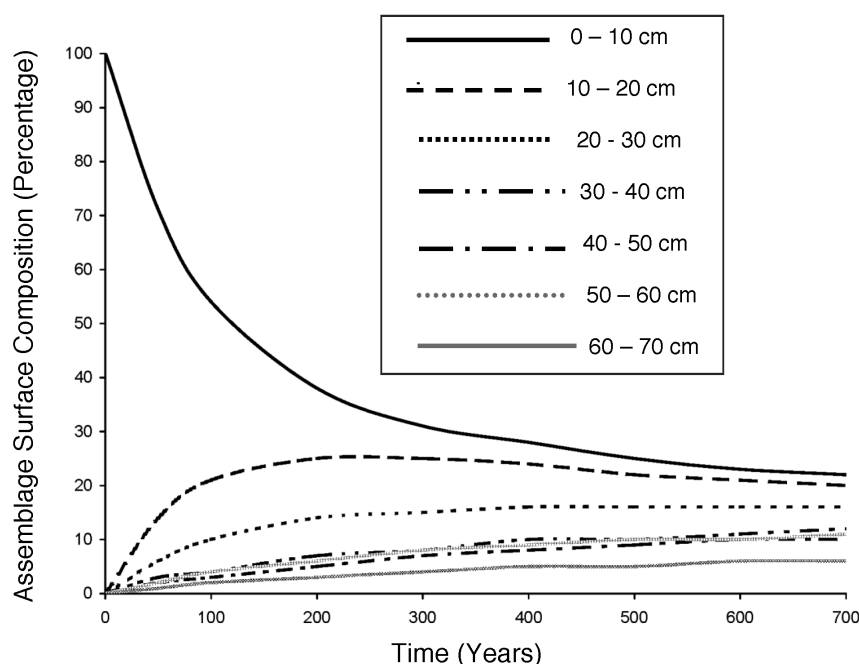


Figure 5. Simulation of gopher activity.

Room block construction and/or adobe melt have covered earlier trash deposits (Pinson 2000; Pinson and Angel 2001), and some later room block constructions mined earlier middens for adobe (Penman 2001). Consequently, although our midden sample is 100 percent of late middens, we do not have a complete sample of earlier middens (Pinson 2000; Pinson and Angel 2001).

Following native abandonment, the settlement continued to be used. In the eighteenth century, the mission area was reoccupied and the church was used as an animal pen (Pinson 2008). Still later, a small dairy was built on San Marcos and the concrete footings of that operation are still visible in the vicinity of Midden 19. In the early twentieth century, a small frame structure associated with farming was built on top of part of Midden 14. Finally, Nelson's test excavations contributed to surface accumulations. His collection strategy was selective, and he did not backfill his trenches. It is possible that artifacts from his excavations have enriched adjacent middens.

Table 3 summarizes the effects of surface formation processes across all middens at San Marcos. All middens have been subjected to these

processes. Surface artifacts have been buried, and buried artifacts have been brought to the surface. As a result, it is possible that surface assemblages are massively time-averaged palimpsests from which any chronological signal has been erased. It is also possible that surface assemblages reflect the deposits buried beneath them and that spatial variation among assemblages captures an informative chronological signal. Frequency seriation offers a means of evaluating which of these possibilities better accounts for the surface record.

Temporal Inference

Frequency Seriation

Analyses reported here are based on a data matrix of 3,680 sherds containing the counts of 19 ceramic types in 20 middens (Ramenofsky and Neiman 2008). Because the Black-on-White rim sherds are a very small proportion of the total, we grouped them into one type that includes Wiyo Black-on-white, Santa Fe Black-on-white, and Galisteo Black-on-white. The glaze-paint types A–F are a paradigmatic classification based on the intersec-

Table 3. Summary of Surface Disturbance at San Marcos Pueblo.

Midden	Erosion	Deposition	Burying Rodents	Cultural Disturbance
1			X	
2			X	
3	X		X	
4	X		X	X
5	X	X	X	
6	X	X	X	
7		X	X	
8		X	X	
9		X	X	
10	X		X	
11	X		X	
12	X	X	X	
13	X		X	X
14		X	X	X
15		X	X	
16	X		X	
17		X	X	
18			X	X
19	X		X	X
20	X		X	

tion of rim shape and slip color.

A frequency seriation for the San Marcos assemblages reveals a strong chronological signal¹ (Figure 6). The type-frequency curves are roughly unimodal. The order of the frequency maxima for the different types matches the order arrived at by earlier researchers of the region (Table 2), with Black-on-White at one end, followed by Glazes A, B, C and D, and finally E and F at the other end. The spread of the rim shapes across the entire sequence does not fit with the beginning and ending dates suggested by ceramic cross dates (Table 2). Time averaging in the San Marcos samples is partially responsible. However, the extent of the contrast suggests that a reevaluation of the dendrochronological evidence for the beginning and ending dates of the Glaze-paint rim shapes is over-

due. We do not pursue the issue further here.

The most striking violation of unimodality occurs near the top of the sequence (Middens 6, 10, and 13), where Black-on-White, Glaze A-Yellow, Glaze A-Red, and/or Glaze B-Yellow increase again in frequency after periods of apparent decline. We offer two hypotheses for this pattern. First, the trend may accurately reflect a later increase in the use and production of these types. In other words, these three types are not historical in the traditional, culture-historical sense. The second hypothesis explains the reappearance of these types as a function of the averaged nature of the middens. Middens 6, 10, and 13 may have been used early in the sequence, when the types were near their frequency peaks, then abandoned, and finally used again at the end of the sequence, when E and F rim shapes

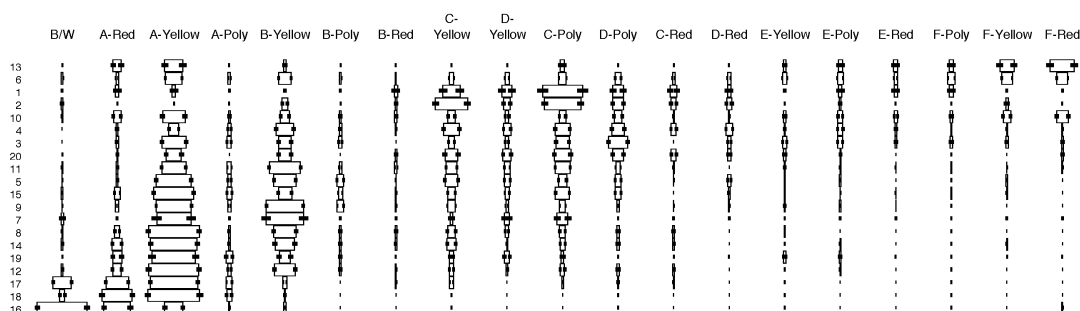


Figure 6. Frequency seriation of 20 midden assemblages from San Marcos.

dominated. In contrast, all the other middens had more uniform periods of use.

The second hypothesis is a more likely explanation of the near-synchronous reappearance of the types. Because these middens are located just north of earlier Middens 11, 12, 14, and 19, an earlier occupation is more likely. Midden 10 is an erosional surface; the mission complex is built on an earlier room block; and Nelson's previously excavated mission complex overlaps Midden 13. The principal lack of fit to the FS model is due to more extensive time averaging in the three assemblages at the end of the sequence.

Correspondence Analysis and Mean Ceramic Dating

Three correspondence analyses summarized on Table 4 were constructed in an effort to discriminate temporal use of middens. In the first analysis (CA 1), the proportion of inertia accounted for by the two CA axes is significantly greater than expected by chance, according to the broken-stick model, which indicates what would happen if the total inertia were randomly apportioned among the axes (Jackson 1993; Legendre and Legendre 1998). A scatterplot of the midden assemblages on the first two axes reveals what initially looks like an arch, implying that CA Axis 1 captures time, and CA Axis 2 has no temporal significance (Figure 7a). The plot of the ceramic types in CA space, however, reveals a different pattern (Figure 7b). The orientation of Axis 1 is heavily influenced by the early types, Black-on-White and Glaze A, on the one hand, and later Glazes B, C and D, on the other. Axis 2 contrasts Glazes B, C, and D with the latest types, Glaze E and F. In other words, Axis 2 is not simply a quadratic function of Axis 1. It, too, is correlated with time. This interpretation is supported by the demonstration that both Axis-1 and Axis-2 scores are significantly correlated with the MCDs computed from marginal counts of rim shapes (Table 4a). These results confound the theoretical expectations outlined above, indicating one of the assumptions of the model behind CA is not met in these data.

The assumption most likely violated in CA 1 is that the temporal spacing of all assemblages is uniformly distributed. The CA scatterplot of middens shows a large gap between the Midden 16 assemblage and all the others. A plot of the inertia val-

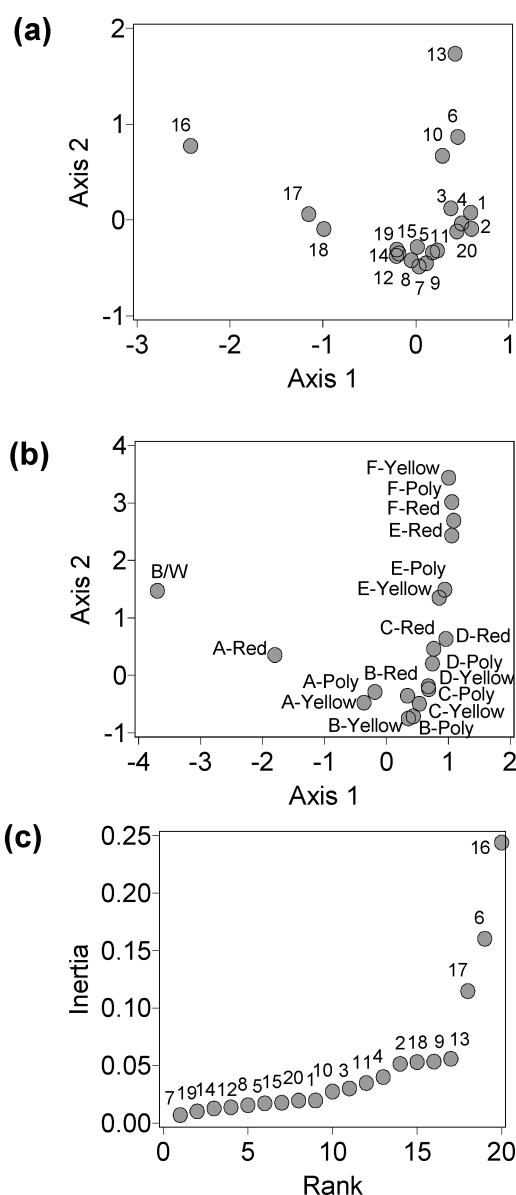


Figure 7. Results of CA 1. (a) Plot of the midden assemblages on Axes 1 and 2. (b) Plot of types on Axes 1 and 2. (c) Plot of midden assemblages inertia values against their temporal rank.

ues for each assemblage against the temporal rank of those values (Figure 7c) confirms that the Midden-16 assemblage is, indeed, an outlier. Midden 16 is so distinctive relative to the others that Axis 1, seeking to maximize inertia, contrasts it with them. Axis 2 is left to capture the later part of the temporal gradient (for a similar result with a dataset

from the Woodland-Period Deep South, see Smith and Neiman 2007).

In the second correspondence analysis (CA 2), we omitted the Midden 16 assemblage (Table 4b). Having estimated the CA axes and the scores of the types without Midden 16, we then plotted Midden 16 on them.² This technique removes the distorting effects of the Midden 16 assemblage on estimation of the type scores, while allowing us to determine its location relative to the other assemblages. Again, the broken-stick model suggests that only the first two axes account for more variation than expected by chance. Both scatterplots of the assemblages and the types reveal the expected arch (Figure 8a, 8b). This time only the Axis-1 scores for the assemblages significantly correlate with the MCDs (Figure 8c). In addition, the order of the Axis-1 type scores fits the traditional culture-historical understanding of the temporal order with Black-on-White preceding the glazes A-F—recall that the positions of the types along Axis 1 are estimates of their points of maximum frequency (Table 1).

Although CA 2 resolves some of the problems of CA 1, it points out others, namely the lack of fit of the Middens 3, 10, 6, and 13 to the seriation model (See Figure 6). The FS showed enrichment of early types (Glaze A-Yellow, Glaze A-Red, and Glaze B) in late assemblages clearly dominated by Glazes E and F. The reappearance of the early types is due to mixing and causes a shift left in the locations of Middens 3 and 10 on the CA-2 scatter plot. The early types may also be pulling Midden 6 toward an earlier position on the scatterplot. A comparison of the midden plot to the type plot demonstrates these shifts. This pattern raises the question regarding CA-2 solution: How robust are the results of CA 2 for the end of sequence in the face of mixing from earlier occupations?

A simple way to evaluate this question is to construct a third CA (CA 3), in which the early types involved in the mixing are excluded, along with the assemblages in which they dominate. Table 4c shows the results of omitting all but the latest eight assemblages, along with the early types (Black-on-White, and Glazes A and B). In this solution, because of the shorter period sampled by these eight assemblages, the inertia is concentrated in Axis 1. The correlation between Axis 1 and the MCDs is near unity. The FS diagram, in which the

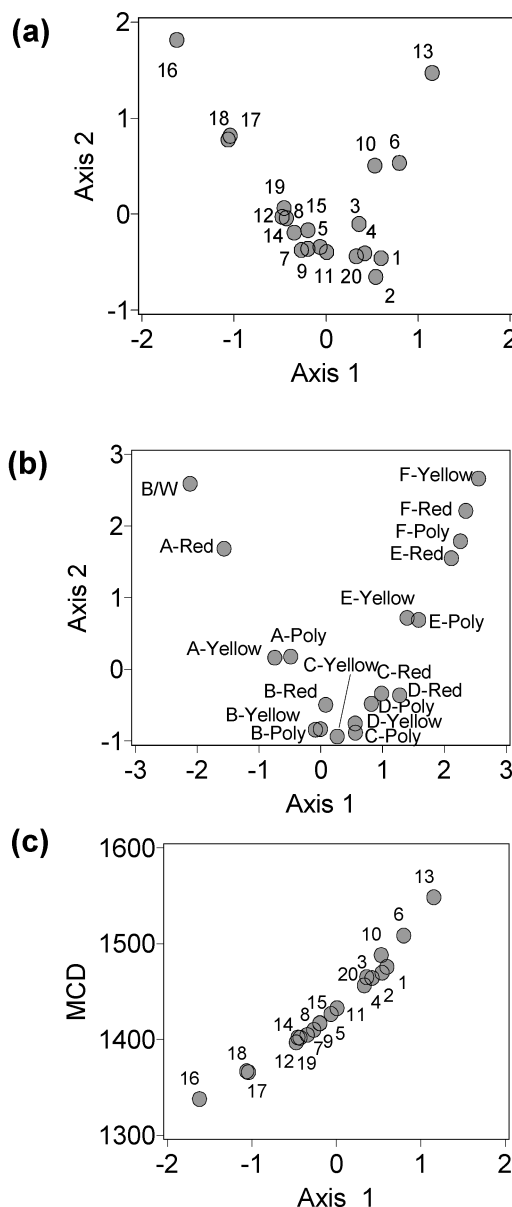


Figure 8. Results of CA 2. (a) Plot of the midden assemblages on Axes 1 and 2. (b) Plot of types on Axes 1 and 2. (c) Plot of midden assemblages MCDs and Axis-1 scores.

assemblage order is based on the Axis-1 scores, yields a good fit to the seriation model (Figure 9). The removal of the earlier types has had the expected consequences. The assemblages of Middens 3 and 10 are now later in the sequence. Midden 10 is nearly contemporary with Middens 6 and 13, and Midden 3 is earlier. In addition, the distance

Table 4. Summaries of Correspondence Analysis Solutions 1–3 (First Five Axes Only).

Axis	Inertia (Percent)	R (Axis 1: MCD)	P ($p=0$)
a. CA 1: All Midden Assemblages.			
1	45.0	–0.84	<0.0001
2	30.6	0.48	–.03
3	14.3	0.05	0.83
4	6.9	–0.14	0.54
5	1.9	–0.22	0.35
b. CA 2: Midden 16 Assemblage Removed.			
1	40.4	0.95	<0.0001
2	29.6	–0.01	0.96
3	13.4	–0.07	0.77
4	4.6	–0.19	0.42
5	3.9	–0.43	0.06
c. CA 3: Latest Middens Only (1, 2, 3, 4, 6, 10, 13, and 20).			
1	72.9	–1.00	<0.0001
2	13.8	0.08	0.85
3	6.2	0.54	0.17
4	3.8	0.44	0.27
5	1.9	–0.11	0.79

between the Period? 4 and Period? 5 assemblages has increased considerably (Figure 10). Finally, the MCDs for the assemblages are later than in the previous analysis. They are probably more accurate estimates of calendar years because sherds associated with early deposits do not bias the results.

Using CA-2 and CA-3 results, we sort middens into spatial clusters and temporal periods. Gaps in Axis-1 scores bound the periods. When the clusters have multiple members, they group together in geographical space, as well as in CA space. The MCDs of middens establish the centuries of use of each cluster and determine the period designation (Table 5; Figure 3).

In the fourteenth century, there are two periods. Midden 16 comprises Period 1. Black-on-White and Glaze A-Red dominate in this assemblage. Period 2 includes Middens 17 and 18, in which Black-on-White declines precipitously and is replaced by Glaze A-Yellow. Middens of both periods are located in the southwest section of the settlement adjacent to the springs. This pattern conforms to that described by Reed (1954) in his small excavation of Room Block 38 adjacent to Middens 16 and 17, as well as to Nelson's original impression of the settlement (Nelson 1912–1915).

Period 3 spans the first half of the fifteenth century and includes Middens 5, 7, 8, 9, 11, 12, 14,

15, and 19. Spatially, the period is located more or less in the central part of settlement, north and east of the first two. These midden assemblages have high frequencies of Glaze A-Yellow and Glaze B-Yellow. Period 4 includes middens 1, 2, 3, 4, and 20 and is located just to the north and east of the Period 3 middens. Temporal estimates place this period in the late fifteenth and early sixteenth centuries. Finally, Period 5 (Middens 6, 10, and 13) dates to the later sixteenth and seventeenth centuries and is characterized by high frequencies of Glazes E and F, especially Glaze F-Yellow and Glaze F-Red. The latest middens surround the mission complex, and their use is likely associated with the construction and use of the mission in the 1630s.

The only exception to this otherwise clear temporal and spatial pattern is Period 4. Although the MCDs place the cluster in the late- fifteenth and early-sixteenth century, ancillary information suggests these middens were reused during Period 5. Historic artifacts, e.g., majolica, iron nails, and colono wares, were only recovered from these two groups of middens, and a seventeenth-century Spanish smelting complex was established on top of previously abandoned Room Blocks 17 and 18 (Ramenofsky et al. 2008) (See Figure 3). Although native use of Period 4 middens likely terminated in the early sixteenth century, the area was reused in the seventeenth century, during which some classic postcontact artifacts were deposited in Period 4 middens. The reuse of the area, however, was not extensive.

There is strong agreement among FS, CA, and MCDs, suggesting that, despite record formation processes, time is the predominant factor responsible for the kind and abundance of decorated rim sherds deposited as middens at San Marcos. The mutual confirmation indicates five clusters of middens and five periods of occupation. Over time the spatial focus of the occupation shifts north and east.

Residential Mobility and Demographic Pulses

How can we use these chronological results to advance our understanding of the population history and settlement use of San Marcos? At least three additional ingredients are necessary to address these questions. The first is a way of estimating the number of people who contributed to the ceramic

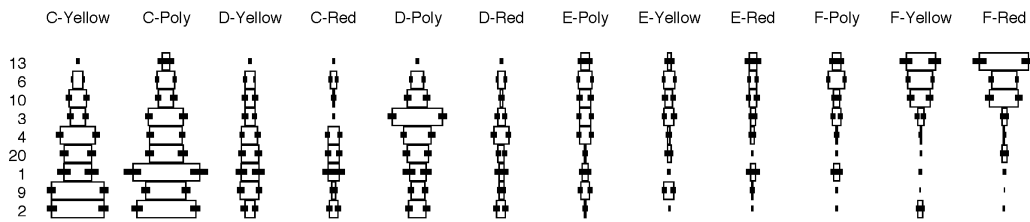


Figure 9. Frequency seriation of the eight latest midden assemblages based on CA 3.

midden assemblages. The second is a single chronology that combines the results of CA 2 for the earlier assemblages and CA 3 for the later ones. The third is a method of modeling how midden use was distributed in time around the mean dates estimated by CA Axis-1 scores and MCDs.

Counts of decorated ceramics deposited into middens are the proxy for measuring population change (Table 5). This technique requires several assumptions. Middens are adjacent to every room block, and we assume their use correlates with room block use. Second, as commonly used in accumulations research (Nelson et al. 1992; Varien 1999; Varien and Mills 1997), the per-capita depositional rates into middens were constant across the entire sequence. A related assumption is that the duration of deposition that resulted in the accumulation of each midden is roughly the same. As we have seen, four midden assemblages at the end of the sequence violate this assumption, but the implication is that the rest do not. By using the

results from CA 3 for the four later middens, we can mitigate these effects. Finally, we assume that the CA Axis-1 scores are a linear function of time. The tight, linear relationship between them and MCDs supports this assumption.

The second ingredient is a way to combine the results from CA 2 and CA 3 into a single, continuous chronology. To accomplish this goal we regress MCDs on Axis-1 scores separately from each CA. We then use the MCDs predicted from the CA 2 to date the Period 1 through 3 assemblages, and the MCDs from CA 3 to date the Period 4 and 5 assemblages. The results retain the relative spacing among assemblages on Axis 1 in each analysis, along with their desirable theoretical properties, while re-expressing them on a common MCD scale.

The third ingredient is a way to model the duration of midden use. CA Axis-1 scores and MCDs yield a single date estimate, but middens do not accumulate in an instant. They are time-transgressive. This kind of accumulation can be visualized with the help of kernel-density estimates (KDEs). KDEs are designed to portray the continuous density that underlies an observed frequency distribution of a variable (Beardah and Baxter 1996; Sheather 2004). A density function, or kernel, is centered over each value and used to assign weights to small increments of the underlying scale. The weights are proportional to the area under the curve for each increment. Applying this procedure to each data point produces as many density functions as there are observations. The final KDE is computed by adding up the areas under each function for each increment. The smoothness of the resulting KDE is controlled by the bandwidth of the kernel, which is typically treated as the standard deviation of the density function.

Although KDEs offer a simple way to model the

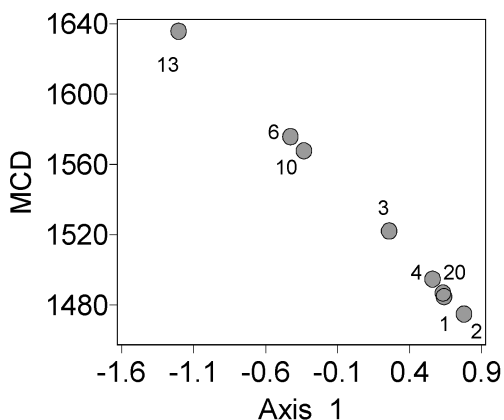


Figure 10. Plot of MCDs and Axis-1 scores from CA 3.

Table 5. Periods, Middens and Ceramic Counts.

Period	Major Ceramic Types	Middens	Midden MCD	Total Ceramics by Midden	Mean MCD
5	E and F	13	1638	42	1577
		6	1575	538	
		10	1567	133	
	Total			713	
4	C, D,	3	1519	182	1496
		4	1494	180	
	E, F	20	1488	90	
		1	1487	32	
		2	1476	80	
	Total			564	
3	A and B	11	439	425	
		5	1433	245	
		15, 7, 9	1422	837	
		8	1413		
		165	1424		
		14, 19, 12	1404	138	
	Total			2024	
2	B/W, A	17	1369	233	1370
		18	1371	90	
	Total			323	
1	B/W, A	16	1377		1318
	Total			56	

implications of the time-transgressive, midden accumulations for site-wide populations, there is a price. Additional assumptions are required, including the appropriate density function and the value of the bandwidth, or the duration of midden accumulation. The methods and data currently available do not permit definitive choices. Consequently, we employ a Gaussian kernel as our density function and explore the implications of several bandwidth values.

This Gaussian kernel implies that the number of people contributing to a midden changed gradually, increasing to a peak and then decreasing. Extensive statistical research shows that KDE results are not sensitive to kernel choice, but they are sensitive to the bandwidth (Sheather 2004). Variation in the amount of time over which each midden accumulated is modeled by changing the bandwidth of the Gaussian function.

What are appropriate bandwidth values? There is a large literature on bandwidth selection (Jones et al. 1996; Sheather 2004). The consensus is to use several bandwidths chosen by different algorithms. With the San Marcos data, the Sheather-Jones Plug-In method yields a bandwidth of 32 MCD years, while Silverman's rule of thumb and the Over-

smoothed methods both yield a bandwidth of 13 MCD years. We explore two scenarios based on these estimates. Using a bandwidth of 32 MCD years implies that about 95 percent of the sherds in each midden were deposited over a 128-year period. The 13 MCD-year bandwidth implies a 48-year period of deposition for 95 percent of the sherds (Figure 12).

Under both scenarios, the population of San Marcos fluctuated dramatically over 400 years. In both cases, the changes were so large that they must have resulted from immigration and emigration. The 32-year kernel reveals that the population increased through the fourteenth century and peaked in the early fifteenth century. A population decline began in the middle of the fifteenth century and ended in the late fifteenth century. A period of stability and perhaps even another increase occurred into the late sixteenth century, with final abandonment in the seventeenth century. The 13-year kernel portrays a more volatile population history punctuated by at least four episodes of population loss, and perhaps even total abandonment: the late fourteenth century, the mid-fifteenth century, the mid-sixteenth century, and the final abandonment in the seventeenth century.

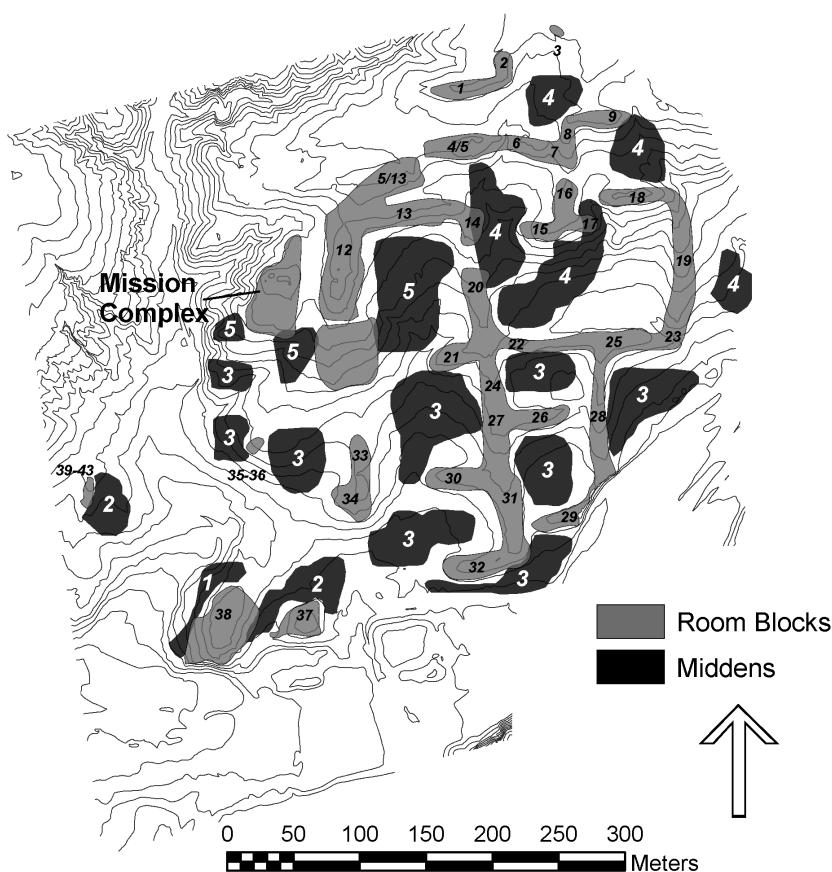


Figure 11. Midden use by Period. (Middens labeled by period).

Because we lack the data and models to estimate midden-use life empirically, we cannot point to one alternative as superior, or more complete, than the other. Each model has strengths and weaknesses. The first scenario with a longer midden use life suggests a smoother demographic growth and decline curve with some portion of the population remaining in residence. A small number of permanent residents also accords well with the demonstrable continuity in glaze-paint ceramics. The excellent fit to the FS model suggests a single stylistic tradition. Ongoing geochemical and petrographic analyses of these ceramics strengthen this inference and point to continuity in production (Dyer 2009; Schleher 2009). Variation in the numbers of residents from one period to the next is then explained by some combination of arrival of new immigrants and emigration of some existing residents. If, however, some portion of the population

remains in residence across the successive periods, it is difficult to explain why the San Marcoseños would abandon some room blocks and construct new ones in a different part of the pueblo. Such a strategy is not only costly in terms of labor; it defies archaeological understanding of room block construction, abandonment, reuse, and recycling.

The second scenario with a shorter midden use life and perhaps total abandonment between periods comes closer to matching the strong spatial signal of midden clusters and dates. If several abandonments occurred, the challenge is to account for the obvious and very strong continuity across 400 years of glaze-paint ceramics.

Despite these ambiguities, the two models agree regarding a massive demographic surge through the early fifteenth century, an equally massive decline in the late fifteenth century, and a final demographic pulse during the late sixteenth through the seven-

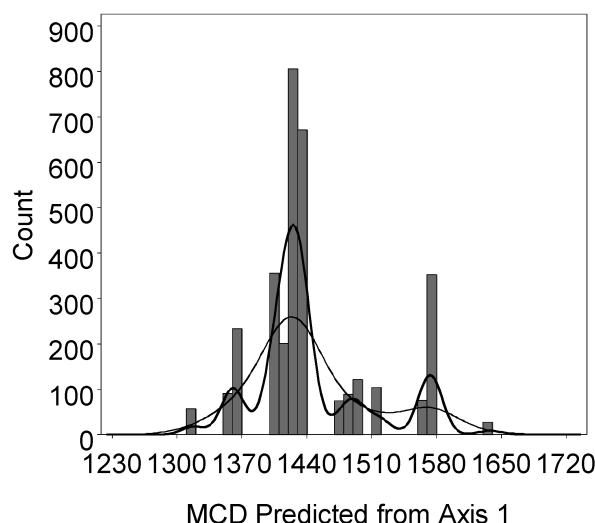


Figure 12. Weighted histogram and Gaussain KDEs for MCDs predicted from Axis-1 scores. (The thicker line is the KDE with a bandwidth of 32 MCD years. The thinner line is the KDE with a bandwidth of 13 MCD years).

teenth centuries. Given the general pattern, we consider how San Marcos fits into the larger southwestern pattern of residential mobility and suggest the causes for the periodic use and abandonment.

Residential mobility is a deep adaptation of sedentary agriculturalists in the Southwest that occurs in response to climatic stress and competition for land, resources, and mates (Kohler 1992; Varien 1999). San Marcos patterns of demographic increase across Periods 1–3 generally reflects the New Mexico pattern of aggregation (Dean et al. 1994), except that the population maximum is 50 to 75 years later than at Pot Creek (Crown and Kohler 1994), Arroyo Hondo (Creamer 1993), Pindi Pueblo (Stubbs and Stallings 1953), and Te'ewi (Wendorf 1953). On the other hand, the timing of the maximum settlement expansion closely tracks the aggregation pattern on the Pajarito Plateau (Kohler et al. 2004). Perhaps settlement growth at San Marcos occurs as populations disperse from areas further north. Immigrants from those areas may have contributed to the fifteenth-century expansion at San Marcos and the Galisteo Basin more generally (Snead et al. 2004).

Elucidating the pattern of initial settlement growth, however, does not address the causes of multiple episodes of aggregation or dispersion at San Marcos. Here we consider several.

Living in groups confers benefits to the individual, including proximity of potential mates and

protection from intercommunity violence.

Buffering the threat of violence may have contributed to the initial establishment of San Marcos. Burnt Corn Pueblo, located a short distance east of San Marcos, was completely burned within twenty years of its founding (Snead 2008). Because the timing of that destruction was coincident with the founding of San Marcos, emigrants from Burnt Corn may have sought refuge at San Marcos.

Increased levels of intergroup violence may also have played a role in the fifteenth-century demographic surge. Initial construction at San Marcos was adjacent to water, but Period 3 constructions were built on higher ground. Their orthogonal alignments within and among the room blocks would have facilitated defense via enfilade fire against attackers (Arkush and Stanish 2005:15). Orthogonal room-block alignments persisted into Periods 4 and 5, as did the preference for higher ground. Steep arroyo slopes helped defend the eastern and northern perimeter of the mission complex and Period 5 room blocks.

Aggregation also has costs: greater intercommunity competition for land and mates as population increases (Kohler 2004), as well as greater risk of mortality from infectious diseases, which became most important after Spanish contact. During Period 1, population size at San Marcos was relatively small and access to agricultural land did not likely constitute a source of conflict. This sit-

uation changed. Recent surveys in the Galisteo Basin point to increasing agricultural intensification associated with increasing population (Cordero and Huntley 2006; Kurota 2006; Snead 2008). The presence of these features cannot be directly linked to San Marcos or implicated as causal in its residential mobility. More generally, however, as agricultural land became scarce, the costs of competition may have outweighed the benefits of cooperation and resulted in dispersion.

Changing precipitation patterns were also important causes of the residential strategy of the San Marcoseños. Periods 1, 2, and 4 overlapped with intervals of greater precipitation, whereas the later part of Period 3 and the onset of Period 5 were more arid (Dean et al. 1994; Rose et al. 1981; Towner and Salzer 2008). The maximum demographic size during Period 3 was coincident with much greater aridity. Perhaps the community threshold for cooperation was exceeded by the combination of worsening climatic conditions and the largest demographic aggregate. Although the climatic conditions were wetter, the population of Period 4 was decidedly smaller and may be reflecting the failure of Period 3 aggregation.

Finally, as discussed for other regions of New Mexico (Kulisheck 2003; Mera 1940), the Spanish likely contributed to the nature of the demographic pulses of Periods 4 and 5. Two variables are particularly relevant. First is probability of disease diffusion.

The demographic curve of Periods 4 and 5 does not match expectations regarding infectious disease diffusion. The largest decline in population occurs during Period 4 (coincident with a wetter climatic conditions), but the dates of Period 4 midden use are simply too early to invoke disease contact as causal. The failure of Period 3 aggregation and/or an ameliorating climate are more parsimonious explanations of the demography of Period 4. Although disease attrition could have played a role during Period 5, it was not a significant one (Kulisheck 2003*, 2005). There was a return to the pueblo, and the population was larger.

This terminal demographic surge has not been previously documented. Others working in the Galisteo Basin (Lycett 1995; Welker 1997) have suggested spatial constriction and smaller populations following Spanish contact. Although our research shows spatial constriction, it is equated with more,

not fewer, immigrants, suggesting that Spanish pathogens did not decimate the community.

According to the shorter use-life model, Spanish aggression was likely a contributing cause to any population decline that preceded the Period 5 pulse. In 1540, Coronado established his winter camp southwest of the Galisteo Basin in the region of the central Tiwish. During that winter, the conquistadors so decimated the central Tiwish towns that the region was never fully reoccupied (Flint 2007). After that devastation in the spring of 1541, the expedition journeyed east to the plains and, on both legs of the journey, traveled through the Galisteo Basin. None of the Coronado documents mention San Marcos (Flint 2007; Hodge et al. 1945). Given its size, it is inconceivable that the town was simply missed. More likely, the San Marcoseños knew what had happened in the Tiwish territory and simply dispersed to more secure locations. Once Coronado had left the colony, the pueblo was resettled. The increase in Period 5 population may have included some survivors from the Tiwish wars.

In summary, reconstructing the demographic trends at San Marcos proceeded from the CA analyses that showed strong spatial and temporal patterning of middens. Using ceramics deposited in middens as a population proxy, we suggested two estimates for the duration of midden accumulations to model demographic change. Despite ambiguities, both models indicated the same sequence of demographic pulses that were too large to be explained by intrinsic growth. Clearly the San Marcoseños were residentially mobile with demographic fluctuations occurring from one period to the next.

Conclusions

The current configuration of San Marcos is the result of Native use that spanned more than 400 years. However, the use was neither continuous nor was the demographic curve a simple function of gradual internal growth and decline. Although one of the archetypal examples of a late prehistoric aggregated settlement in the Southwest, the size, as well as room block and midden arrangement, cannot be equated with a model of deep sedentism.

This demonstration has significant substantive, methodological, and theoretical implications. The substantive decoupling of sedentism from size for

the largest aggregated settlements in the Southwest reintroduces these places into the discussion of residential mobility. We doubt that San Marcos is unique in its demographic pattern. If we are correct, then this initial demonstration can serve as a comparative case as other such settlements are explored. Additionally, because the use life of the pueblo extends to the Pueblo Revolt, demographic change across Spanish conquest need not be assumed or inferred from historical documents; it can be investigated over a temporal span that begins before and continues after Spanish conquest.

Methodologically, our noninvasive methods were sufficient for reconstructing the occupational history of the pueblo. Using these methods to understand surface distributions means that these ancestral Pueblo settlements are not beyond our analytic reach for questions of residential mobility and demographic change. Is San Marcos unique regarding the strong temporal signal of the midden record? We think not, especially given the evidence marshaled to demonstrate surface modification. Extending the methodology to other aggregated pueblos will determine the general utility of the method.

Temporal control was the weakest aspect of our surface methods. A finer temporal resolution would have helped in more precise bounding of the episodes of occupation and abandonment, the duration of individual occupation spans, and whether abandonments were complete or partial. To improve temporal resolution requires additional dating. Tree-ring cross-dates are one possibility, but cross-dates require excavation, and excavation is not encouraged at these large persistent places. Moreover, the duration of ceramic production need not be isomorphic with tree-ring cutting dates. Direct dating of artifacts is a feasible and efficient alternative for surface assemblages. Luminescence dating of ceramics typically provides direct dates of ceramic manufacture, and is appropriate for surface assemblages. When used as an ordinal temporal tool, obsidian hydration can also be employed to create a chronology of obsidian manufacture and use. Both temporal methods are currently underutilized in the Southwest in large part because of the potential precision of tree-ring dates.

The demonstration of residential mobility at San Marcos brings the investigation of its causes into focus. We touched on possible triggers of the strat-

egy, but the lack of comparative information, as well as in-depth understanding of Galisteo Basin archaeology, curtailed the inferences. Prior to contact, combinations of climate, external aggression, and the costs or benefits of group living need to be more fully explored. Because San Marcos was occupied to the Pueblo Revolt, Spaniards and the resulting tumult must be more completely investigated. Here, we suggested that social conflict—not disease contact—was the key explanatory variable.

In the end, then, this research represents a preliminary effort at understanding residential strategies of late aggregated settlements. We are hopeful that it will stimulate a renewed research focus on the late large settlements of the pueblo world. These places are too dynamic and important for understanding the nature of change and persistence of Puebloan groups before and after Spanish colonization and settlement of the Southwest.

Acknowledgments. This research was made possible with the help and support of numerous people. Financial support was provided by UNM, who sponsored two surface field schools, and by the McCune Charitable Foundation and Standard Products. Field school students were enthusiastic participants in this surface research. Shawn Penman laid out the grid, was responsible for spatial control, and helped with map construction. She also digitized Nelson's original planimetric map of the pueblo. David Vaughan, Jon Van Hoose, Ariane Oberling-Pinson, and Julie Angel were wonderful teaching assistants in the field and laboratory. The drafts were improved by the careful readings of Anastasia Steffen, Jeremy Kulisheck, and Michael Graves. Lawrence Straus translated the abstract into Spanish. Finally we thank the three anonymous reviewers who provided invaluable insights. All other errors in understanding are ours.

References Cited

- Adams, E. Charles, and Andrew I. Duff
2004 Settlement Clusters and the Pueblo IV Period. In *The Protohistoric Pueblo World, A.D. 1275–1600*, edited by E. Charles Adams and Andrew I. Duff, pp. 3–16. University of Arizona Press, Tucson.
- Adler, Michael A.
1996 "The Great Period": The Pueblo World during the Pueblo III Period. In *The Prehistoric Pueblo World, A.D. 1150–1350*, edited by Michael A. Adler, pp. 1–10. University of Arizona Press, Tucson.
- Adler, Michael A., Todd Van Pool, and Robert D. Leonard
1996 Ancestral Pueblo Population Aggregation and Abandonment in the North American Southwest. *Journal of World Prehistory* 10:375–438.
- Arkush, Elizabeth, and Charles Stanish
2005 Interpreting Conflict in the Ancient Andes: Implications for the Archaeology of Warfare. *Current Anthropology* 46:3–28.

- Balek, Cynthia L.
2002 Buried Artifacts in Stable Upland Sites and the Role of Bioturbation: A Review. *Geoarchaeology* 17:41–51.
- Beardah, Christian, and Michael Baxter
1996 The Archaeological Use of Kernel Density Estimates. Internet Archaeology 1. Electronic document. http://intarch.ac.uk/journal/issue1/beardah_index.html Date Accessed?
- Bech, Jens-Henrik
1988 Correspondence Analysis and Pottery Chronology: A Case from the Late Roman Iron Age Cemetery Slusegard, Bornholm. In *Multivariate Archaeology: Numerical Approaches in Scandinavian Archaeology*, edited by Torsten Madsen, pp. 29–36. Jutland Archaeological Society Publications Vol. 21. Aarhus University Press, Aarhus.
- Beck, Charlotte
1999 Dating the Archaeological Record and Modeling Chronology. In *Models for the Millennium*, edited by Charlotte Beck, pp. 171–181. University of Utah Press, Salt Lake City.
- Bernardini, Wesley
1998 Conflict, Migration, and the Social Environment: Interpreting Architectural Change in Early and Late Pueblo IV Aggregations. In *Migration and Reorganization: The Pueblo IV Period in the American Southwest*, edited by Katherine A. Spielmann, pp. 91–114. Anthropological Research Papers Vol. 51. Arizona State University, Tempe.
- Bintliff, John L.
2000 The Concepts of 'site' and 'off-site' in Surface Artefact Survey. In *Non-Destructive Techniques Applied to Landscape Archaeology*, edited by Marinella Pasquinucci and Frédéric Tremont, pp. 200–215. The Archaeology of Mediterranean Landscapes Vol. 4. Oxbow Books, Oxford.
- Bølviken, Eric, Ericka Hilskog, Knut Hilskog, Inger Marie Holm-Olsen, Leiv Solheim, and Reidar Bertelsen
1982 Correspondence Analysis: An Alternative to Principal Components. *World Archaeology* 14:41–60.
- Breternitz, David A.
1966 *An Appraisal of Tree-Ring Dating in the Southwest*. University of Arizona Anthropological Papers 10. University of Arizona, Tucson.
- Christenson, Andrew L.
1994 A Test of Mean Ceramic Dating Using Well-Dated Kayenta Anasazi Sites. *Kiva* 59:297–317.
- Clausen, Sten-Erik
1998 Applied Correspondence Analysis: An Introduction. Quantitative Applications in Social Sciences. Sage Publications, Thousand Oaks, California.
- Cordell, Linda S.
1994 Introduction: Community Dynamics of Population Aggregation in the Prehistoric Southwest. In *The AncientSouthwestern Community: Models and Methods for the Study of Prehistoric Social Organization*, edited by Wirt H. Wills and Robert D. Leonard, pp. 79–84. University of New Mexico Press, Albuquerque.
1997 *Archaeology of the Southwest*. 2nd ed. Academic Press, New York.
- Cordell, Linda S. (editor)
1980 *Tijeras Canyon: Analyses of the Past*. University of New Mexico Press, Albuquerque.
- Cordell, Linda S., and Fred Plog
1979 Escaping the Confines of Normative Thought: A Reevaluation of Puebloan Prehistory. *American Antiquity* 44:405–429.
- Cordero, Robin M., and Deborah L. Huntley
2006 *A Cultural Resources Inventory of 289 ha. on the former Cash Ranch: Implications for the San Lazaro Pueblo (LA 91, LA 92)*. Southwestern Archaeological Consultants, Santa Fe.
- Creamer, Winifred
1993 *The Architecture of Arroyo Hondo Pueblo, New Mexico*. Arroyo Hondo Archaeological Series 7. School of American Research Press, Santa Fe.
1996 Developing Complexity in the American Southwest: Constructing a Model for the Rio Grande Valley. In *Emergent Complexity: The Evolution of Intermediate Societies*, edited by Jean Arnold, pp. 91–106. Archaeological Series Vol. 9. International Monographs in Prehistory, Ann Arbor.
- Creamer, Winifred, David Burdick, Patrick Hamlen, Jonathan Haas, Lisa Renken, Aaron Wenzel, and Kit Nelson
2002 Ceramic Analysis of Intra- and Intersite Occupation at Protohistoric Pueblos in the Northern Rio Grande. In *Traditions, Transitions and Technologies: Themes in Southwestern Archaeology*, edited by Sarah H. Schlanger, pp. 59–69. University Press of Colorado, Boulder.
- Crown, Patricia L.
1991 Evaluating the Construction Sequence and Population at Pot Creek Pueblo, Northern New Mexico. *American Antiquity* 56:291–314.
- Crown, Patricia L., and Timothy A. Kohler
1994 Community Dynamics, Site Structure, and Aggregation in the Northern Rio Grande. In *The Ancient Southwestern Community: Models and Method for Prehistoric Social Organization*, edited by Wirt H. Wills and Robert D. Leonard, pp. 103–117. University of New Mexico Press, Albuquerque.
- Dancey, William S.
1998 The Value of Surface Archaeological Data in Exploring the Dynamics of Community Evolution in the Middle Ohio Valley. In *Surface Archaeology*, edited by Alan P. Sullivan III, pp. 3–19. University of New Mexico Press, Albuquerque.
- Dean, Jeffrey S.
1978 Independent Dating in Archaeological Analysis. In *Advances in Archaeological Method and Theory*, Vol. 1, edited by Michael B. Schiffer, pp. 223–255. Academic Press, New York.
- Dean, Jeffrey S., William H. Doelle, and Janet D. Orcutt
1994 Adaptive Stress, Environment, and Demography. In *Themes in Southwestern Prehistory*, edited by George J. Gumerman, pp. 53–86. School of American Research Advanced Seminar Series, Santa Fe.
- De Leeuw, Jan
1983 On the Prehistory of Correspondence Analysis. *Statistica Neerlandica* 37:161–164.
- Duff, Andrew I.
1996 Ceramic Micro-Seriation: Types or Attributes? *American Antiquity* 61:89–101.
- Dunnell, Robert C.
1970 Seriation Method and its Evaluation. *American Antiquity* 35:305–319.
- Dunnell, Robert C., and William S. Dancey
1983 The Siteless Survey: A Regional Scale Data Collection Strategy. In *Advances in Archaeological Method and Theory*, Vol. 6, edited by Michael B. Schiffer, pp. 267–288. Academic Press, New York.
- Dyer, Jennifer Boyd
2009 Colono Wares in the Western Spanish Borderlands: A Ceramic Technological Study. Unpublished Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.
- Ebert, James I.
1992 *Distributional Archaeology*. University of New Mexico Press, Albuquerque.

- Eddy, Frank W., Dale R. Lightfoot, Eden Welker, Layne L. Right, and Delores C. Torres
1996 Air Photographic Mapping of San Marcos Pueblo. *Journal of Field Archaeology* 23:1–13.
- Feathers, James K.
1997 The Application of Luminescence Dating in American Archaeology. *Journal of Archaeological Method and Theory* 4:1–66.
- 2000 Luminescence Dating and Why it Deserves Wider Application. In *It's about Time: A History of Archaeological Dating in North America*, edited by Stephen E. Nash, pp. 152–167. University of Utah Press, Salt Lake City.
- Flint, Richard
2007 *No Settlement, No Conquest*. University of New Mexico Press, Albuquerque.
- Foley, Robert
1981 *Off-site Archaeology and Human Adaptation in Eastern Africa. Patterns of the Past: Studies in Honor of David Clarke*. BAR International Series 97. British Archaeological Reports, London.
- Ford, James A.
1962 *A Quantitative Method for Deriving Cultural Chronology. Technical Manual 1*. Pan American Union, Washington D.C.
- Gower, John C.
1990 Fisher's Optimal Scores and Multiple Correspondence Analysis. *Biometrics* 46:947–949
- Haas, Jonathan, and Winifred Creamer
1992 Demography of the Protohistoric Pueblos of the northern Rio Grande, A.D. 1450–1680. In *Current Research on the Late Prehistory and Early History of New Mexico*, edited by Bradley J. Vierra, pp. 21–29. New Mexico Archaeological Council Special Publication 1, Albuquerque.
- Habicht-Mauche, Judith A., T. Glenn Stephen, Homer Milford, and A. Russell Flegel
2000 Isotopic Tracing of Prehistoric Glaze-Paint Production and Trade. *Journal of Archaeological Science* 27:709–713.
- Herhahn, Cynthia L.
2006 Inferring Social Interaction from Pottery Recipes. In *The Social Life of Pots: Glaze Wares and Cultural Dynamics in the Southwest, A.D. 1250–1680*, edited by Judith A. Habicht-Mauche, Suzanne L. Eckert, and Deborah L. Huntley, pp. 179–196. The University of Arizona Press, Tucson.
- Hill, Mark O.
1974 Correspondence Analysis: A Neglected Multivariate Method. *Applied Statistics* 23:340–354.
- Hinz, Emily A., John F. Ferguson, Louise Pellerin, and Ann F. Ramenofsky
2008 A Geophysical Investigation of Subsurface Structures and Quaternary Geology at San Marcos Pueblo, NM, LA 98. *Archaeological Prospection* 15:1–19.
- Hodge, Frederick W., George P. Hammond, and Agapito Rey
1945 *Fray Alonso de Benavides' Memorial of 1634, IV. Coronado Cuarto Centennial Publications, 1540–1940*. Albuquerque.
- Huntley, Deborah L., and Keith Kintigh
2004 Archaeological Patterning and Organizational Scale of Late Prehistoric Settlement Clusters in the Zuni Region of New Mexico. In *The Protohistoric Pueblo World, A.D. 1275–1600*, edited by E. Charles Adams and Andrew Duff, pp. 62–71. The University of Arizona Press, Tucson.
- Ivey, James E., and David H. Thomas
2005 “The Feeling of Working Completely in the Dark”: The Uncertain Foundations of Southwestern Mission Archaeology. In *Southwest Archaeology in the Twentieth Century*, edited by Linda S. Cordell and Don D. Fowler, pp. 204–220. University of Utah Press, Salt Lake City.
- Jackson, Donald A.
1993 Stopping Rules in Principal Components Analysis: A Comparison of Heuristical and Statistical Approaches. *Ecology* 74:2204–2214.
- Jones, George T., and Charlotte Beck
1992 Chronological Resolution in Distributional Archaeology. In *Space, Time, and Archaeological Landscapes*, edited by Jacqueline Rossignol and LuAnn Wandsnider, pp. 167–192. Plenum Press, New York.
- Jones, George T., Charlotte Beck, Eric E. Jones, and Richard E. Hughes
2003 Lithic Source Use and Paleoarchaic Foraging Territories in the Great Basin. *American Antiquity* 68:5–38.
- Jones, M. Chris, J. Steven Marron, and Simon. J. Sheather
1996 A Brief Survey of Bandwidth Selection for Density Estimation. *Journal of the American Statistical Association* 91:401–407.
- Kidder, Alfred V.
1927 Southwestern Archaeological Conference. *Science* 66:489–491.
- 1936 *The Glaze Paint, Culinary, and Other Wares. The Pottery of Pecos, Vol. II*. Phillips Academy by Yale University Press, London.
- 1958 *Pecos New Mexico: Archaeological Notes*. Phillips Academy, Andover, Massachusetts.
- Kidder, Alfred, and Charles A. Amsden
1931 *The Pottery of Pecos: The Dull Paint Wares, Vol. I*. Phillips Academy by Yale University Press. London.
- Kohler, Timothy A.
1992 Field Houses, Villages, and the Tragedy of the Commons in the Anasazi Southwest. *American Antiquity* 57:617–635.
- Kohler, Timothy A.
2004 Introduction. In *Archaeology of Bandelier National Monument: Village Formation on the Pajarito Plateau, New Mexico*, edited by Timothy A. Kohler, pp. 1–18. University of New Mexico Press, Albuquerque.
- Kohler, Timothy A. Sarah Kerr and Matthew J. Root
2004 The Rise and Fall of Towns on the Pajarito. In *Archaeology of Bandelier National Monument: Village Formation on the Pajarito Plateau, New Mexico*, edited by Timothy A. Kohler, pp. 215–264. University of New Mexico Press, Albuquerque.
- Kreiger, Alex D.
1944 The Typological Concept. *American Antiquity* 9:271–288.
- Kroeber, Alfred L.
1916 Zuni Potsherds. *American Museum of Natural History Anthropological Papers* 18(1):1–36.
- Kruskal, Joseph B.
1971 Multi-dimensional Scaling in Archeology: Time Is Not the Only Dimension. In *Mathematics in the Archaeological and Historical Sciences*, edited by F.R. Hodson, David G. Kendall, and Petre Tautu, pp.119–132. Edinburgh University Press, Edinburgh.
- Kulisheck, Jeremy R
2003 Pueblo Population Movements, Abandonment and Settlement Change in Sixteenth and Seventeenth Century New Mexico. *Kiva* 69:30–54.
- 2005 *The Archaeology of Pueblo Population Change on the Jemez Plateau, A.D. 1200 to 1700: The Effects of Spanish Contact and Conquest*. Ph.D. dissertation, Department of Anthropology, Southern Methodist University, Dallas.

- University International Microfilms, Ann Arbor.
- Kurota, Alexander
2006 *Class III Cultural Resources Inventory of 435 Acres in Pueblo Blanco Country, Galisteo Basin, New Mexico*. Office of Contract Archaeology, University of New Mexico Report OCA-185-880. University of Mexico, Albuquerque.
- Lambert, Marjorie F.
1954 *Pa-ako: Archaeological Chronicle of an Indian Village in North Central New Mexico, Vol. 9*. School of American Research Monograph, Santa Fe.
- Legendre, Pierre, and Louis Legendre
1998 *Numerical Ecology. Developments in Environmental Modelling 20*. Elsevier, Amsterdam.
- Lekson, Stephen H.
1990 Sedentism and Aggregation in Anasazi Archaeology. In *Perspectives on Southwestern Prehistory*, edited by Paul R. Minnis and Charles L. Redman, pp. 333-340. Westview Press, Boulder.
- Lightfoot, Kent G., and Steadman Upham
1989 Complex Societies in the Prehistoric American Southwest: A Consideration of the Controversy. In *The Sociopolitical Structure of Prehistoric Southwestern Societies*, edited by Steadman Upham, Kent G. Lightfoot, and Roberta A. Jewett, pp. 3-30. Westview Press, Boulder.
- Lipo, Carl P.
2001 *Science, Style, and the Study of Community Structure: An Example from the Central Mississippi River Valley*. BAR International Series 918. British Archaeological Reports, Oxford.
- Lycett, Mark T.
1995 Archaeological Implications of European Contact: Demography Settlement, and Land Use in the Middle Rio Grande Valley, New Mexico. Unpublished Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.
2002 Transformation of Place: Occupation History and Differential Persistence in Seventeenth-Century New Mexico. In *The Archaeologies of the Pueblo Revolt*, edited by Robert W. Preucel, pp. 61-76. University of New Mexico Press, Albuquerque.
- Lyman, R. Lee, and Michael J. O'Brien
1999 Americanist Stratigraphic Excavation and the Measurement of Culture Change. *Journal of Archaeological Method and Theory* 6:1-34.
- Lyman, R. Lee, Steve Wolverton, and Michael J. O'Brien
1998 Seriation, Superposition, and Interdigitation: A History of Americanist Graphic Depictions of Culture Change. *American Antiquity* 63:239-261.
- Madsen, Torsten
1988 Multivariate Statistics and Archaeology. In *Multivariate Archaeology: Numerical Approaches in Scandinavian Archaeology*, edited by Torsten Madsen, pp. 7-28. Jutland Archaeological Society Publications 21. Aarhus University Press, Aarhus.
- McKenna, Peter, and James A. Miles
1991 Archaeological Survey Ceramic Manual. Manuscript on file, Branch of Cultural Resource, Southwest Regional Office, Santa Fe.
- Mera, Herbert P.
1933 *A Proposed Revision of the Rio Grande Glaze Paint Sequence*. Bulletin 6. The Laboratory of Anthropology Technical Series, Santa Fe.
1935 *Ceramic Clues to the prehistory of north central New Mexico*. Laboratory of Anthropology Archaeological Survey Bulletin 8, Santa Fe.
1940 *Population Changes in the Rio Grande Glaze Paint Area*. Laboratory of Anthropology Technical Series 8, Santa Fe.
- Morin, Eugène
2006 Beyond Stratigraphic Noise: Unraveling the Evolution of Stratified Assemblages in Faunal-turbated Sites. *Geoarchaeology* 21:541-565.
- Nash, Stephen E.
1999 *Time, Trees, and Prehistory: Tree-Ring Dating and the Development of North American Archaeology, 1914-1950*. University of Utah Press, Salt Lake City.
- Neiman, Fraser D., and Ned Alcock
1995 Archaeological Seriation by Correspondence Analysis: An Application to Undated English Medieval Deeds. *History and Computing* 7:1-21.
- Nelson, Ben A., Timothy A. Kohler, and Keith W. Kintigh
1992 Demographic Alternatives: Consequences for Current Models of Southwestern Prehistory. In *Understanding Complexity in the Prehistoric Southwest*, edited by George J. Gumerman and Murray Gell-Mann, pp. 113-146. Santa Fe Institute Studies in the Sciences of Complexity Vol. 16. Addison-Wesley Publishing, Reading.
- Nelson, Kit, and Judith A. Habicht-Mauche
2006 Lead, Paint, and Pots: Rio Grande Intercommunity Dynamics from a Glaze Ware Perspective. In *The Social Life of Pot: Glaze Wares and Cultural Dynamics in the Southwest, AD 1250-1680*, edited by Judith A. Habicht-Mauche, Suzanne L. Eckert, and Deborah L. Huntley, pp. 197-215. The University of Arizona Press, Tucson.
- Nelson, Nels C.
1912-1915 *Field Notes of the Excavations at San Marcos Pueblo*. American Museum of Natural History, New York.
1914 *Pueblo Ruins of the Galisteo Basin, New Mexico*. Anthropological Papers Vol. 15, Pt. 1. American Museum of Natural History, New York.
1916 Chronology of the Tano Ruins, New Mexico. *American Anthropologist* 18:159-180.
- Nielsen, Karen H.
1988 Correspondence Analysis Applied to Hoards and Graves of the Germanic Iron Age. In *Multivariate Archaeology: Numerical Approaches in Scandinavian Archaeology*, edited by Torsten Madsen, pp. 47-54. Jutland Archaeological Society publications Vol. 21. Aarhus University Press, Aarhus.
- Odell, George H., and Richard Cowan
1987 Estimating Tillage Effects on Artifact Distributions. *American Antiquity* 52:456-484.
- O'Brien, Michael J., and R. Lee Lyman
2003 *Cladistics and Archaeology*. University of Utah Press, Salt Lake City.
- Penman, Shawn L.
2001 Re-excavation of Rooms in Room Block 13. In *Summary Report of the 2000 Season of Archaeological Research at San Marcos Pueblo (LA98) by the University of New Mexico (Permit SE-155; ABE-427)*, by Ann F. Ramenofsky, pp. 51-65. Submitted to State Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- Phillips, Phillip, James A. Ford, and James B. Griffin
1951 Archaeological Survey in the Lower Mississippi Alluvial Valley. Papers of the Peabody Museum of American Ethnology and Archaeology 25, Harvard University, Cambridge.
- Pierce, Christopher D.
1992 Effects of Pocket Gopher Burrowing on Archaeological Deposits: A Simulation Approach. *Geoarchaeology* 7:185-208.
- Pierce, Christopher D., and Ann F. Ramenofsky

- 2000 *Summary of the 1999 Field Season at San Marcos Pueblo (LA 98) by the University of New Mexico, SE-272*. Submitted to State Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- Pinson, Ariane O.
2000 The Rise and Fall of Room Blocks 29 and 29: Architecture and Site Formation Processes. In *Report of Archaeological Research at Pueblo San Marcos (LA98) during 1999 by University of New Mexico by Christopher Pierce and Ann F. Ramenofsky*, pp. 58–76. Submitted to State Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- 2008 The Geology of Mission San Marcos, New Mexico (combined 1999 and 2000 field seasons). Manuscript on file at American Museum of Natural History, New York, New York.
- Pinson, Ariane O., and Julie Angel
2001 Room Blocks 28 and 29. In *Summary Report of the 2000 Season of Archaeological Research at San Marcos Pueblo (LA98) by the University of New Mexico (Permit SE-155; ABE-427)*, by Ann F. Ramenofsky, pp. 81–115. Submitted to State Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- Potter, James M.
1998 The Structure of Open Space in Late Prehistoric Settlements in the Southwest. In *Migration and Reorganization: The Pueblo IV Period in the American Southwest*, edited by Katherine A. Spielmann, pp. 137–164. Anthropological Research Papers Vol. 51. Arizona State University, Tempe.
- Powell, Shirley
1990 Sedentism or Mobility: What do the Data Say? What did the Anasazi Do? In *Perspectives on Southwestern Prehistory*, edited by Paul R. Minnis and Charles L. Redman, pp. 92–102. Westview Press, Boulder.
- Ramenofsky, Ann F.
2001 *Summary Report of the 2000 Season of Archaeological Research at San Marcos Pueblo (LA 98) by the University of New Mexico (Permit SE-155, ABE-427)*. Submitted to State Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- 2003 *Report on an Archaeological Investigation of Metallurgy at San Marcos Pueblo (LA 98) Summer 2002 (Permit SE-183, ABE-538)*. Submitted to State Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- Ramenofsky, Ann F., and James K. Feathers
2002 Documents, Ceramics, Tree-Rings, and Luminescence: Estimating Final Native Abandonment from the Lower Rio Chama. *Journal of Anthropological Research* 58:121–159.
- Ramenofsky, Ann F. and Fraser D. Neiman
2008 Counts of Rim Sherds in 20 Middens from Surface Collection at San Marcos Pueblo. Electronic document, <https://www.unm.edu/~aramenof/Table4.pdf>
- Ramenofsky, Ann F., and Christopher D. Pierce
1998 *Summary Report of Surface Research at San Marcos Pueblo, LA 98, 1997–1998*. Submitted to State Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- 1999 *Summary Report on Archaeological Mapping at Pueblo San Marcos (LA 98), 1997, 1998*. Submitted to State Historic Preservation Division, Laboratory of Anthropology Museum of New Mexico, Santa Fe.
- Ramenofsky, Ann F., C. David Vaughan, and Michael N. Spilde
2008 Seventeenth Century Metal Production at San Marcos Pueblo, North-Central New Mexico. *Historical Archaeology* 24:105–131.
- Reed, Eric
1954 A Test Excavation at San Marcos. *El Palacio* 61:323–343.
- Rose, Martin R., Jeffrey S. Dean and William J. Robinson
1981 The Past Climate of Arroyo Hondo New Mexico Reconstructed from Tree Rings. Arroyo Hondo Archaeological Series 4. School of American Research Press, Santa Fe.
- Schiffer, Michael B.
1987 *Formation Processes of the Archaeological Record*. University of New Mexico Press, Albuquerque.
- Schlanger, Sarah H.
1992 Recognizing Persistent Places in Anasazi Settlement Systems. In *Space Time and Archaeological Landscapes*, edited by Jacqueline Rossignol, and LuAnn Wandsnider, pp. 91–112. Plenum Press, New York.
- Schleher, Kari L.
2009 The Role of Standardization in the Specialization of Ceramic Production at San Marcos Pueblo, New Mexico. Unpublished Ph. D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.
- Scholnick, Jonathan
2003 Seriation and the Identification of Social Dimensions of Ceramic Consumption Patterns. Poster Presented at the 68th Annual Meeting of the Society for American Archaeology, Minneapolis.
- Sheather, Simon J.
2004 Density Estimation. *Statistical Science* 19: 588–597.
- Shennan, Stephen
1997 *Quantifying Archaeology*. 2nd ed. University of Iowa Press, Iowa City.
- 2003 *Genes, Memes, and Human History: Darwinian Archaeology and Cultural Evolution*. Thames and Hudson, London.
- Shepard, Anna O.
1942 *Rio Grande Glaze Paint Ware: A Study Illustrating the Place of Ceramic Technological Analysis in Archaeological Research*. Carnegie Institute of Washington Publication 528, Contributions to American Anthropology and History 39, Washington. D. C.
- Simmons, Alan H.
1998 Exposed Fragments, Buried Hippos: Assessing Surface Archaeology. In *Surface Archaeology*, edited by Alan P. Sullivan III, pp. 159–167. University of New Mexico Press, Albuquerque.
- Smith, Karen Y., and Fraser D. Neiman
2007 Frequency Seriation, Correspondence Analysis and Woodland-Period Ceramic Assemblage Variation in the Deep South. *Southeastern Archaeology* 26:47–72.
- Snead, James E.
2008 *Ancestral Landscapes of the Pueblo World*. The University of Arizona Press, Tucson.
- Snead, James E., Winifred Creamer, and Tineke Van Zandt
2004 “Ruins of our Forefathers”: Large Sites and Site Clusters in the Northern Rio Grande. In *The Protohistoric Pueblo World, A.D. 1275–1600*, edited by E. Charles Adams and Andrew I. Duff, pp. 26–34. University of Arizona Press, Tucson.
- South, Stanley
1972 Evolution and Horizon as Revealed in Ceramic Analysis in Historical Archaeology. *Conference on Historic Sites Archaeology Papers* 6:71–116.
- 1977 *Method and Theory in Historical Archaeology*. Aca-

- demic Press, New York.
- Spaulding, Albert C.
1953 Statistical Techniques for the Discovery of Artifact Types. *American Antiquity* 18:305–313.
- Spielmann, Katherine A.
1998 The Pueblo IV Period: History of Research. In *Migration and Reorganization: The Pueblo IV Period in the American Southwest*, edited by Katherine A. Spielmann, pp. 1–30. Anthropological Research Papers Vol. 51. Arizona State University, Tempe.
- Spier, Leslie
1917 Outline for a Chronology of Zuni Ruins. *American Museum of Natural History, Anthropological Papers* 18(3):207–331.
1918 Notes on some Little Colorado Ruins. *American Museum of Natural History, Anthropological Papers* 18(4):303–362.
1919 Ruins in the White Mountains, Arizona. *American Museum of Natural History, Anthropological Papers* 18(5):363–387.
- Stubbs, Stanley A., and William S. Stallings
1953 The Excavation of Pindi Pueblo, New Mexico. Monograph 18. Laboratory of Anthropology and School of American Research. Santa Fe.
- Sullivan III, Alan P. (editor)
1998 Surface Archaeology. University of New Mexico Press, Albuquerque.
- ter Braak, Cajo J. F.
1985 Correspondence Analysis of Incidence and Abundance Data: Properties in Terms of a Unimodal Response Model. *Biometrics* 41:859–873.
- ter Braak, Cajo J. F., and I. Colin Prentice
1988 A Theory of Gradient Analysis. *Advances in Ecological Research* 18:271–317.
- Thomas, David H.
1975 *Nonsite Sampling in Archaeology: Up the Creek without a Site*. In *Sampling in Archaeology*, edited by James W. Mueller, pp. 61–81. University of Arizona Press, Tucson.
2000 Excavations at Mission San Marcos, New Mexico. SE-143 and BE022. Summer 1999. Submitted to the Historic Preservation Division, Laboratory of Anthropology, Museum of New Mexico, Santa Fe.
- Toulouse, Joseph H. Jr., and Robert L. Stevenson
1980 Excavations at Pueblo Pardo. Papers in Anthropology 2. The Museum of New Mexico, Santa Fe.
- Towner, Ronald H.
2002 Archaeological Dendrochronology in the Southwestern United States. *Evolutionary Anthropology* 11:68–84.
- Towner, Ronald H., and Matthew W. Salzer
2008 Dendroclimatic Reconstructions in the Northern Rio Grande. In *The Land Conveyance and Transfer Project: 7000 Years of Land Use on the Pajarito Plateau*, edited by Bradley J. Vierra and Kari Schmidt, pp. 185–238. Baseline Studies Vol. 1. CRM Report 273. Los Alamos National Laboratory, Los Alamos.
- Upham, Steadman
1982 *Politics and Power: An Economic and Political History of the Western Pueblo*. Academic Press, New York.
- Van Hoose, Jonathan E.
2008 Learning Lineages as Reflected in Ceramic Production in Early Historic Northwestern New Mexico. Unpublished Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.
- Varien, Mark D.
1999 Sedentism and Mobility in a Social Landscape. University of Arizona Press, Tucson.
- Varien, Mark D., and Barbara J. Mills
1997 Accumulations Research: Problems and Prospects for Estimating Site Occupation. *Journal of Archaeological Method and Theory* 4:141–191.
- Vint, James M.
2000 Ceramic Artifacts. In *The Bandelier Survey, Vol. II*, edited by Robert P. Powers, and Janet D. Orcutt, pp. 389–467. Department of Interior Intermountain Cultural Resource Management Professional Paper 57, Washington D. C.
- Warren, A. Helene
1976 The Ceramics and Mineral Resources of LA 70 and the Cochiti Area. In Archaeological Excavations at Pueblo del Enciero, LA 70, Cochiti Dam Salvage Project, Cochiti NM. Final Report, 1964–1965. Laboratory of Anthropology No. 75. Santa Fe.
1979 Historic Pottery of the Cochiti Reservoir Area. In *Archaeological Investigation in Cochiti Reservoir, New Mexico, Vol. 4*, edited by Jan V. Biella and Richard Chapman, pp. 235–245. University of New Mexico Office of Contract Archaeology, Albuquerque.
- Welker, Eden A.
1997 *Attributes of Aggregation at Pueblo San Marcos and Pecos Pueblo in the Northern Rio Grande*. Ph.D. dissertation, Department of Anthropology, University of Colorado. University International Microfilms, Ann Arbor.
- Wendorf, Fred
1953 Excavations at Te'ewi. In *Salvage Archaeology in the Chama Valley*, edited by Fred Wendorf, pp. 34–124. Monograph 17. School of American Research, Santa Fe.
- Wilcox, David R.
1981 Changing Perspectives on the Protohistoric Pueblos. In *The Protohistoric Period in the North American Southwest*, edited by David R. Wilcox, and W. Bruce Masse, pp. 378–409. Arizona State Anthropological Research Papers 24, Tempe.
- Wilkins, Kenneth T., and Heather R. Roberts
2007 Comparative Analysis of Burrow Systems of Seven Species of Pocket Gophers (Rodentia: Geomyidae). *The Southwestern Naturalist* 52:83–8.

Notes

1. This order was derived by sorting the assemblages on the Axis-1 scores from CA-2, as described below. We used CA because FS offers no generally applicable figure of merit to measure the goodness of fit of alternative orders to the model (Ford 1962; Phillips et al. 1951; Spaulding 1953).
2. In the idiom of correspondence analysis, Midden 16 was treated as supplementary point.

Submitted October 20, 2008; Accepted February 3, 2009.