Journal of Archaeological Science 35 (2008) 1224–1239

Journal of Archaeological SCIENCE

http://www.elsevier.com/locate/jas

# The spatial organization of food sharing in Early Postclassic households: an application of soil chemistry in Ancient Oaxaca, Mexico

Stacie M. King*

*Department of Anthropology, Indiana University, Student Building 130, Bloomington, IN 47405, USA*

Received 20 December 2006; received in revised form 27 July 2007; accepted 24 August 2007

**Abstract**

This article considers the relationship between food sharing, commensality, and household social organization at the site of Río Viejo in coastal Oaxaca, Mexico, through a study of the distribution of soil chemical residues in contemporaneous occupation surface and floor deposits in two residential neighborhoods dating to the Early Postclassic (AD 975–1220). Based on the analysis of 12 chemicals in 475 samples using inductively coupled plasma–atomic emission spectroscopy (ICP/AES), I show that these two neighborhoods differ significantly from each other in the amount of deposited residues of organic debris, both inside and outside house buildings, which suggests economic variation and/or differences in the length of occupation between the two neighborhoods. Variation within neighborhoods is present in the form of burn features with higher levels of enrichment within buildings, suggesting some repetition in the use of the interior house space, which could be indicative of multiple households. Soil chemistry also confirms the presence of chemically enriched midden deposits located in the narrow exterior corridors between houses. Soil chemistry did not successfully identify cooking facilities in open, presumably shared, public spaces outside of houses. For this reason, I argue that cooking likely occurred beyond the limits of excavation, and thus, would have socially linked members of multiple households to one another and would have integrated the larger community.


*Keywords:* Soil chemical analysis; ICP/AES; Food sharing; Hearths; Residues; Mesoamerica

## 1. Introduction

In 2000, I designed a research project at Río Viejo to examine and critically evaluate the notion of the "household" in ancient Mesoamerica. After more than two decades of theory building in household archaeology, a major tension in archaeological interpretation exists between focusing on what households *do* (as in Wilk and Rathje, 1982) and the *people* who comprise them (as in Brumfiel, 1991; Hegmon et al., 2000; Hendon, 1996; Meskell, 1998; Moore, 1992; Schortman, 1989; Wilk, 1989). Another lingering problem is how households are defined, by us and by people in the past, and the methods we use to investigate households. Archaeologists have applied definitions of the household which include kinship, co-residence, economic cooperation, hearth-groups, and most recently, adaptations of the Lévi-Straussian concept of "house" (see Carsten and Hugh-Jones, 1995; Joyce and Gillespie, 2000; Lévi-Strauss, 1982).

Ethnographic cases in Mesoamerica and from around the world have suggested that sharing a common hearth often symbolically defines membership in a household, since food sharing creates and cements social ties and affinities between people (Carsten, 1995; Evans-Pritchard, 1940, pp. 84–85; Janowski, 1995; Meigs, 1984; Monaghan, 1995, 1996). Food items, like other material goods, have both economic and symbolic value, and the sharing of food is often bound up with social and symbolic meanings (Grantham, 1995; Lupton, 1994; Weismantel, 1988). In this way, food sharing and commensality may be a significant component of face-to-face household social relations (Joyce, 1999, p. 20). Food preparation and consumption of

* Tel.: +1 812 855 3900; fax: +1 812 855 4358.
*E-mail address:* kingsm@indiana.edu

0305-4403/$ - see front matter 
doi:10.1016/j.jas.2007.08.010

food are activities that are likely to be universally present in domestic contexts (more so than economic production, distribution, ''kinship'', etc.). In this study, I have chosen to use soil chemistry as a way to look at the everyday practices involved in food processing and cooking activities and consider whether food-sharing was connected to smaller-scale social interactions and household membership in coastal Oaxaca.

### *1.1. Activity area research and micro-remains*

Activity area research originally depended on the gross patterning of artifacts in relation to architectural spaces to suggest locations used for particular activities (Carr, 1984; Flannery and Winter, 1976; Hill, 1970; Kent, 1984, 1987; Longacre, 1968; Reid and Whittlesey, 1982). However, because of the problems presented by secondary deposition, cleaning and refuse disposal, the mode and nature of abandonment, length of occupation and reuse, all of which are present in most Mesoamerican sites, most researchers have become dissatisfied with using artifact distributions as signatures of specific activity locations (Cameron and Tomka, 1993; Hayden and Cannon, 1983; Kent, 1990; LaMotta and Schiffer, 1999; Manzanilla, 1986; Schiffer, 1987). Ethnoarchaeological work undertaken for the purpose of building bridging arguments between patterned material remains and social relations helped to show how complicated these correspondences actually were (Alexander, 1999; Hayden and Cannon, 1982, 1983; Killion, 1992; Smyth, 1989, 1991; Sutro and Downing, 1986, 1988). Micro-residues, however, remain in sediments in the form of chemical concentrations, botanical remains, and micro-debitage, which are relatively unaltered by the depositional processes affecting larger artifacts (Dunnell and Stein, 1989). A critical re-engagement with site formation processes, ethnoarchaeology, and innovative research tools involving micro-scale approaches has once again allowed researchers to *explicitly* undertake activity area research (e.g. papers in Allison, 1999; Diehl, 1998; Matthews et al., 1997).

Identifying hearth-groups depends on both a thorough understanding of the distribution of organic remains in residential areas, as well as being able to relate food processing activities with architecture and other features. Plants and animals are used in wide-ranging tasks and are also archaeologically detectable using micro-scale methods. Thus, the distribution of food processing and cooking activities can be used as empirical means for examining the spatial distribution of food-sharing activities and household space. For my research, I have used soil chemistry, paleoethnobotany, and micro-morphology as three techniques for understanding activity areas, since each targets micro-residues that are more likely to stay closer to original activity locations. This paper reports specifically on the soil chemistry results, where variation or enriched levels in soil chemistry are interpreted as proxy measures for the relative contribution of organic debris.

### *1.2. Soil chemistry*

The analysis of chemical residues has become a powerful analytical technique in the study of activity areas and prehistoric land use. Human activities alter the physical and chemical properties of sediments through the addition or modification of organic and inorganic constituents. Anthropogenic influences on sediments can be revealed by determining elemental concentrations in anthrosols relative to natural background levels (Eidt, 1985).

Phosphate ($PO_4$, an oxyanion) analysis is the most widely used chemical analysis in archaeological research. This is because human activities redistribute the phosphorus (P) contained in animal excretions, bones, and plant remains into sediments and soils (Arrhenius, 1963; Bethell and Maté, 1989; Eidt, 1977; Lutz, 1951; Proudfoot, 1976; Provan, 1971; Sjöberg, 1976). Phosphorus naturally occurs in inorganic and organic forms as phosphate.

Archaeological interpretations of phosphate levels have been supported by ethnoarchaeological data, where known features and activities have been measured for phosphate concentrations. Phosphate levels are highly correlated with human activities involving organic refuse, including food processing, hearths, butchering debris, middens, cemeteries and burial, fertilized cropland, stabling, pastureland, and composting, and storage and deposition of organic refuse (Allen and Hamroush, 1984; Dormaar and Beaudoin, 1991; Entwistle et al., 2000; Farswan and Nautiyal, 1997; Goffer et al., 1983; Hurley and Heidenreich, 1971; Jenkins, 1994; Kerr, 1995; Lambert et al., 1984; Linderholm and Lundberg, 1994; MacPhail et al., 2004; Mejia Pérez Campos and Barba Pingarrón, 1988; Moore and Denton, 1988; Sánchez et al., 1996; Sarris et al., 2004; Schuldenrein, 1995; Solecki, 1951; Sullivan and Kealhofer, 2004; Wells et al., 2000). Decreased levels have been shown to correspond with walkways, under beds, entrances, in workshops where organics were not used, recently leveled terrain and harvested agricultural fields (Entwistle et al., 1998; Leonardi et al., 1999; Mejia Pérez Campos and Barba Pingarrón, 1988; Middleton and Price, 1996; Moore and Denton, 1988; Wells et al., 2000). P levels can also be used as a relative indicator of continued use and intensity of occupation, since as the length of occupation increases, more refuse containing P will be deposited (Kerr, 1995; Lillios, 1992; Wells et al., 2000). Phosphorus and phosphates are both excellent general indicators of anthropogenic activity.

Most researchers identify *specific* activities using a combination of elemental signatures (Bethell and Maté, 1989; Cook and Heizer, 1965; Entwistle et al., 1998; Linderholm and Lundberg, 1994; Manzanilla and Barba, 1990; Middleton and Price, 1996). Many elements other than P have been linked to anthropogenic sources at archaeological sites. Magnesium (Mg) is concentrated in ash and burn features (Knudson et al., 2004; Moore and Denton, 1988), and increased levels have been interpreted as cooking areas, animal food processing locations, smokehouses, and middens (Heidenreich and Konrad, 1973; Hurley and Heidenreich, 1971; Knudson et al., 2004; Middleton and Price, 1996; Schuldenrein, 1995). Potassium (K) is associated with cooking and burning, and is present in food scraps, animal fodder, and bedding (Entwistle et al., 1998; Middleton and Price, 1996; Schuldenrein, 1995).

Barium (Ba) is present in the ash of bone, marine plants, woody legumes and mollusk shells, and in bones and teeth in trace amounts (Burton and Price, 1990; Entwistle et al., 1998). Elevated calcium (Ca) levels are associated with kitchens, dwellings, shell, bone, food processing, and middens (Barba and Ortiz, 1992; Entwistle et al., 1998; Hurley and Heidenreich, 1971; Knudson et al., 2004; Lambert et al., 1984; Linderholm and Lundberg, 1994; Middleton and Price, 1996; Stimmell et al., 1984; Sullivan and Kealhofer, 2004). Strontium (Sr), found in bone and terrestrial plants, is both a good dietary and activity indicator (Lambert et al., 1984). Manganese (Mn), zinc (Zn), iron (Fe) and sodium (Na) have been interpreted as general indicators of human activity (Barba and Ortiz, 1992; Linderholm and Lundberg, 1994; Middleton and Price, 1996; Wells et al., 2000), and elevated Na levels have been linked to the use of salt water in fish processing (Knudson et al., 2004).

Studies of activity areas using soil chemical methods have a short but rich history in Mesoamerica. Barba and colleagues conducted numerous ethnoarchaeological investigations to correlate specific elemental and pH patterns with activities in residential contexts and have applied these data to several archaeological cases in Mesoamerica, notably Teotihuacán and Cobá (Barba, 1986; Barba and Bello, 1978; Barba and Manzanilla, 1987a,b; Barba and Ortiz, 1992; Manzanilla and Barba, 1990). Recent studies at Maya sites and in Oaxaca have applied soil chemistry in both modern and prehispanic residential contexts to interpret activity areas, which have been especially successful in locating food processing areas and midden deposits (Middleton and Price, 1996; Parnell et al., 2002; Robin, 1998; Terry et al., 2000; Wells et al., 2000). In addition, several researchers have used chemical analysis (mostly phosphates) to study land usage and agricultural practices at prehispanic archaeological sites (Ball and Kelsay, 1992; Dunning and Beach, 1994; Dunning et al., 1997, 1998; Healy et al., 1983; Muhs et al., 1985). Others have examined trace elements to try to identify the use of pigments and metals in craft production and architectural decoration (Cook et al., 2006; Hutson and Terry, 2006; Parnell et al., 2002; Terry et al., 2004).

### *1.3. Excavations at Río Viejo*

In 2000, Arthur Joyce and I directed excavations in residential areas at the site of Río Viejo in coastal Oaxaca, Mexico (Joyce and King, 2001) (Fig. 1). I chose to focus on a broad, residential platform at the site, Operation B (Op. B), whose surface was covered with the remains of numerous building foundations pertaining to Early Postclassic period structures (reported in King, 2003) (Fig. 2). Joyce directed excavations in a second Early Postclassic period neighborhood on the top of the abandoned Late Classic period acropolis, called Operation A (Op. A) (reported and illustrated in Joyce et al., 2001). The sampling areas at Río Viejo were selected for excavation on the basis of their surface-visible structural remains and the relative lack of disturbance. There is no discernible Early Postclassic site center or plaza at Río Viejo, nor are there known remnants of other neighborhoods at the site that appear obviously different from those attested in the 2000 field excavations.

I conducted large-scale horizontal excavations to expose a broad contiguous area in a single field season that totaled 284 $m^2$. The excavations uncovered thousands of artifact including over 265,000 fragments of ceramic vessels. Also found were groundstone *metates* and *manos* (grinding stones and pestles), axes and hammerstone implements, animal bone, molds for making figurines, ceramic manufacturing tools such as *azotadores* (pounders for flattening out wet clay) and highly polished and well-used burnishers, spindle whorls and bone needles used in producing cotton thread and woven textiles (King, 2007), jewelry including earflares and pendants, as well as obsidian blade fragments, ceramic stamps, carved human and animal bone, and beautiful clay bells.

Burials were located beneath the house floors in at least two of the structures in Op. B (Fig. 3). The people interred in these houses were all adults, both males and females, placed in nearly identical positions and orientations with their heads to the south (King, 2003, 2005). Each burial included between one to three ceramic vessel offerings placed around the feet. The only obvious activity area-related features in Operation B were large *metate* fragments that may still be *in situ* and two shallow burning pits found within Structures 4 and 8.

Early Postclassic residents lived here for at least 250 years and enjoyed many generations of community continuity, which included some architectural renovations and new construction in the residential zone. The spatial arrangement of architecture at Río Viejo suggests that patio groups with enclosed courtyards and structures aligned according to a similar orientation were not the primary architectural units in coastal Oaxaca as they are in many other parts of Mesoamerica (King, 2003). Instead, architectural similarity and the spatial arrangement show that each building was likely its own distinct unit. The individual residences were connected to other residences in loosely defined clusters of houses, separated by narrow corridors. Sometimes irregularly shaped courtyards were present between two or more residences, such as that present in Operation A (Fig. 4), but each residence had access to more than one of these small courtyards. The evidence of construction events that adopted similar alignments and accretional building layouts is indicative of long standing continuity of occupation and community growth during the Early Postclassic.

## 2. Materials and methods

### *2.1. Sample collection procedures and controls*

We collected sediment samples from contemporaneous earthen living surfaces in each excavation area, which are distinguishable as subtle changes in sediment color, texture, and compaction. These include earthen house floors and exterior occupation surfaces. Excavation units were placed contiguously within each area to take advantage of known occupation surfaces and to expose large horizontal areas. The soil chemistry of occupation surfaces applied to the final phase of occupation, when all of these houses were occupied, except where

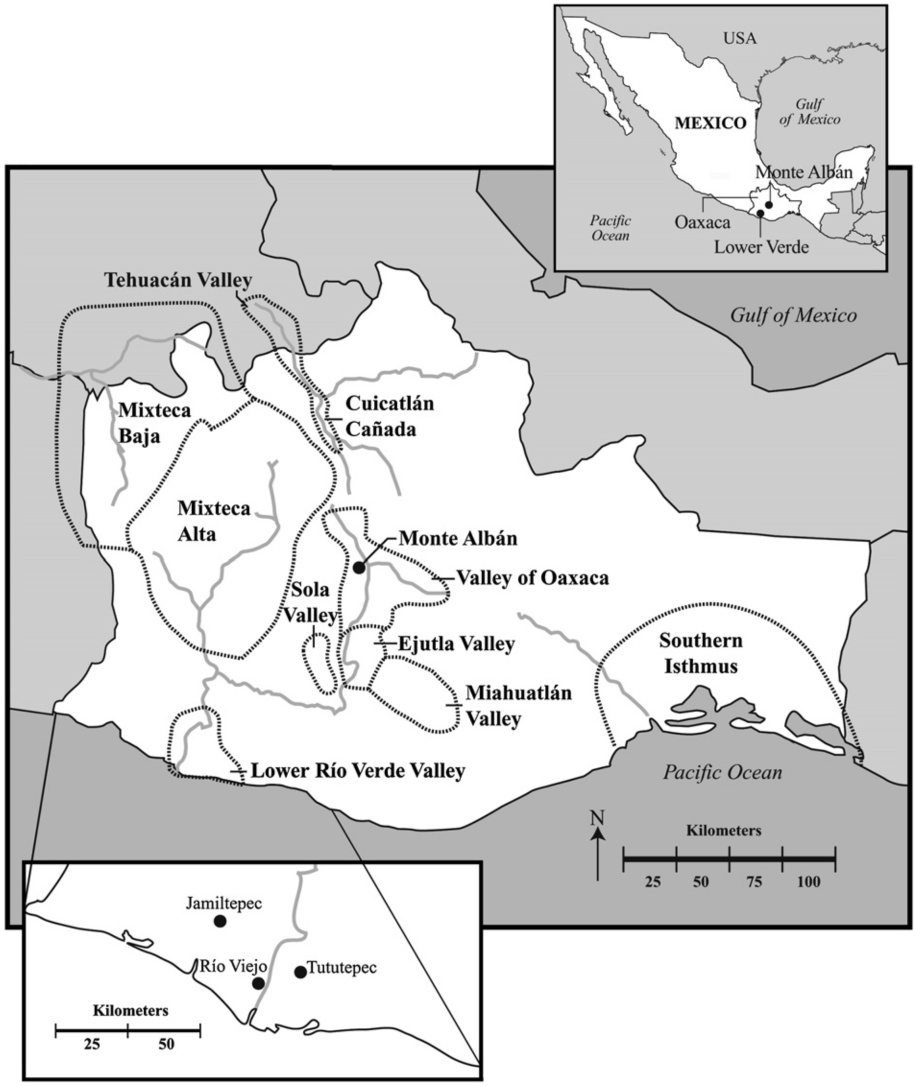


Fig. 1. Map of Oaxaca, showing the location of Río Viejo.

special features were selectively sampled. Samples of 500 mg were taken at every intersection of a meter square to provide broad, systematic coverage (Terry et al., 2000). While some researchers take samples every 50 cm (e.g. Middleton and Price, 1996; Sánchez et al., 1996), most employ intervals between 2 and 5 m (Barba and Ortiz, 1992; De Miguel et al., 1998; Konrad et al., 1983). Given my interest in fine scale spatial patterns, we collected samples every 1 m to provide analytically effective, cost-effective coverage. A total of 435 archaeological samples were collected from occupation surfaces, features, and ceramic vessels. In addition, I collected 40 control samples from off-site deposits from roughly contemporaneous contexts to establish mean background levels.

### 2.2. Sample processing

Initial treatment of the samples included sieving through a 2 mm (No. 10) stainless steel geological sieve at the time of collection and storage in plastic bags. Due to humid conditions on the coast during the field season, air-drying proved impossible. Instead, about a gram of each sample was oven-dried at the University of California, Berkeley Archaeological Research Facility for 48 h at a low, constant temperature between 81.6 and 84.3 °C. Each sample was then placed in a dessicator for 48 h immediately following removal from the oven to avoid re-absorption of humid air and condensation. Between 0.2 and 0.21 g of sediment from each dried and dessicated sample was then separated for analysis.

I conducted the final processing and analysis of the samples at the Laboratory for Archaeological Chemistry of the University of Wisconsin Madison, under the direction of Dr James H. Burton using ICP/AES. Although there are numerous techniques available for multi-elemental characterization of chemical residues, ICP/AES is popular for its accuracy, speed, availability, simplicity, and low cost (Pollard and Heron, 1996; Sharp, 1991; Soltanpour et al., 1996). The use of ICP/AES has worked well both ethnoarchaeologically and archaeologically for the determination of activity areas (Bethell and Smith, 1989; Knudson et al., 2004; Linderholm and Lundberg, 1994; Middleton, 1998; Middleton and Price, 1996). Following a modified version

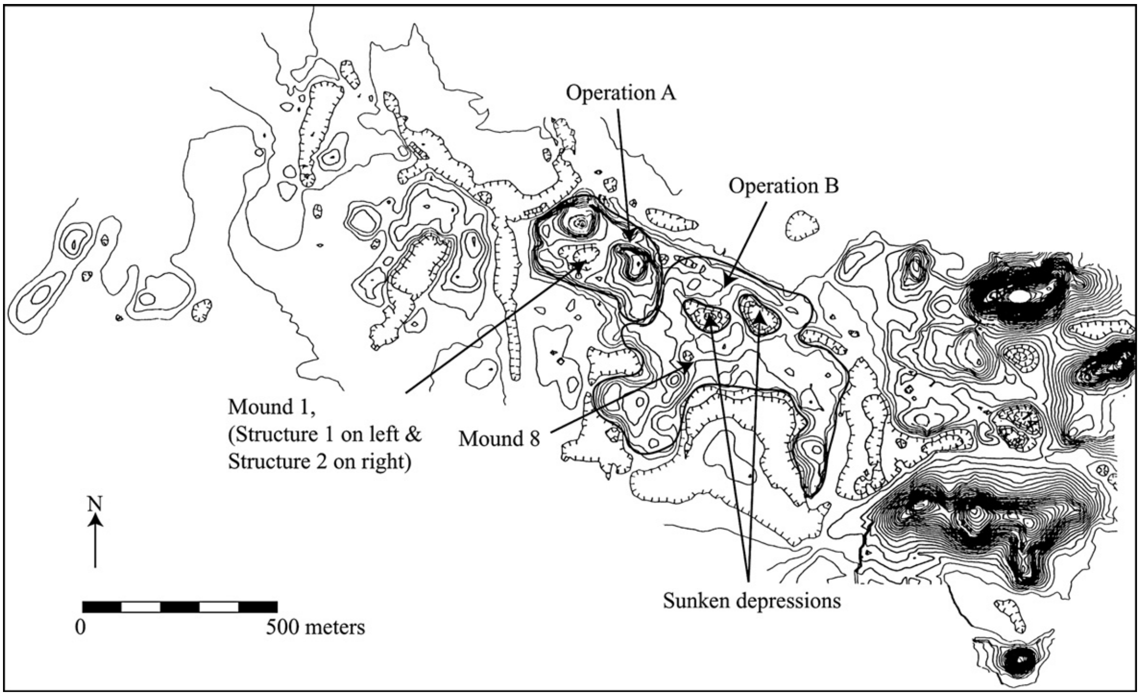


Fig. 2. Topographic map of Río Viejo, showing the locations of the two neighborhoods (base map adapted from Joyce et al., 2001).

of protocols used by Bethell and Smith (1989), Entwistle et al. (1998), and the Soil Science Society of America (Soltanpour et al., 1996), we extracted the samples for 2 weeks at room temperature in 20 ml 1 M HCl as outlined in Middleton and Price (1996). Approximately every 48 h, the samples were manually agitated for about 30 s to aid dissolution. After 2 weeks, the liquid solution was poured off and any residual material was discarded. Sometimes filtering was necessary due to increased particulates, and "blank" samples were processed to show that selective filtering did not affect the results.

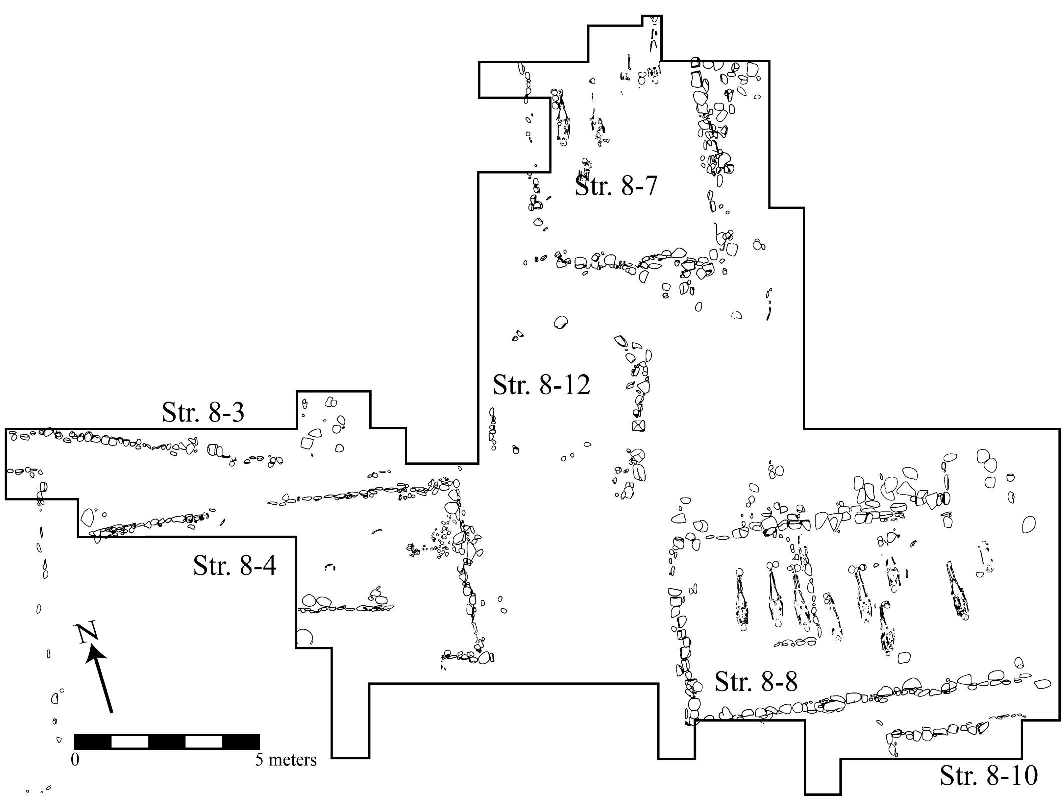


Fig. 3. Operation B plan.

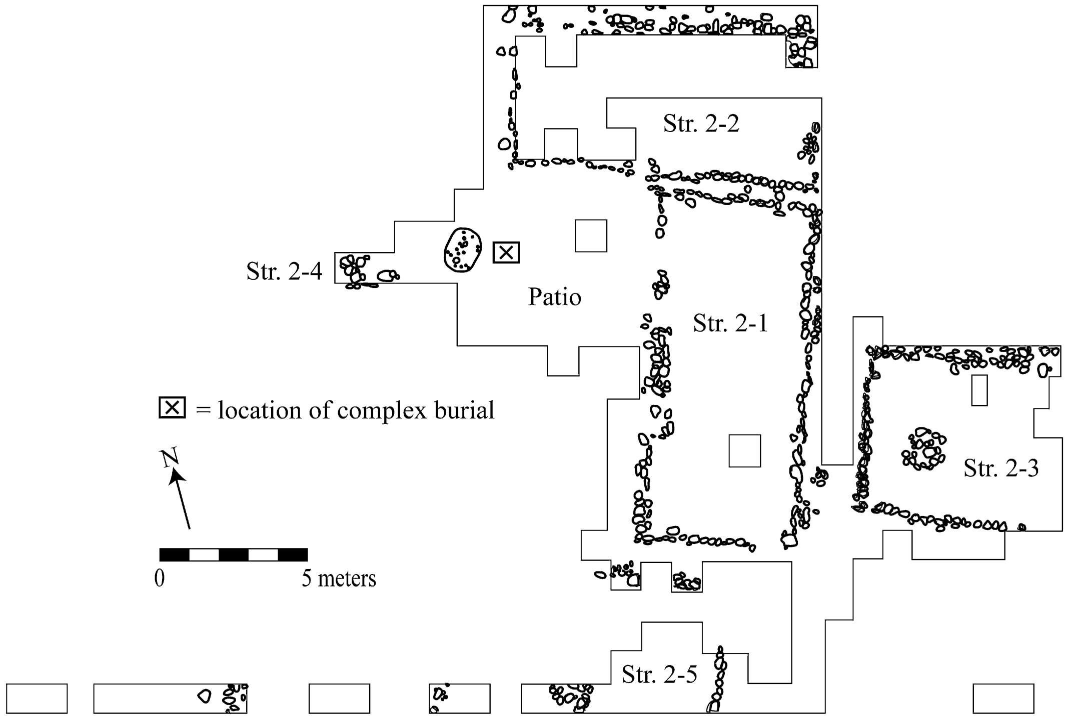


Fig. 4. Operation A plan (adapted from Joyce and King, 2001).

With ICP/AES, there are few interferences for elements introduced through organic residues of food-processing activities (Herz and Garrison, 1998). For the purposes of this study Al, Ba, Ca, Fe, K, Mg, Mn, Na, P, Sr, Ti, and Zn were analyzed for all 475 collected and prepared samples (see the Online Appendix to view the raw data generated by the soil chemical analysis).

## 3. Results

### 3.1. Comparison of archaeological samples and control samples

Areas of human occupation at Río Viejo demonstrate variation from the controls for most elements tested. *T*-tests show that the means are significantly different at the $p < 0.05$ level, except Na and Ti (Table 1). Levels of P are significantly lower in the control samples, attesting to anthropogenic residues in the archaeological samples. For several of the elements (Al, Ba, Ca, Fe, Mg, and Mn), the control samples are more enriched than the archaeological samples. This enrichment can be at least partially accounted for by the high clay composition of the control samples. Clay-sized particles generally have a high capacity for adsorbing cations such as Ca, Mg, and Mn. The higher concentrations of Fe and Al in the controls may be due to the finer texture of clay-sized minerals. I chose overbank deposits for control sampling based on the likelihood that Early Postclassic residents used alluvial overbank deposits to build platforms and houses. In retrospect, this may not have been the best choice. Overbank deposits lie at a lower elevation and are formed by alluvial deposits (clays), whereas structure platforms are raised well above the floodplain surface and are well-drained. I also probably underestimated the extent to which Early Postclassic residents used sediment from earlier occupations in construction. To address this problem, I instead calculated background levels within each neighborhood using the mean of the five lowest values for each element, following Wells et al. (2000). The raw data output was then corrected for background levels by subtracting the background means from the results for each element in each sample. In this way, the archaeological samples themselves serve as controls for assessing chemical enrichment.

### 3.2. Comparison of the two neighborhoods

The Op. B neighborhood exhibits higher raw (uncorrected) levels of enrichment in all elemental categories, except Fe and Ti. Differences in mean values between the neighborhoods are statistically significant at the $p < 0.05$ level for all elements except Mg and Na, with or without the correction for background levels (Table 2). After correction (see Section 3.1), mean values are higher in Op. B for Ca, P, Sr, and Zn only. This includes a doubling of mean P levels in Op. B. Given the strong association of P with plant debris and animal products, residents of Op. B might have conducted more food processing and animal care activities in and around their homes, were more involved in economic activities that involved the use of plant and animal products, or the Op. B neighborhood was more heavily populated, by humans and animals.

The high P levels may also show that the Op. B residential platform was occupied for longer than the flat mound-top terrace of Op. A. We can identify two phases of construction in

Table 1
Concentration of elements (mg/kg) in control and archaeological samples

| | Al | Ba | Ca | Fe | K | Mg | Mn | Na | P | Sr | Ti | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Archaeological samples* ($n = 435$) | | | | | | | | | | | | |
| Mean | 9267* | 143* | 13819* | 14773* | 3772* | 5544* | 505* | 331 | 4621* | 55* | 359 | 92* |
| SD | 749.1 | 13.1 | 5160.9 | 1149.6 | 394.7 | 394.6 | 43.0 | 40.7 | 1653.6 | 19.0 | 33.3 | 16.8 |
| % Variation | 8.08 | 9.15 | 37.35 | 7.78 | 10.46 | 7.12 | 8.52 | 12.23 | 35.78 | 34.55 | 9.28 | 18.22 |
| Max | 15329 | 214 | 48728 | 18262 | 5413 | 7157 | 648 | 595 | 10320 | 213 | 468 | 136 |
| Min | 6360 | 98 | 6074 | 11626 | 2417 | 4531 | 291 | 228 | 1994 | 28 | 205 | 50 |
| *Control samples* ($n = 40$) | | | | | | | | | | | | |
| Mean | 12145 | 211 | 41007 | 19181 | 3415 | 7938 | 836 | 331 | 500 | 58 | 370 | 70 |
| SD | 938.3 | 23.6 | 11073.7 | 1628.3 | 324.8 | 347.1 | 72.5 | 45.9 | 40.3 | 7.7 | 74.4 | 4.9 |
| % Variation | 7.73 | 11.20 | 27.00 | 8.49 | 9.51 | 4.37 | 8.68 | 13.87 | 8.06 | 13.23 | 20.09 | 7.05 |
| Max | 14571 | 277 | 60865 | 23249 | 4108 | 8829 | 1023 | 507 | 631 | 77 | 600 | 81 |
| Min | 10567 | 182 | 18326 | 16486 | 2885 | 7298 | 705 | 275 | 431 | 44 | 291 | 61 |

*Statistically different from control samples at the $p < 0.05$ level.

the Op. B area, showing that some structures were added later. It is likely that, once constructed, all structures were occupied throughout the Early Postclassic. With potentially only half the length of time represented, Op. A exhibits a similar clustered arrangement. This supports the interpretation that this clustered spatial arrangement was an intentional neighborhood design, one that is unique compared to other parts of ancient Mesoamerica.

### 3.3. Operation B neighborhood

Analysis of each neighborhood by itself allows us to begin to look at specific locations where activities involving organic remains may have preferentially taken place. I compare the elemental levels by context within each neighborhood using one-way analysis of variation (ANOVA) and either Bonferroni's or Tamhane's post-hoc tests depending on whether or not equal variances can be assumed. The density plots are formatted so that increased shading represents increased levels of chemical enrichment. I also use principal components analysis with varimax rotation to group elements with highly correlated signatures and overlapping distributions into single variables to more effectively illustrate areas of enrichment for multiple chemicals. Scatterplots of the components with eigenvalues greater than 1 show a consistent overlap of Ca, P, and Sr and Al, Fe, K, and Mg in both neighborhoods (Figs. 5 and 6). Barium is more variable in its grouping and overlaps more closely with Al, Fe, K and Mg in the Op. A neighborhood, while it is more closely linked with Ca, P and Sr in Op. B. Mn and Zn produced very different distribution results that were not easily reduced in PCA and thus were eliminated from this portion of the analysis (see below). Tables 3 and 4 provide the rotated component scores for each of the elements in each neighborhood. For Operation B, the first and second components have eigenvalues of 4.08 and 2.23 respectively explaining 78.9% of the variance, while the first and second components in Op. A have eigenvalues of 3.64 and 2.49 respectively accounting for 76.6% of the variance. PCA produced a third component with an eigenvalue over 1 (at 1.06)

Table 2
Concentration of elements (mg/kg) in Operations A and B before and after correction for background levels

| | Operation A ($n = 168$) | | Operation B ($n = 267$) | |
|---|---|---|---|---|
| | Raw levels (mg/kg) | Corrected for background (mg/kg) | Raw levels (mg/kg) | Corrected for background (mg/kg) |
| Al | 9177.8* | 1919.9* | 9322.4 | 1368.8 |
| Ba | 136.2* | 28* | 147.2 | 19.4 |
| Ca | 10398.5* | 3158.7* | 15971.7 | 4984.7 |
| Fe | 14927* | 2912.9* | 14675.3 | 2379.5 |
| K | 3417* | 652.1* | 3996.2 | 575.3 |
| Mg | 5540.3 | 849.3 | 5546.4 | 847.4 |
| Mn | 475.3* | 113.6* | 523.8 | 94.6 |
| Na | 311.5 | 71.9 | 343.1 | 70.3 |
| P | 3120.1* | 1041.1* | 5566 | 2156 |
| Sr | 37.8* | 8.9* | 65.7 | 19.1 |
| Ti | 365.6* | 99.8* | 354.1 | 78.5 |
| Zn | 74.1* | 16.1* | 103.6 | 21.5 |

*Difference between Operation A and B mean values is significant at the $p < 0.05$ level.

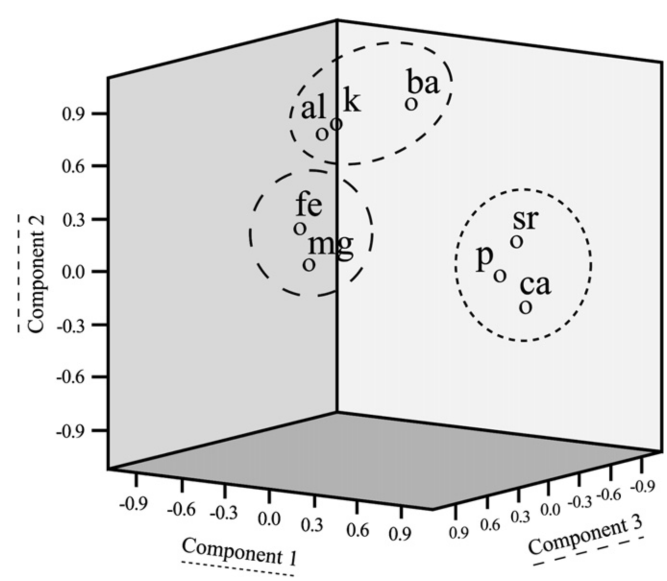


Fig. 5. Scatterplot of principal components for Operation A.

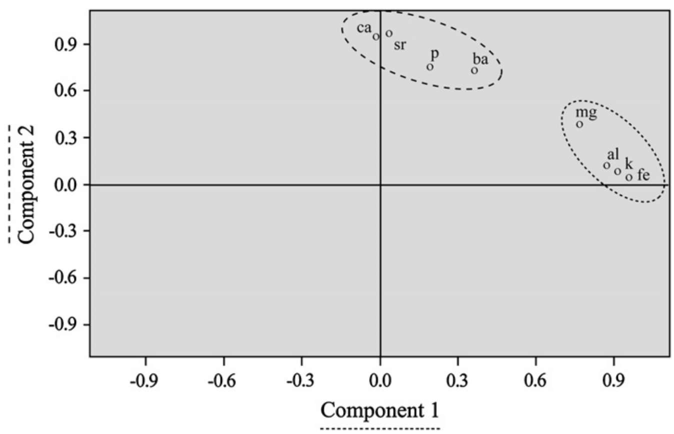


Fig. 6. Component plot for Operation B.

for Op. A grouping Mg and Fe, which explains another 13.2% of the variance, for a total of 89.8% cumulative variance explained. The consistency in the components shows that certain chemical signatures are highly correlated with one another, probably due to similar chemical pathways as well as overlapping deposition, thus producing similar distributions across the excavated areas. The differences between the two neighborhoods, however, are best explained by differences in activities and variation in the deposition of chemically enriched debris, as described in the sections below.

Correlation matrices confirm the strong association between nearly all of the elements in Op. B (Table 5). Enrichment levels of Ba, Ca, Sr, and P overlap in distribution, with obvious concentrations within Structures 8-4 and 8-8, just outside of Str. 8-8's SW wall, and in the narrow space between Str. 8-8 and Str. 8-10 (Fig. 7). The areas of highest enrichment for these elements occur in the samples collected from the burn pits identified within each of these structures. The burn pits were distinguishable as reddened rings of burned earth with no obvious artifact or shell inclusions. These were not kilns or large cooking hearths and did not contain fire-cracked rock, dense charcoal, and thick lenses of ash. Rather, the pits were small fire installations measuring about 20–25 cm in diameter with a depth of 9–20 cm. The concentration of these elements in these features may suggest the presence of animal bone ash and/or shells. However, carbon flecks and the elements associated with extensive burning and cooking, K and Mg, are not as concentrated in these areas.

Table 3
Rotated component scores for Operation B

| | Component | |
|---|---|---|
| | 1 | 2 |
| Mg | 0.956 | 0.036 |
| Ba | 0.915 | 0.075 |
| Fe | 0.872 | 0.114 |
| K | 0.767 | 0.376 |
| Al | 0.035 | 0.959 |
| P | −0.017 | 0.936 |
| Ca | 0.192 | 0.747 |
| Sr | 0.365 | 0.722 |

Table 4
Rotated component scores for Operation A

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 2 |
| Sr | 0.951 | 0.233 | 0.081 |
| Ca | 0.915 | −0.161 | −0.060 |
| P | 0.905 | 0.054 | 0.179 |
| Ba | 0.188 | 0.928 | 0.008 |
| K | −0.065 | 0.838 | 0.377 |
| Al | −0.062 | 0.812 | 0.524 |
| Mg | 0.134 | 0.136 | 0.925 |
| Fe | 0.057 | 0.332 | 0.902 |

Other elements show different patterns. Fe and Mg are most concentrated around the walls of Str. 8-8, including a swath across the center of the structure as well as a concentration outside the SW corner of Str. 8-8. K too falls within these areas, with a concentration in the center of Str. 8-8 and a separate concentration outside of the SW corner of the structure (Fig. 8). K and Mg are most often associated with burning, cooking and animal food processing, but perhaps might also reflect baked mud-wall construction material.

Mn and Zn have patterns that are distinct from the others and cannot be easily reduced using PCA (PCA produced better results by eliminating Mn and Zn from the analysis), showing a swath of enriched levels oriented east-west north running just outside of Str. 8-8's NW corner. Since no specific activity has been linked to these elements, the activity related associations remain unknown and do not contribute significantly to the interpretation.

It is perhaps just as interesting to consider where the levels of organic debris are decreased, which could be indicative of high traffic zones or swept surfaces (as in Hutson and Terry, 2006; Parnell et al., 2002; as in Robin, 2002). The most significant is the lack of dense organic debris in Str. 8-12 or in any of the supposed "patio" area. The only outdoor location that consistently contains elevated concentrations of organic debris is just outside the SW corner of Str. 8-8. In excavation, there was no obvious way to differentiate this area from the rest of the patio in terms of stratigraphy or artifact debris. However, the presence of these concentrations would suggest that some sort of work area or refuse dump existed in this location. The relative lack of organic debris in most of the patio area says something about what kinds of activities were associated with this space and most significantly shows that food processing and cooking did not take place in the patio. Instead, these data suggest that the interiors of structures and immediately adjacent zones were more frequently used for activities involving organic materials than were the patio areas. Levels of Ba, Ca, P, and Sr were all enriched inside houses at statistically significant levels.

The frequent removal of portions of floor surfaces to place burials beneath the houses could perhaps account for the less intense chemical concentrations in Str. 8-8 and Str. 8-7. That burials were common in these two structures and were not placed in another (Str. 8-4) also shows that these spaces were differentiated in some important way.

Table 5
Correlation matrix for Operation B, reporting Kendall's Tau-B correlation coefficients

| | Ba | Ca | Fe | K | Mg | Mn | Na | P | Sr | Ti | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Al | 0.382** | 0.161** | 0.704** | 0.627** | 0.619** | 0.207** | 0.375** | 0.218** | 0.192** | 0.470** | 0.484** |
| Ba | | 0.382** | 0.215** | 0.256** | 0.293** | 0.161** | 0.207** | 0.322** | 0.430** | 0.073 | 0.412** |
| Ca | | | 0.106* | 0.086* | 0.257** | −0.291** | 0.288** | 0.800** | 0.816** | −0.064 | 0.348** |
| Fe | | | | 0.609** | 0.715** | 0.148** | 0.423** | 0.163** | 0.097* | 0.578** | 390** |
| K | | | | | 0.546** | 0.171** | 0.372** | 0.156** | 0.118** | 0.474** | 0.391** |
| Mg | | | | | | 0.063 | 0.482** | 0.237** | 0.215** | 0.503** | 0.410** |
| Mn | | | | | | | −0.067 | −0.286** | −0.227** | 0.167** | 0.206** |
| Na | | | | | | | | 0.348** | 0.292** | 0.326** | 0.365** |
| P | | | | | | | | | 0.747** | −0.029 | 0.411** |
| Sr | | | | | | | | | | −0.088* | 0.377** |
| Ti | | | | | | | | | | | 0.233** |

*Correlation is significant at the $p < 0.05$ level (two-tailed).
**Correlation is significant at the $p < 0.01$ level (two-tailed).

### 3.4. Operation A neighborhood

In Op. A, a different pattern of activity emerges (Table 6). Here, rather than the structure interiors being favored locations for activities involving organic materials, the patio instead is a major focus. Increased levels of Sr, Ca, and P occur in high concentrations in the narrow corridor between Str. 2-1 and Str. 2-3, or in the southwestern corner of Str. 2-1, which stand out from the rest of the excavated area (Fig. 9). As in Op. B, these three elements again co-occur in Op. A. Without overt signs of burning, these areas are probably best interpreted as middens where organic refuse was deposited, especially animal bone and shells.

The distribution of Ba anticipates a second major locus of activity in this neighborhood, with a concentration in the center of the patio. This concentration in the center of the patio is clearly marked in the plot of the second component, grouping Ba, K, and Al (Fig. 10). Hotspots of Al overlap with Mg and Fe in the eastern central portion of Str. 2-1 and the extreme NW corner of Str. 2-3 (Fig. 11). The combination of these elements suggests the presence of ash, burning, and bone debris in these areas. The complete suite of chemical signatures across the Operation A neighborhood suggest that the eastern interior of Str. 2-1 and the very NW corner of Structure 2-3 were likely the loci of activities involving burning, while the patio area remains a major focal point. The dense chemical

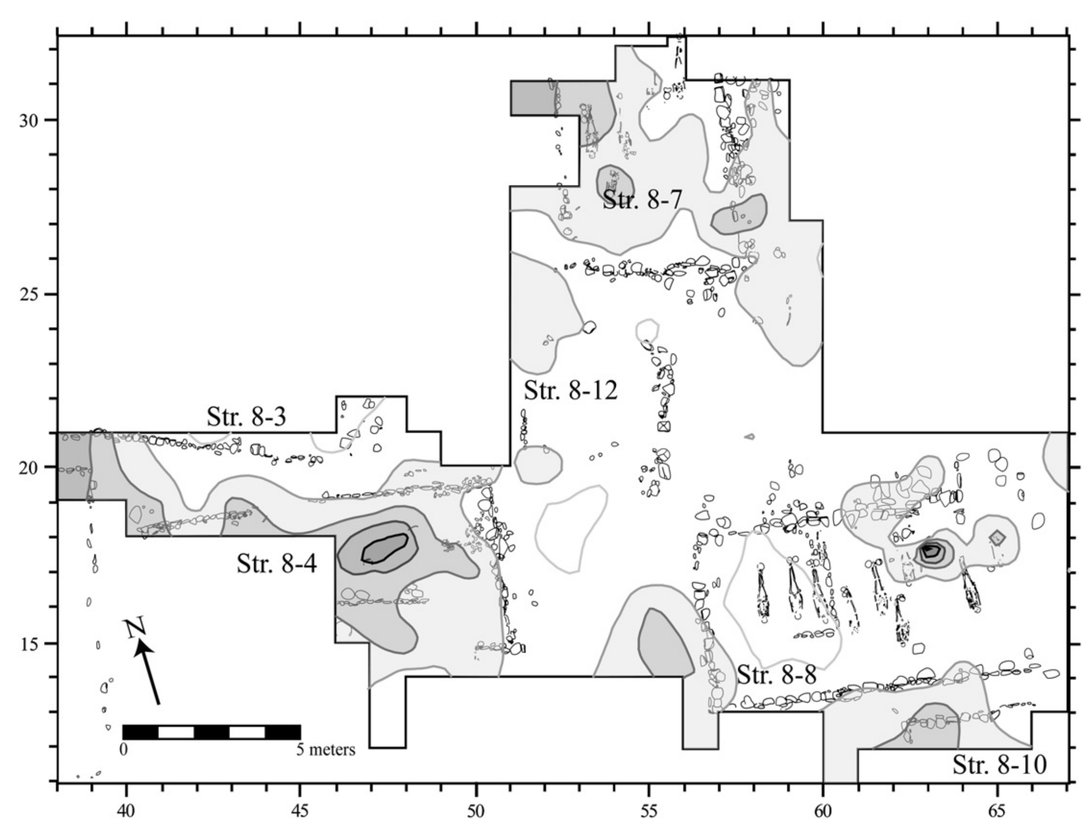


Fig. 7. Distribution of Ba, Ca, P, and Sr (Component 2) in Operation B.

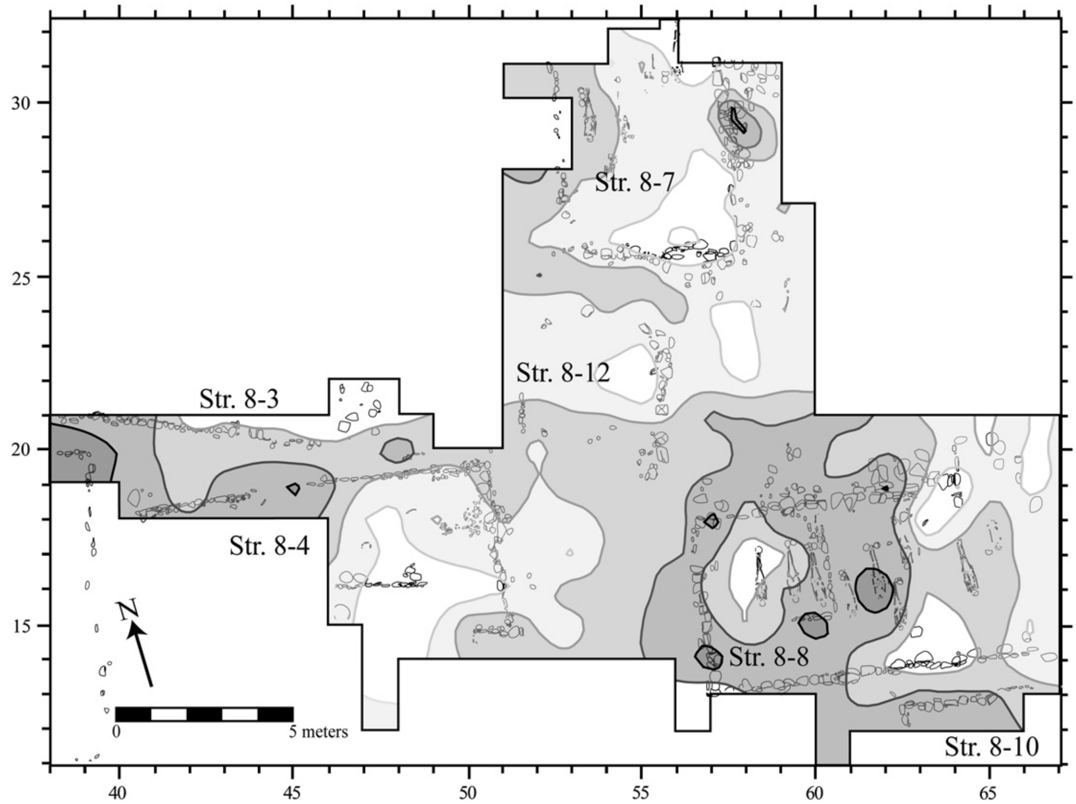


Fig. 8. Distribution of Al, Fe, K, and Mg (Component 1) in Operation B.

deposits in the patio area occur in an area around a multiple burial that showed visible signs of burning. Joyce et al. (2001) have interpreted this as a ritual deposit involving a bundled female burial, which was then burned, linked to sacrifice. The odd circular rock feature inside Str. 2-3 showed little enrichment in most elements, and thus was not likely to have been used as a hearth.

## 4. Discussion

The distribution of activities involving organic remains can be connected to larger questions about households and the interpretation of ‘‘household-ness’’ at Río Viejo during the Early Postclassic. While these data do not identify *specific* activities that were undertaken within and around these domestic structures, they instead help us to think about the various ways in which different spaces were used, and how organic debris was differentially deposited across the excavated area. Based on comparisons with ethnographically described households in Mesoamerica, I expected that the densest concentrations of organic debris would have been located in outdoor patio areas, where most food processing and household activities likely took place. Outdoor facilities allow multiple people to work together in a social setting and were important parts of

Table 6
Correlation matrix for Operation A, reporting Kendall's Tau-B correlation coefficients

| | Ba | Ca | Fe | K | Mg | Mn | Na | P | Sr | Ti | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Al | 0.456** | 0.110* | 0.625** | 0.638** | 0.577** | 0.431** | 0.239** | 0.144** | 0.224** | 0.279** | 0.362** |
| Ba | | 0.199** | 0.237** | 0.392** | 0.222** | 0.367** | 0.091 | 0.108* | 0.253** | −0.007 | 0.319** |
| Ca | | | 0.180** | 0.072 | 0.173** | −0.058 | 0.230** | 0.643** | 0.696** | 0.160** | 0.274** |
| Fe | | | | 0.507** | 0.642** | 0.376** | 0.321** | 0.285** | 0.306** | 0.500** | 0.454** |
| K | | | | | 0.491** | 0.437** | 0.259** | 0.108** | 0.175** | 0.244** | 0.403** |
| Mg | | | | | | 0.425** | 0.337** | 0.162** | 0.204** | 0.364** | 0.378** |
| Mn | | | | | | | 0.121* | −0.073 | 0.015 | 0.135** | 0.390** |
| Na | | | | | | | | 0.279** | 0.306** | 0.273** | 0.377** |
| P | | | | | | | | | 0.671** | 0.317** | 0.373** |
| Sr | | | | | | | | | | 0.294** | 0.409** |
| Ti | | | | | | | | | | | 0.345** |

*Correlation is significant at the $p < 0.05$ level (two-tailed).
**Correlation is significant at the $p < 0.01$ level (two-tailed).

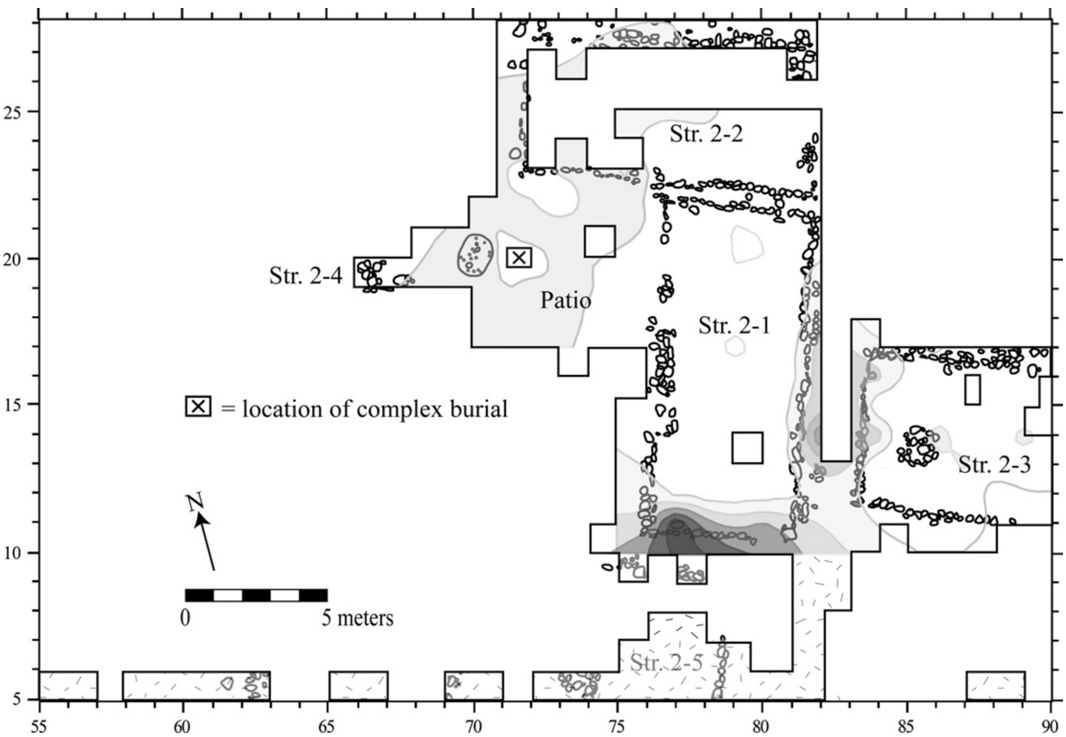


Fig. 9. Distribution of Sr, Ca, and P (Component 1) in Operation A.

everyday life in ancient Mesoamerica (Robin, 2002; Robin and Rothschild, 2002).

Although an exterior workspace may have existed in the Op. A neighborhood, patio-based activities resulting in elevated chemical levels are largely absent in the Op. B residential area. Instead, the main work areas and middens were located *within* or immediately adjacent to buildings. Shallow depressions used for heating organic debris were found inside at least two of the structures. Although quite unexpected for this subtropical climate, the presence of burn pits

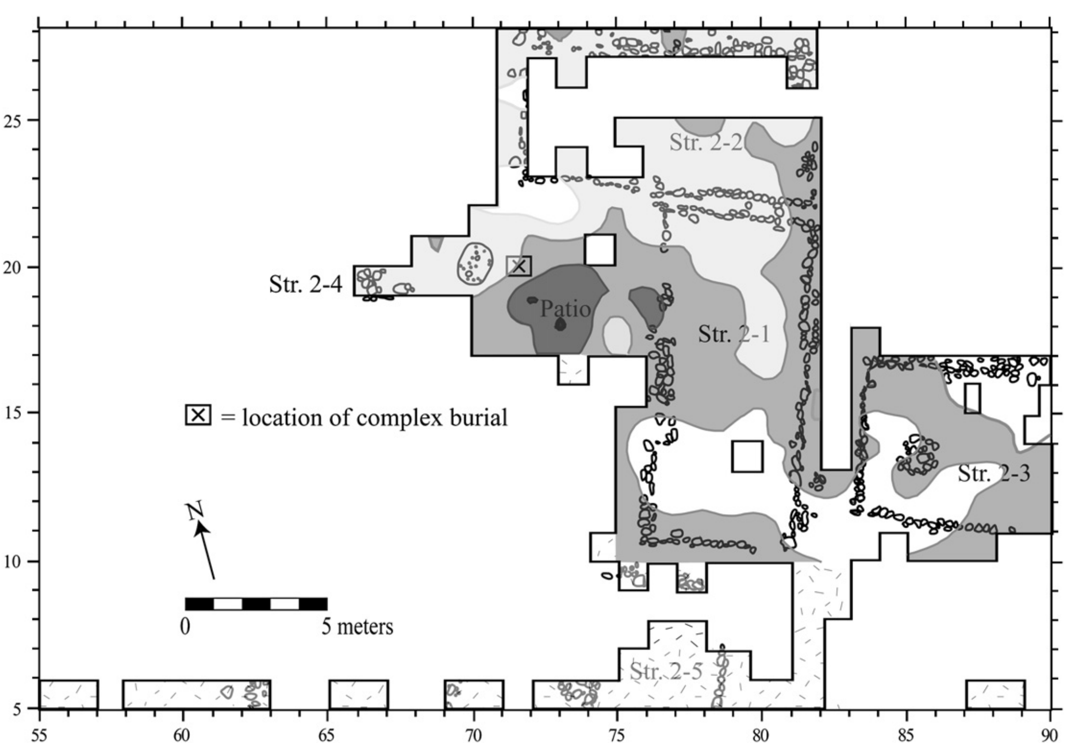


Fig. 10. Distribution of Ba, K, Al (Component 2) in Operation A.

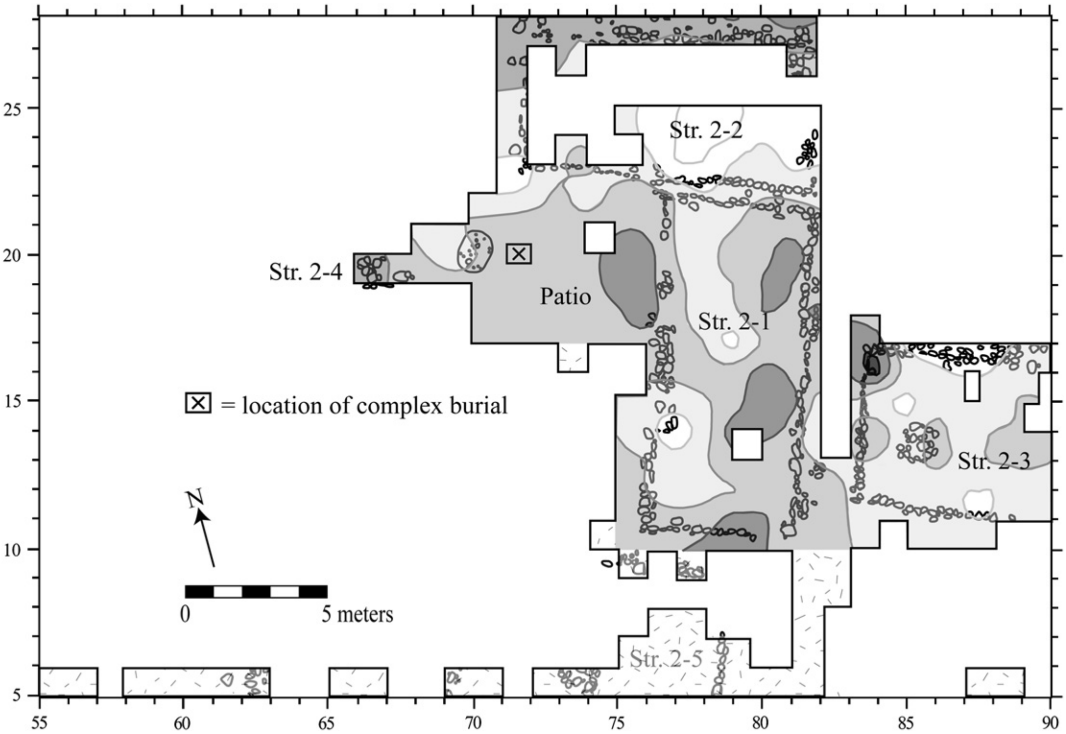


Fig. 11. Distribution of Mg and Fe (Component 3) in Operation A.

inside two residential structures shows that similar activities were undertaken in more than one building. This means that residents used and occupied at least two buildings in similar ways, a replication of activities that might indicate separate and differentiated social groups or households.

At least one burn pit with similar chemical concentrations was present during each construction episode in the Op. B neighborhood. The burn pits contained remnants of maize phytoliths, charcoal flecks, and some ash, and were periodically extinguished with algae-filled water (King, 2003). I had expected that regularly used hearths should be wider and deeper, perhaps stone-lined, with adobe melt and/or larger quantities of ash and carbon found *in situ*. These smaller pits were probably used for a stage of food processing that would have required heating, such as roasting maize kernels or toasting nuts. Their small size and lack of fire cracked rock, charcoal, melted adobe, and lower than average K and Mg enrichment levels suggests small-scale cooking. Hearths at Oaxacan sites are rarely described in detail in published reports, but some may have indeed been smaller, sometimes stone-lined, installations similar to Río Viejo burn pits (Feinman and Nicholas, 2000; Joyce, 1994; Spencer and Redmond, 1997). If the Río Viejo burn pits were hearths, they were likely used for single pot cooking and were cleaned of ash and charcoal debris on a regular basis. A comparison of cooking vessel and burn pit diameter might help to clarify the interpretation of these features, but unfortunately cooking vessels and *comales* (griddles) are not diagnostic to the Early Postclassic and very few fragments have been found in unmixed deposits. I remain most comfortable with the interpretation that these are not hearths receiving daily use, but were smaller special-purpose burn installations.

Soil chemical analysis showed that indoor house space was utilized more for smaller scale house-centered food processing activities than were patio areas or intervening spaces. Refuse was frequently deposited in the narrow corridors between buildings. Outdoor spaces were relatively un-enriched from a chemical standpoint, except in the area of the Op. A patio burial, suggesting that these zones were high traffic zones, less frequently used for activities involving organic remains, or were more frequently altered or leveled. However, the absence of cooking facilities within either excavated area probably means that the final food preparation and cooking of food occurred in as-yet-unexcavated locations, perhaps servicing residents of multiple buildings. If there is a shared communal cooking space located some distance from these structures (outside the excavation limits), then we might be able to argue that households were comprised of multiple families and/or that multiple households participated in food sharing. If individual households conducted some food processing activities within their own house structures, but then shared communal cooking areas, a different picture of household and community social relationships emerges, where individual households were closely linked to one another and cooperative food sharing was a common practice.

At Río Viejo, individual houses and the people who resided within them seem to have comprised the minimal social unit. Patio groups are not well defined and structures were instead the focus of a consistent set of activities. At the same time residents of each house were closely connected to neighboring families through shared social practices, including larger-scale food preparation, cooking, craft production, and ritual activities. The boundaries of this group remain unclear without further excavation, but likely correspond to the cluster of houses present on the surface of each platform.

The hearth-group was more difficult to identify than I had anticipated, and the soil chemistry did not necessarily provide a clear answer. Sharing food, however, is only one example of a shared practice in which household or *barrio* residents participated. Craft activities, such as spinning and weaving, the manufacture of ceramic vessels and costume ornaments, and ritual activities are equally indicative of a shared group identity. In the end, correctly identifying the indigenous definition of the household at Río Viejo is perhaps less important an issue than recognizing the ways in which Early Postclassic social groups were created and maintained. Standardization in artifacts, architecture and mortuary practices in Op. B show that the residents actively maintained their connections to one another by creating and enacting a shared collective house identity. They participated in life-cycle ceremonies and mortuary ritual within the residential compound, and participated in the same broad range of activities. But they also perhaps shared cooking facilities located beyond the excavated area, another way in which communal ties were enacted. Craft production, ritual practices, and food preparation then were activities that forged connections between houses, which cemented relationships between people and linked individual persons, residents, and ancestors of each house to the social whole.

## 5. Conclusion

The soil chemistry identified differential use of space in both neighborhoods. The Op. B neighborhood at Río Viejo was either occupied for a much longer period of time, had a larger human and/or population, or was the scene of more intense activities involving organic remains, resulting in a near doubling of P levels. Consistently increased levels of chemical enrichment in the burn pits indicate that these features were used for some amount of food processing or small-scale cooking. The decreased quantity of chemicals in exterior areas and the increased levels in interior structure floor surfaces were also consistent, showing that indoor and outdoor spaces were used in different ways. Outdoor spaces were much less intensively used for activities involving organic remains than were structure interiors. The same patterns were reflected in the artifact distributions, but chemical concentrations and artifact deposits were the result of different formation processes. The thick artifact deposits inside structures were associated with filling the structure interiors with occupation debris derived from another location during building construction (secondary deposition). The soil chemistry samples were taken from the very top of the floor surfaces, where organics and chemicals would have accumulated during use (primary deposition). For this reason, the soil chemistry was an excellent method for testing primary archaeological contexts, especially in the absence of primary deposits of artifacts on floor surfaces.

In the end, these soil chemical data inspire many more questions and provide a baseline framework within which to interrogate other lines of evidence. Rather than merely "confirming" that which is already obvious from excavation (see Bethell and Maté, 1989), these data help us to marshal support for particular interpretations or help eliminate alternative scenarios. The soil chemical data at Río Viejo tell us much more than we would have otherwise known about the use of domestic space and households, since they help us to reconstruct the movements of people, identify locations that were more or less heavily used for certain kinds of activities, and think about how people—and households—were connected to one another and to the community.

## Acknowledgments

The work herein was completed as part of the Río Viejo Residence Project in 2000, which operated under the permit granted to Arthur Joyce by the Consejo of Arqueología at Instituto Nacional de Antropología e Historia (INAH) in Mexico City and the Centro INAH Oaxaca. The Foundation for the Advancement of Mesoamerican Studies, Inc. (FAMSI) funded the residential excavations in a grant to Arthur Joyce and myself (#99012). A National Science Foundation Doctoral Dissertation Improvement Grant (#0122226) and a University of Wisconsin Madison Laboratory for Archaeological Chemistry Research Award Grant funded the sediment sample processing and soil chemistry analysis. I would like to thank James Burton for his generosity with his time and knowledge during my stay in Madison in 2001. I would also like to thank Paul Jamison for advice on the statistics. This manuscript benefited from comments from numerous colleagues over the last few years, including Christine Hastorf, Rosemary Joyce, Harvey Doner, Raymond Mueller, Laura Scheiber, as well as several graduate students at Indiana University. As always, errors contained within are my own.

## Appendix. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jas.2007.08.010.

## References

Alexander, R.T., 1999. Mesoamerican house lots and archaeological site structure: problems of inference in Yaxcaba, Yucatan, Mexico, 1750–1847. In: Allison, P.M. (Ed.), The Archaeological of Household Activities. Routledge, London, pp. 78–100.

Allen, R., Hamroush, H., 1984. The application of geochemical techniques to the investigation of two Predynastic sites in Egypt. In: Lambert, J.B. (Ed.), Archaeological Chemistry – III. Advances in Chemistry Series, 205. American Chemical Society, Washington, DC, pp. 51–65.

Allison, P.M. (Ed.), 1999. The Archaeology of Household Activities. Routledge, New York.

Arrhenius, O., 1963. Investigation of soil from old Indian sites. Ethnos 2-4, 122–136.

Ball, J.W., Kelsay, R.G., 1992. Prehistoric intrasettlement land use and residual soil phosphate levels in the Upper Belize Valley, Central America. In: Killion, T.W. (Ed.), Gardens of Prehistory: The Archaeology of Settlement Agriculture in Greater Mesoamerica. University of Alabama Press, Tuscaloosa, AL, pp. 234–262.

Barba, L., 1986. La química en el estudio de areas de actividad. In: Manzanilla, L. (Ed.), Unidades Habitacionales Mesoamericanas y Sus

Areas de Actividad. Universidad Nacional Autonoma de México, Mexico, pp. 21–39.

Barba, L., Bello, G., 1978. Análisis de fosfatos en el piso de una casa habitada actualmente. Notas Antropológicas I 24, 188–193.

Barba, L., Manzanilla, L., 1987a. Estudio de areas de actividad. In: Manzanilla, L. (Ed.), Cobá, Quintana Roo: Análisis de dos Unidades Habitacionales Mayas. Universidad Autónoma de México, México, pp. 69–115.

Barba, L., Manzanilla, L., 1987b. Superficie/excavación, un ensayo de predicción de rasgos arqueológicos en Oztoyohualco. Antropologicas 1, 19–46.

Barba, L., Ortiz, A., 1992. Análisis químico de pisos de ocupación: un caso etnográfico in Tlaxcala, México. Latin American Antiquity 3, 63–82.

Bethell, P.H., Maté, I., 1989. The use of soil phosphate analysis in archaeology: a critique. In: Henderson, J. (Ed.), Scientific Analysis in Archaeology and its Interpretation. Monograph No. 19. Oxford University Committee for Archaeology, Oxford, pp. 1–29.

Bethell, P.H., Smith, J.U., 1989. Trace-element analysis of an inhumation from Sutton Hoo, using inductively coupled plasma emission spectrometry: an evaluation of the technique applied to analysis of organic residues. Journal of Archaeological Science 16, 47–55.

Brumfiel, E.M., 1991. Weaving and cooking: woman's production in Aztec Mexico. In: Gero, J.M., Conkey, M.W. (Eds.), Engendering Archaeology: Women and Prehistory. Basil Blackwell, Oxford, pp. 224–251.

Burton, J.H., Price, T.D., 1990. The ratio of barium to strontium as a paleodietary indicator of consumption of marine resources. Journal of Archeological Science 17, 547–557.

Cameron, C.M., Tomka, S.A. (Eds.), 1993. Abandonment of Settlements and Regions: Ethnoarchaeological and Archaeological Approaches. Cambridge University Press, Cambridge, UK.

Carr, C., 1984. The nature of organization of intrasite archaeological record and spatial analytic approaches to their investigation. Advances in Archaeological Method and Theory 7, 103–222.

Carsten, J., 1995. The substance of kinship and the heat of the hearth: feeding, personhood, and relatedness among Malays in Pulau Langkawi. American Ethnologist 22, 223–241.

Carsten, J., Hugh-Jones, S. (Eds.), 1995. About the House: Lévi-Strauss and Beyond. Cambridge University Press, Cambridge, UK.

Cook, D.E., Kovacevich, B., Beach, T., Bishop, R., 2006. Deciphering the inorganic chemical record of ancient human activity using ICP-MS: a reconnaissance study of late classic soil floors at Cancuén, Guatemala. Journal of Archaeological Science 33, 628–640.

Cook, S.F., Heizer, R.F., 1965. Studies on the chemical analysis of archeological sites. In: University of California Publications in Anthropology, Volume 2. University of California Press, Berkeley, CA.

De Miguel, E., Grado, M.J.d, Llamas, J.F., Martín-Dorado, A., Mazadiego, L.F., 1998. The overlooked contribution of compost application to the trace element load in the urban soil of Madrid (Spain). The Science of the Total Environment 215, 113–122.

Diehl, M.W., 1998. The interpretation of archaeological floor assemblages: a case study from the American Southwest. American Antiquity 63, 617–634.

Dormaar, J.F., Beaudoin, A.B., 1991. Application of soil chemistry to interpret cultural events at the Calderwood Buffalo Jump (DkPj-27), Southern Alberta, Canada. Geoarchaeology 6, 85–98.

Dunnell, R.C., Stein, J.K., 1989. Theoretical issues in the interpretation of microartifacts. Geoarchaeology 4, 31–42.

Dunning, N.P., Beach, T., 1994. Soil erosion, slope management, and ancient terracing in the Maya Lowlands. Latin American Antiquity 5, 51–69.

Dunning, N.P., Beach, T., Rue, D., 1997. The paleoecology and ancient settlement of the Petexbatun Region, Guatemala. Ancient Mesoamerica 8, 255–266.

Dunning, N.P., Rue, D., Beach, T., Covich, A., Traverse, A., 1998. Human-environment interactions in a tropical watershed: the paleoecology of Laguna Tamarindito, El Petén, Guatemala. Journal of Field Archaeology 25, 139–151.

Eidt, R.C., 1977. Detection and examination of anthrosols by phosphate analysis. Science 197, 1327–1333.

Eidt, R.C., 1985. Theoretical and practical considerations in the analysis of anthrosols. In: Rapp Jr., G., Gifford, J.A. (Eds.), Archaeological Geology. Yale University Press, New Haven, CT, pp. 155–190.

Entwistle, J.A., Abrahams, P.W., Dodgshon, R.A., 1998. Multi-element analysis of soils from Scottish historical sites. Interpreting land-use history through the physical and geochemical analysis of soil. Journal of Archaeological Science 25, 54–68.

Entwistle, J.A., Abrahams, P.W., Dodgshon, R.A., 2000. The geoarchaeological significance and spatial variability of a range of physical and chemical soil properties from former habitation site, Isle of Skye. Journal of Archaeological Science 27, 287–303.

Evans-Pritchard, E.E., 1940. The Nuer: a Description of the Modes of Livelihood and Political Institutions of a Nilotic People. Oxford University Press, Oxford, UK.

Farswan, Y.S., Nautiyal, V., 1997. Investigation of phosphorus enrichment in the burial soil of Kumaun, mid-central Himalaya, India. Journal of Archaeological Science 24, 251–258.

Feinman, G.M., Nicholas, L.M., 2000. High-intensity household-scale production in ancient Mesoamerica: a perspective from Ejutla, Oaxaca. In: Feinman, G.M., Manzanilla, L. (Eds.), Cultural Evolution: Contemporary Viewpoints. Kluwer Academic/Plenum Publishers, New York, pp. 119–142.

Flannery, K.V., Winter, M., 1976. Analyzing household activities. In: Flannery, K.V. (Ed.), The Early Mesoamerican Village. Academic Press, New York, pp. 34–45.

Goffer, Z., Molcho, M., Beit-Arieh, I., 1983. The disposal of wastes in ancient Beer-Sheba. Journal of Field Archaeology 10, 231–235.

Grantham, B., 1995. Dinner in Buqata: the symbolic nature of food animals and meal sharing in a Druze village. In: Ryan, K., Crabtree, P.J. (Eds.), The Symbolic Role of Animals in Archaeology, MASCA Research Papers in Science and Archaeology. MASCA. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia, PA, pp. 73–78.

Hayden, B., Cannon, A., 1982. The corporate group as an archaeological unit. Journal of Anthropological Archaeology 1, 132–158.

Hayden, B., Cannon, A., 1983. Where the garbage goes: refuse disposal in the Maya Highlands. Anthropological Archaeology 2, 117–163.

Healy, P.F., Lambert, J.D.H., Anderson, J.T., Hebda, R.J., 1983. Caracol, Belize: evidence of ancient Maya agricultural terraces. Journal of Field Archaeology 10, 397–410.

Hegmon, M., Ortman, S.G., Mobley-Tanaka, J.L., 2000. Women, men, and the organization of space. In: Crown, P. (Ed.), Women and Men in the Prehispanic Southwest. School of American Research Press, Santa Fe, NM, pp. 43–90.

Heidenreich, C.E., Konrad, V.A., 1973. Soil analysis at the Robitaille site, Part II: a method useful in determining the location of longhouse patterns. Ontario Archaeology 20, 33–62.

Hendon, J.A., 1996. Archaeological approaches to the organization of domestic labor. Annual Review of Anthropology 25, 45–61.

Herz, N., Garrison, E.G., 1998. Geological Methods for Archaeology. Oxford University Press, New York.

Hill, J., 1970. Broken K Pueblo: Prehistoric Social Organization in the American Southwest. Anthropological Papers of the University of Arizona, No. 18. University of Arizona Press, Tucson, AZ.

Hurley, W.M., Heidenreich, C.E., 1971. Palaeoecology and Ontario Prehistory. Department of Anthropology, University of Toronto, Research Report No.2.

Hutson, S.R., Terry, R.E., 2006. Recovering social and cultural dynamics from plaster floors: chemical analyses at ancient Chunchucmil, Yucatan, Mexico. Journal of Archaeological Science 33, 391–404.

Janowski, M., 1995. The hearth-group, the conjugal couple and the symbolism of the rice meal among the Kelabit of Sarawak. In: Carsten, J., Hugh-Jones, S. (Eds.), About the House: Lévi-Strauss and Beyond. Cambridge University Press, Cambridge, UK, pp. 84–104.

Jenkins, D.A., 1994. Interpretation of interglacial cave sediments from a hominid site in North Wales: translocation of Ca-Fe-phosphates. In: Ringrose-Voase, A.J., Humphreys, G.S. (Eds.), Soil Micromorphology: Studies in Management and Genesis. Developments in Soil Science, 22. Elsevier, Amsterdam, pp. 293–305.

Joyce, A.A., 1994. Late formative community organization and social complexity on the Oaxaca coast. Journal of Field Archaeology 21, 147–168.

Joyce, A.A., Bustamante, L.A., Levine, M.N., 2001. Commoner power: a case study from the classic period collapse on the Oaxaca coast. Journal of Archaeological Method and Theory 8, 343–385.

Joyce, A.A., King, S.M., 2001. Household Archaeology in Coastal Oaxaca, México. Report on file with the Foundation for the Advancement of Mesoamerican Studies, Inc.

Joyce, R.A., 1999. Social dimensions of pre-classic burials. In: Grove, D.C., Joyce, R.A. (Eds.), Social Patterns in Pre-Classic Mesoamerica. Dumbarton Oaks, Washington, DC, pp. 15–48.

Joyce, R.A., Gillespie, S.D. (Eds.), 2000. Beyond Kinship: Social and Material Reproduction in House Societies. University of Pennsylvania Press, Philadelphia, PA.

Kent, S., 1984. Analyzing Activity Areas: An Ethnoarchaeological Study of the Use of Space. University of New Mexico Press, Albuquerque, NM.

Kent, S. (Ed.), 1987. Method and Theory for Activity Area Research: An Ethnoarchaeological Approach. Columbia University Press, New York.

Kent, S., 1990. Activity areas and architecture: an interdisciplinary view of the relationship between the use of space and domestic built environments. In: Kent, S. (Ed.), Domestic Architecture and the Use of Space: an Interdisciplinary Cross-cultural Study. Cambridge University Press, Cambridge, UK, pp. 1–8.

Kerr, J.P., 1995. Phosphate imprinting within Mound A at the Huntsville site. In: Collins, M.E., Carter, B.J., Gladfelter, B.G., Southard, R.J. (Eds.), Pedological Perspectives in Archaeological Research, SSSA Special Publication Number 44. Soil Science Society of America, Madison, WI, pp. 133–149.

Killion, T.W., 1992. Residential ethnoarchaeology and ancient site structure: contemporary farming and prehistoric settlement agriculture at Matacapan, Veracruz, Mexico. In: Killion, T.W. (Ed.), Gardens of Prehistory: The Archaeology of Settlement Agriculture in Greater Mesoamerica. University of Alabama Press, Tuscaloosa, AL, pp. 119–149.

King, S.M., 2003. Social Practices and Social Organization in Ancient Coastal Oaxacan Households. PhD dissertation, University of California, Berkeley. University Microfilms, Ann Arbor, CA.

King, S.M., 2005. Cloth production as gendered social practice in coastal Oaxaca, in: Midwest Conference on Mesoamerican Archaeology and Ethnohistory 2005. Bloomington, IN.

King, S.M., 2007. Interregional networks of the Oaxacan early postclassic: connecting the coast and the highlands. In: Blomster, J. (Ed.), After Monte Albán: Transformation and Negotiation in Late Classic/Postclassic Oaxaca, Mexico. University Press of Colorado, Boulder, CO.

Knudson, K.J., Frink, L., Hoffman, B.W., Price, T.D., 2004. Chemical characterization of Arctic soils: activity area analysis in contemporary Yup'ik fish camps using ICP-AES. Journal of Archaeological Science 31, 443–456.

Konrad, V.A., Bonnichsen, R., Clay, V., 1983. Soil chemical identification of ten thousand years of prehistoric human activity areas at the Munsungun Lake Thoroughfare, Maine. Journal of Archaeological Science 10, 13–28.

Lambert, J.B., Simpson, S.V., Buikstra, J.E., Charles, D.K., 1984. Analysis of soil associated with woodland burials. In: Lambert, J.B. (Ed.), Archaeological Chemistry – III. Advances in Chemistry Series, 205. American Chemical Society, Washington, DC, pp. 97–113.

LaMotta, V.M., Schiffer, M.B., 1999. Formation processes of house floor assemblages. In: Allison, P. (Ed.), The Archaeology of Household Activities. Routledge, New York, pp. 19–29.

Leonardi, G., Miglavacca, M., Nardi, S., 1999. Soil phosphorus analysis as an integrative tool for recognizing buried ancient ploughsoils. Journal of Archaeological Science 26, 343–352.

Lévi-Strauss, C., 1982. The Way of the Masks. University of Washington Press, Seattle, WA.

Lillios, K.T., 1992. Phosphate fractionation of soils at Agroal, Portugal. American Antiquity 57, 495–506.

Linderholm, J., Lundberg, E., 1994. Chemical characterization of various archaeological soil samples using main and trace elements determined by inductively coupled plasma atomic emission spectroscopy. Journal of Archaeological Science 21, 303–314.

Longacre, W., 1968. Some aspects of prehistoric society in East-Central Arizona. In: Binford, L.R., Binford, S.R. (Eds.), New Perspectives in Archaeology. Aldine Publishing Co, Chicago, IL, pp. 89–102.

Lupton, D., 1994. Food, memory and meaning: the symbolic and social nature of food events. Sociological Review 42, 664–685.

Lutz, H.J., 1951. The concentration of certain chemical elements in the soils of Alaskan archaeological sites. American Journal of Science 249, 925–928.

MacPhail, R.I., Cruise, G.M., Allen, M.J., Linderholm, J., Reynolds, P., 2004. Archaeological soil and pollen analysis of experimental floor deposits; with special reference to Butser Ancient Farm, Hampshire, UK. Journal of Archaeological Science 31, 175–191.

Manzanilla, L., 1986. Unidades habitacionales mesoamericanas y sus áreas de actividad, 1a ed.. In: Serie antropológica; Arqueología 76 Universidad Nacional Autónoma de México, México.

Manzanilla, L., Barba, L., 1990. The study of activities in classic households: two case studies from Cobá and Teotihuacán. Ancient Mesoamerica 1, 41–49.

Matthews, W., French, C.A.I., Lawrence, T., Cutler, D.F., Jones, M.K., 1997. Microstratigraphic traces of site formation processes and human activities. World Archaeology 29, 281–308.

Meigs, A.S., 1984. Food, Sex, and Pollution: A New Guinea Religion. Rutgers University Press, New Jersey.

Mejia Pérez Campos, E., Barba Pingarrón, L., 1988. El análisis de fosfatos en la arqueología: historia y perspectivas. Anales de Antropología 25, 127–147.

Meskell, L.M., 1998. An archaeology of social relations in an Egyptian village. Journal of Archaeological Method and Theory 5, 209–243.

Middleton, W.D., 1998. Craft specialization at Ejutla, Oaxaca, Mexico: an archaeometric study of the organization of household craft production. Unpublished PhD dissertation, Department of Anthropology, University of Wisconsin, Madison, WI.

Middleton, W.D., Price, T.D., 1996. Identification of activity areas by multi-element characterization of sediments from modern and archaeological house floors using inductively coupled plasma-atomic emission spectroscopy. Journal of Archaeological Science 23, 673–687.

Monaghan, J., 1995. The Covenants with Earth and Rain: Exchange, Sacrifice, and Revelation in Mixtec Sociality. University of Oklahoma Press, Norman, OK.

Monaghan, J., 1996. The Mesoamerican community as "Great House". Ethnology 35, 181–194.

Moore, H.L., 1992. Households and gender relations: the modelling of the economy. In: Ortiz, S., Lees, S. (Eds.), Understanding Economic Process, Monographs in Economic Anthropology, No. 10. University Press of America, New York, pp. 131–148.

Moore, T.R., Denton, D., 1988. The role of soils in the interpretation of archaeological sites in Northern Quebec. In: Bintliff, J.L., Davidson, D.A., Grant, E.G. (Eds.), Conceptual Issues in Environmental Archaeology. University Press, Edinburgh, pp. 25–37.

Muhs, D.R., Kautz, R.R., MacKinnon, J.J., 1985. Soils and the location of cacao orchards at a Maya site in Western Belize. Journal of Archaeological Science 12, 121–137.

Parnell, J.J., Terry, R.E., Nelson, Z., 2002. Soil chemical analysis applied as an interpretive tool for ancient human activities in Piedras Negras, Guatemala. Journal of Archaeological Science 29, 379–404.

Pollard, A.M., Heron, C., 1996. Archaeological Chemistry. RSC paperbacks. Royal Society of Chemistry. Cambridge, UK.

Proudfoot, B., 1976. The analysis and interpretation of soil phosphorus in archaeological contexts. In: Davidson, D.A., Shackley, M.L. (Eds.), Geoarchaeology: Earth Science and the Past. Westview Press, London, pp. 93–113.

Provan, D.M.J., 1971. Soil phosphate analysis as a tool in archaeology. Norwegian Archaeological Review 4, 37–50.

Reid, J.J., Whittlesey, S.M., 1982. Households at Grasshopper Pueblo. In: Wilk, R.R., Rathje, W.L. (Eds.), Archaeology of the Household: Building a Prehistory of Domestic Life. American Behavioral Scientist, 25, pp. 687–704.

Robin, C., 1998. Where people really live: methods for the identification of household spaces and activities. Paper presented at the 63rd Annual Meeting of the Society of American Archaeology, Seattle, WA.

Robin, C., 2002. Outside of houses: the practices of everyday life at Chan Nòohul, Belize. Journal of Social Archaeology 2, 245–268.

Robin, C., Rothschild, N.A., 2002. Archaeological ethnographies: social dynamics of outdoor space. Journal of Social Archaeology 2, 159–172.

Sánchez, A., Cañabate, M.L., Lizcano, R., 1996. Phosphorus analysis at archaeological sites: an optimization of the method and interpretation of the results. Archaeometry 38, 151–164.

Sarris, A., Galaty, M.L., Yerkes, R.W., Parkinson, W.A., Gyucha, A., Billingsley, D.M., Tate, R., 2004. Geophysical prospection and soil chemistry at the early copper age settlement of Vésztõ-Bikeri, Southeastern Hungary. Journal of Archaeological Science 31, 927–939.

Schiffer, M.B., 1987. Formation Processes of the Archaeological Record. University of New Mexico Press, Albuquerque, NM.

Schortman, E.M., 1989. Interregional interaction in prehistory: the need for a new perspective. American Antiquity 54, 52–65.

Schuldenrein, J., 1995. Geochemistry, phosphate fractionation, and the detection of activity areas at prehistoric North American sites. In: Collins, M.E., Carter, B.J., Gladfelter, B.G., Southardq, R.J. (Eds.), Pedological Perspectives in Archaeological Research, SSSA Special Publication Number 44. Soil Science Society of America, Madison, WI, pp. 107–132.

Sharp, B.L., 1991. Inductively coupled plasma spectrometry. In: Smith, K.A. (Ed.), Soil Analysis: Modern Instrumental Techniques. Marcel Dekker, Inc, New York.

Sjöberg, A., 1976. Phosphate analysis of anthropic soils. Journal of Field Archaeology 3, 447–454.

Smyth, M.P., 1989. Domestic storage behavior in Mesoamerica: an ethnoarchaeological approach. Archaeological Method and Theory 1, 89–138.

Smyth, M.P., 1991. Modern Maya storage behavior: ethnoarchaeological case examples from the Puuc Region of Yucatan. In: University of Pittsburgh Memoirs in Latin American Archaeology. No. 3. University of Pittsburgh Department of Anthropology, Pittsburgh, PA.

Solecki, R.S., 1951. Notes on soil analysis and archaeology. American Antiquity 3, 254–256.

Soltanpour, P.N., Johnson, G.W., Workman, S.M., Jones Jr., J.B., Miller, R.O., 1996. Inductively coupled plasma emission spectrometry and inductively coupled plasma-mass spectrometry. In: Bigham, J.M. (Ed.), Methods of Soil Analysis. Part 3: Chemical Methods, Soil Science Society of America Book Series, No. 5. Soil Science Society of America, Inc., Madison, WI, pp. 91–139.

Spencer, C.S., Redmond, E.M., 1997. Archaeology of the Cañada de Cuicatlán, Oaxaca. In: Anthropological Papers of the American Museum of Natural History, No. 80. American Museum of Natural History, New York.

Stimmell, C.A., Hancock, R.G.V., Davis, A.M., 1984. Chemical analysis of archaeological soil from Yagi Site, Japan. In: Lambert, J.B. (Ed.), Archaeological Chemistry – III. Advances in Chemistry Series, 205. American Chemical Society, Washington, DC, pp. 79–96.

Sullivan, K.A., Kealhofer, L., 2004. Identifying activity areas in archaeological soils from a Colonial Virginia house lot using Phytolith analysis and soil chemistry. Journal of Archaeological Science 31, 1659–1673.

Sutro, L.D., Downing, T.E., 1986. Changes in the uses of Zapotec domestic space. Mexicon 8, 73–76.

Sutro, L.D., Downing, T.E., 1988. A step toward a grammar of space: domestic space use in Zapotec villages. In: Wilk, R.R., Ashmore, W. (Eds.), Household and Community in the Mesoamerican Past. University of New Mexico Press, Albuquerque, NM, pp. 29–50.

Terry, R.E., Fernández, F.G., Parnell, J.J., Inomata, T., 2004. The story in the floors: chemical signatures of ancient and modern Maya Activities at Aguateca, Guatemala. Journal of Archaeological Science 31, 1237–1250.

Terry, R.E., Hardin, P.J., Houston, S.D., Nelson, S.D., Jackson, M.W., Carr, J., Parnell, J., 2000. Quantitative phosphorus measurement: a field test procedure for archaeological site analysis at Piedras Negras, Guatemala. Geoarchaeology 15, 151–166.

Weismantel, M.J., 1988. Food, Gender, and Poverty in the Ecuadorian Andes. University of Pennsylvania Press, Philadelphia, PA.

Wells, E.C., Terry, R.E., Parnell, J.J., Hardin, P.J., Jackson, M.W., Houston, S.D., 2000. Chemical analyses of ancient anthrosols in residential areas at Piedras Negras, Guatemala. Journal of Archaeological Science 27, 449–462.

Wilk, R.R., 1989. Decision making and resource flows within the household: beyond the black box. In: Wilk, R.R. (Ed.), The Household Economy: Reconsidering the Domestic Mode of Production. Westview Press, Boulder, CO, pp. 23–51.

Wilk, R.R., Rathje, W.L. (Eds.), 1982. Archaeology of the Household: Building a Prehistory of Domestic Life. American Behavioral Scientist 25.