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INVESTIGATING ACTIVITY PATTERNS IN PREHISPANIC PLAZAS: WEAK ACID-EXTRACTION ICP–AES ANALYSIS OF ANTHROSOLS AT CLASSIC PERIOD EL COYOTE, NORTHWESTERN HONDURAS

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Weak acid-extraction ICP–AES analysis was performed to obtain multi-elemental characterizations of anthropogenic sediments from plaza spaces that no longer contain artefacts and adjacent trash deposits at the prehispanic site of El Coyote in northwestern Honduras. Multivariate quantitative assessments of the anthrosol chemical data, along with associated inventories of midden materials, are examined to derive signatures for activity areas and refuse dumps that can be linked across portions of the site. The findings of this study permit the reconstruction of activity patterns in the site's main plaza and in its environs. This has important implications for understanding the relationship among ritual practice, craft production and political economy during the Late and Terminal Classic periods, c. AD *600–1000.*

KEYWORDS: HONDURAS, EL COYOTE, CLASSIC PERIOD, ANTHROSOL CHEMISTRY, WEAK ACID EXTRACTION, ICP–AES, SOILS, MIDDENS, PLAZAS, POLITICAL ECONOMY

INTRODUCTION

Recent advances in geoarchaeological research on pedogenesis in cultural settings have demonstrated that soil science has a powerful analytical potential for archaeological investigations concerned with feature prospection, household studies, agricultural practices and a wide range of other topics central to anthropological research. The past decade has witnessed a dramatic increase in the reliance on and development of techniques in the analysis of soil chemistry in particular, which has enhanced greatly the interpretive capabilities of archaeologists working at a range of scales: feature, site and region (e.g., Barba 1990; Bintliff *et al*. 1990; Dormaar and Beaudoin 1991; Ball and Kelsay 1992; Kshirsagar 1996; Sánchez *et al*. 1996; Middleton and Price 1996; Dunning *et al*. 1997; Entwistle *et al*. 1998; Terry *et al*. 2000; Wells *et al*. 2000). In this paper, the explanatory capability of these types of analyses is extended through a multi-elemental characterization by weak-acid extraction ICP–AES of anthropogenic sediments from plaza spaces that no longer contain artefacts and adjacent trash deposits at El Coyote, the prehispanic capital settlement of the lower Cacaulapa River Valley in northwestern Honduras (Fig. 1). Multivariate quantitative assessments of the soil chemical data, along with associated inventories of midden materials, are examined to derive signatures for different classes of activity areas and refuse dumps, which can be linked across portions of the site. The findings of this study permit the reconstruction of activity patterning in El Coyote's main plaza, which can be used to evaluate hypotheses regarding site structure and function during the Late and Terminal Classic periods, *c*. AD 600–1000. More broadly, by studying the chemical behaviour

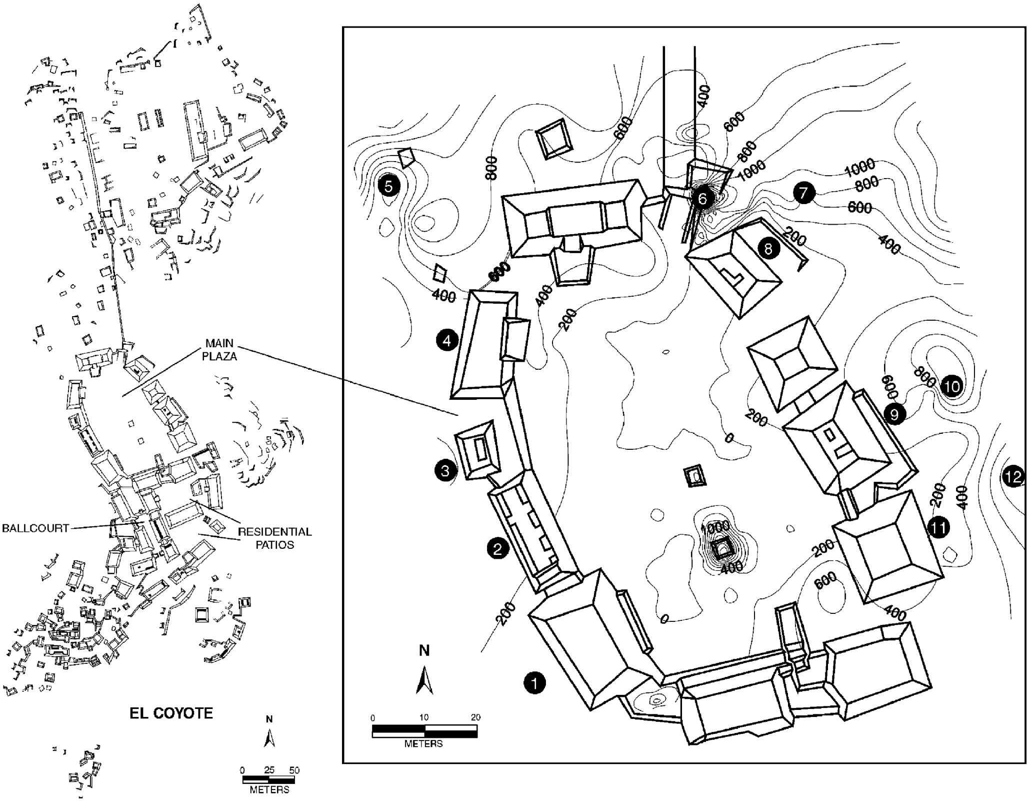

Figure 1 *A plan view of the site of El Coyote, showing the location of the main plaza (redrawn after original inked by P. Urban, 2000–1). The inset on the right-hand side is a kriged contour map of artefact density inside the plaza (kriging type = point, based on a linear variogram model where slope = 1, anisotropy = 1, 0: see Cressie 1990; Kitanidis 1997). The density is expressed as the number of artefacts per cubic metre of excavated soil. The black dots represent midden deposits: 1–4, 'West Middens'; 5, 'NW Midden'; 6, 'NE Midden'; 7–8, 'Lithic Midden'; 9–12, 'East Middens'.*

of anthrosols, the research presented here provides a design for generating inferences about the ranges and locations of activities within archaeological contexts where little or no direct material evidence persists.

THE LOWER CACAULAPA VALLEY AND EL COYOTE

Bounded by steep escarpments of tall sedimentary hills, the lower Cacaulapa River has carved out a narrow passage that links the middle Chamelecon and Ulua Valleys in northwestern Honduras. The two primary geomorphological features that characterize the Cacaulapa Valley are bottomlands composed of alluvium and sedimentary conglomerate and uplands composed of gently sloping alluvial and colluvial fans that overlie limestone bedrock. The northern part of the valley consists of Palaeozoic gneissose mica schists, metamorphosed andesite and tuff (the Minitas Formation), massive limestone (the Atima Formation), and dykes and stocks of granodiorite and andesite intruding into the beds of the Minitas Formation (see UNDP 1974; MMAJ 1979). The southern region is dominated by volcanic layers of andesite, basalt, basaltic pyroclastic rocks and rhyolite (the Matagalpa Formation) that overlie the Minitas and Atima Formations.

Soils in the bottomlands can be characterized as mildly acidic inceptisols (typic ustropept and ustic dystropept) and entisols (typic ustifluvents and mollic ustifluvents) that are silty to sandy loam with good to imperfect drainage, while those of the uplands represent neutral to mildly alkaline mollisols (typic rendolls) that are clayey to sandy or gravely loam with relatively good drainage (for details, see Soil Survey Staff 1975, 1998). In the valley, areas of generally flat to gently sloping (1–5°) terrain are limited to discontinuous segments of remnant and active floodplain and alluvial and colluvial shelves, none of which measure more than 1 km across. Together, these zones compose approximately 7 km^2 of agriculturally productive land. Local informants prize the soils around El Coyote for their fertility (Urban *et al.* 1999, 22), a feature that most probably results from their great depth (over 3 m thick in some areas), generally good drainage and formation from limestone parent materials, which provide high concentrations of available calcium and nitrogen, among other plant nutrients. Yet, while valley soils are generally productive, the paucity and dispersed nature of their distribution probably impeded prehispanic efforts at population nucleation crucial to political centralization within the lower Cacaulapa.

Tropical deciduous forest was probably the natural vegetation type in the valley prior to human occupation, as indicated by remnants of this plant community that are still found in the neighbouring Naco and Ulua Valleys (Smith and Johnson 1945). Today, most bottomland areas have been cleared for *milpa* farming and cattle raising. Tobacco, sugarcane and coffee are the primary cash crops for export. Ethnohistoric sources reveal that *cacao* (chocolate), and possibly cotton, were major export products in the Ulua Valley at the time of the Spanish conquest in the mid-16th century (see Millon 1955; Bergman 1969). Upland areas on either side of the valley are dominated by pine–oak forest, which is exploited presently as a timber source and for coffee production following clearance. Annual precipitation averages approximately 1300 mm, which is generally low compared to other parts of northwestern Honduras but sufficient to support rainfall agriculture (Andrade 1990). In the adjacent Naco Valley, which experiences a similar pattern of precipitation, farmers harvest two maize crops per year on the most fertile soils, without the benefit of irrigation.

The site of El Coyote covers nearly 0.25 km^2 of high terrace land about 150 m west of the lower Cacaulapa River. A recent survey in the valley by Urban, Schortman and their colleagues (1999) has revealed a scattered occupation of 37 sites. These sites range from artefact scatters and clusters of cobble arrangements to aggregations of stone-faced platforms of considerable size, located on limited terrace segments overlooking the Cacaulapa River. Using these data, Urban and Schortman have proposed a three-level hierarchy of sites in the valley based on the sizes of sites. The largest settlement, El Coyote, is delimited by deep, narrow arroyos to the north and south, the steep hillside terrain of Cerro Macutalo on the west and a precipitous descent on the east of roughly 30 m down to the lower floodplain. The site is composed of a monumental core that contains 28 platforms (1–10 m high) arranged around six contiguous plazas (the largest of which, the main plaza, covers approximately 5450 m^2), a ballcourt and as many as 226 other structures.

The focus of the present paper is on work conducted in and around the main plaza, a lime-plastered surface measuring approximately 107 m north to south by 51 m east to west. A number of monumental buildings delimit the plaza, and can be divided into two formal categories: generally square edifices with steep flanks and very restricted summits, located on the eastern side; and rectangular buildings with gradually sloping sides and broader summit areas on the west. Excavations were conducted around these buildings in the environs of the plaza over two three-month field seasons (2000 and 2001), as part of a research project aimed at understanding the range of activities carried out in the plaza and the ways in which plaza activities articulated with the ancient political economy (Wells 2003).

Excavation of the plaza surface consisted of 40 test units, each measuring 2 m × 2 m, arranged in a hexagonal 100 m × 50 m lattice grid. This work yielded fragments of large plainware jars (constituting roughly 80–90% of the ceramic assemblage), some with burned or sooted exteriors and lime deposits on their interiors, large bowls (10–20% of the assemblage), with diameters in excess of 25 cm, and groundstone implements (for grinding corn and seeds), as well as a variety of multifunctional obsidian and chert tools. All of these items were found resting on the plastered surface of the plaza, mostly clustering in the south-east quadrant and around one of the cobble platforms near the centre of the plaza (see Fig. 1). Artefact density was generally low (an average of 58 ceramic sherds per cubic metre of excavated soil, four obsidian fragments per cubic metre and two chert flakes per cubic metre) compared to residential areas at the site, which yielded nearly three to five times as many artefacts per cubic metre of excavated soil. This is not surprising, however, since ethnohistoric reports (e.g., Tozzer 1941; Herrera y Tordesillas 1944) indicate that plazas in this region often were ritually cleaned before and after major events, thereby erasing most of the material residues of plaza activities. Taken together, these materials suggest that the plaza was the locus for the preparation and consumption of food and beverages on a large scale.

Additional investigations situated behind the plaza's component buildings encountered numerous midden deposits, most of which probably contain the material culture employed in plaza activities. Table 1 summarizes the contents of each major trash deposit (more detailed inventories appear in Wells 2003). While the presence of ceramic dishes, grinding implements and faunal remains suggests food production and consumption, most of the materials recovered from the middens indicate other practices, particularly craft manufacture (lithic debris from fashioning stone tools, bark beaters for bark cloth- or paper-making, and mortars and pestles for processing pigments or preparing foods) and ritual activities (incense-burning censers).

Table 1 *A summary of materials recovered from middens around the main plaza*

	Material class								
Deposit	*Ceramic*	*Censer*	*Obsidian**	*Chert**	*Groundstone†*	*NISP vertebrate fauna*	*Total materials*	*Excavation volume‡*	*Material density§*
NE Midden	24 808	201	1 216	251	3	1	26 480	53.2	497.7
NW Midden	12 565	56	4 500	974	43	11	18 149	27.3	665.3
Lithic Midden	1 847	3	4 288	997	1	10	7 146	13.2	541.4
East Middens	11 652	73	4 215	1 004	13	32	16 989	58.6	289.9
West Middens	8 619	55	2 813	657	9	160	12 313	61.5	200.2
Totals	59 491	388	17 032	3 883	69	214	81 077	213.8	379.3

* Includes tools and production debris.

† Includes manos, metates, mortars, pestles and bark beaters.

‡ Reported in cubic metres of excavated soil.

§ Represents the proportion of total materials to excavation volume, as reported in the table.

RECONSTRUCTING ACTIVITY PATTERNS USING SOIL CHEMISTRY

Locating activity areas is crucial to modelling the organization of plaza events at El Coyote and to developing inferences about the relationship between these practices and political development at the site (see Fox 1996; Fash 1998; Wells 2003). While excavations in and around El Coyote's main plaza have been useful for determining the range of materials employed during the activities performed therein, the precise locations of activities remain unknown, since artefact patterns indicate that plaza debris was moved to secondary locations at its margins and, in some cases, probably transported to external middens. In order to develop a better understanding of activity distributions in the plaza, soils were sampled from all excavation contexts and characterized chemically for available phosphates and other anthropogenic compounds, which can implicate chemical residues and their corresponding activity loci.

This line of research is possible because certain chemical compounds are deposited in soils as a result of certain human activities (for a detailed overview, see Hammond 1983; Gurney 1985; Barba 1986; Craddock *et al.* 1986; Bethell and Máté 1989; Barba *et al.* 1995; Sánchez *et al.* 1996; Entwistle *et al.* 2000), such as phosphates with food preparation and consumption (Terry *et al.* 2000), sodium and potassium compounds with the production of wood ash in hearths (Middleton and Price 1996), and iron oxide and mercuric sulphide with the use of pigments in ritual settings (Wells *et al.* 2000). Since these compounds are rapidly fixed to the mineral surfaces of sediment grains, they tend to remain stable and immobile (resistant to horizontal and vertical migration) for very long periods in the form of adsorbed and complexed ions on clay surfaces, and as insoluble oxides, sulphides and carbonates, all of which can be detected with weak acid-extraction or strong acid-digestion procedures and appropriate analytical instrumentation (e.g., Linderholm and Lundberg 1994; Entwistle and Abrahams 1997). In this paper, soils that have been affected by human activities, such as those mentioned above, are referred to as 'anthrosols' or 'anthropogenic sediments' (see Hassan 1978; Stein 1985).

Sampling procedures and analytical methods

At El Coyote, soils were sampled from all excavation contexts inside and outside of the plaza, which resulted in a total of 388 samples (for details, see Wells 2003). In addition, soils were sampled opportunistically between excavation loci at 10 m intervals, yielding an additional 74 samples across the surface of the plaza. These samples were taken from approximately 0.1–0.15 m below the modern ground surface, which is the approximate level of the plaza surface as determined by formal test unit excavations. Also, 21 samples were collected from the lime-plastered playing surface of the ballcourt located to the south-west of the main plaza, as well as 47 samples from the plastered patio surfaces of the two largest elite residential groups at the site, in each case collecting samples at 5 m intervals on a hexagonal lattice grid. Overall, a total of 530 samples were collected and analysed. Soil samples were predominantly soft, compact sandy silts or clays and ranged in colour (moist) from grey (Munsell designation 10YR 4/1–5/1) to dark greyish brown (10YR 3/2–4/2). The mean pH value for all samples was 6.9 ± 0.4 (samples were processed with a commercial soil pH testing kit). For each sample, approximately 0.5 kg was selected from an area of roughly 0.1 m in diameter with a corrosion-resistant, stainless steel sample scoop, which was cleaned with water between sample collections. Samples were placed directly into sterilized polyethylene bags and sealed for transport back to the field laboratory for processing, where they were air-dried and sieved in a 2 mm^2 mesh plastic screen to remove organic debris and clastic materials larger than sand.

Later, samples were transported to the Laboratory for Archaeological Chemistry at the University of Wisconsin–Madison, where they were analysed for phosphorus and other major and minor elements using a weak acid-extraction approach developed by Burton and Simon (1993, 1996) and adapted for soil analysis by Middleton and Price (1996). For this technique, a 0.2 g portion was taken from each sample, pulverized with a Coors porcelain mortar, mixed with 20 ml of 1M HCl in a polyethylene vial, and shaken vigorously for approximately 30 s. For each sample, the resultant solution was then allowed to sit for 14 days at room temperature (approximately 26°C), with intermittent agitation, after which the solution was filtered using ashless filter paper and decanted into clean polyethylene vials. The concentrations of aluminium (Al), barium (Ba), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), phosphorus (P), strontium (Sr), zinc (Zn), manganese (Mn) and titanium (Ti) were determined using an ARL 3520 OES inductively coupled plasma – atomic emission spectrometer (for system specifications, see Routh and Paul 1985; Burton and Simon 1993, table 1). The results were reported in parts per million (ppm) of the element and subsequently converted to base 10 logarithms for comparability, since natural abundances of elements tend not to have normal distributions but to be positively skewed and log-normally distributed (Burton and Simon 1993, 48; see also Ahrens 1965). While this standardization procedure is useful for the analyses and visual displays of the data presented here, it is less useful for describing patterns in terms of elemental concentrations. Therefore, in the discussion that follows, I refer to elemental concentrations using the more intuitive ppm unit of measurement.

The raw chemical data on which this study is based are too numerous to be listed in the present paper, but are presented elsewhere (Wells 2003, appendix III). Summary statistics for the results of the chemical analysis of the anthrosols (in ppm) are presented in Table 2. The table also lists the summary data for 13 off-site standards ('controls') collected from geomorphic points within 1 km of El Coyote that approximate conditions (elevation, slope, aspect,

Table 2 *Summary statistics for soil chemical data*

	Anthrosols (n = 530)					*Off-site controls (n = 13)*				
Element	*Min.*	*Max.*	*μ*	*S*	*CV**	*Min.*	*Max.*	*μ*	*S*	*CV**
Al	1 846.3	24 530.2	13 192.1	3 070.8	23.3	3 993.5	29 297.0	14 839.0	5 737.6	38.7
Ba	22.7	234.0	72.3	16.9	23.4	37.7	130.1	88.8	31.8	35.8
Ca	3 322.6	337 385.0	28 845.6	47 370.4	164.2	1 748.4	21 143.6	9 771.3	4 502.5	46.1
Fe	1 112.3	24 013.0	8 114.4	2 552.6	31.5	5 497.2	17 604.9	10 027.1	4 146.1	41.3
K	104.4	1 619.4	834.1	273.2	32.8	170.9	1 811.8	809.7	507.0	62.6
Mg	1 561.2	11 796.1	5 432.4	1 552.6	28.6	3 128.2	15 319.7	7 551.9	3 089.6	40.9
Na	95.1	2 852.9	264.6	278.3	105.2	163.3	6 158.2	1 081.6	1 632.2	150.9
P	202.0	4 115.8	1 197.4	1 116.4	93.2	173.4	1 783.9	634.5	486.0	76.6
Sr	12.1	327.1	41.3	27.2	66.0	19.4	90.0	56.9	20.4	35.9
Zn	10.0	82.8	51.5	15.4	29.8	29.2	77.1	49.6	15.4	31.0
Mn	139.6	1 119.7	631.7	156.1	24.7	301.9	756.8	583.7	127.2	21.8
Ti	35.8	494.7	160.6	94.0	58.5	39.5	241.6	150.4	54.3	36.1

* The coefficient of variation, calculated by the standard deviation (s) divided by the mean (μ) multiplied by 100.

flora and fauna) found at the site and that are believed to represent prehispanic Classic period strata unaffected by human occupation. That the mean concentration for most elements is less than or equal to the elemental means of the controls may reflect differences in the parent materials of the soils from both sample sets. Many of the anthrosol samples derive from plastered surfaces of the plaza and residential patios, which are naturally high in Ca and low in P, while the controls derive from natural soil surfaces where Ca likely was depleted by weathering and P probably was enriched over time.

In addition to natural variation in Ca and P levels, the compositional differences between anthrosols and controls may reflect a high degree of soil movement at the site, such as was probably involved in the creation of the middens that abut the back sides of the buildings bordering the plaza. Activity areas constantly swept clean of refuse and debris would not always provide an opportunity for compounds to fix to the surfaces of mineral particles in soils. Also, by constantly moving, removing and shifting soils, one possible result is a depletion of some ions in soils, which could explain the particularly low concentrations of some elements in the samples compared to the controls (e.g., Bintliff *et al.* 1990; Entwistle *et al.* 1998). This was probably the case for some mobile cations, such as Na^+, K^+ and Fe^{2+}, which are highly reactive towards oxidizing agents. However, given the mildly acidic nature of El Coyote's soils, oxidation–reduction reactions may not account for the high number of exchangeable cations (Eidt 1985, 162; see also Jeffery 1960). Instead, lower quantities of active cations (especially Na^+) might reflect the degree to which soils at the site experienced leaching as a result of weathering and bioturbation processes (Eidt 1977, 1328; see also Woods 1977).

Chemical characterization of plaza anthrosols

Since some activities, especially those involving organic materials, result in the production and deposition of elemental P and K in the form of compounds that bind to the surfaces of mineral particles in soils, studying the horizontal distribution of the concentrations of different chemical elements is one way to detect activity loci (e.g., Skinner 1986; Cavanagh *et al.* 1988; Lippi 1988; Ortíz Butrón and Barba 1992; Dunning 1993). This approach is particularly useful when the sampling matrix involves plastered or stuccoed surfaces, since it has been demonstrated that these surfacings are highly effective in trapping and preserving chemical residues due to the calcareous nature of constituent sediments (Barba 1990; Manzanilla and Barba 1990; Ortiz Butrón *et al.* 1994). Figure 2 shows the distribution of P standardized by Al (a major component of local soils) for all soils, minus the mean ratio of P to Al for the control samples. By subtracting the control sample P/Al ratios from those of the anthrosols, the relative degree to which soils were enriched by P can be plotted spatially. It should be noted, however, that higher P concentrations do not necessarily correspond to higher intensity or greater longevity of the activity responsible for P deposition, since these characteristics of activities are affected by numerous long-term processes that differentially impact the chemistry of P deposition and retention (see Hammond 1983; Bethell and Máté 1989).

In Fig. 2, the colour black represents areas of highest concentration, generally > 2000 ppm of P. The high concentration of P (5156–11 107 ppm) in the upper right-hand corner of the map corresponds to the large midden (number 6 in Fig. 1) at the base of the monumental staircase that provides formal access to the plaza. Generally, however, the areas of highest P concentration are situated in the middle and at the southern end of the plaza, around the two small platforms, with the highest levels appearing in a linear pattern to the east of the southernmost platform. Together with the information about the presence and distribution of large

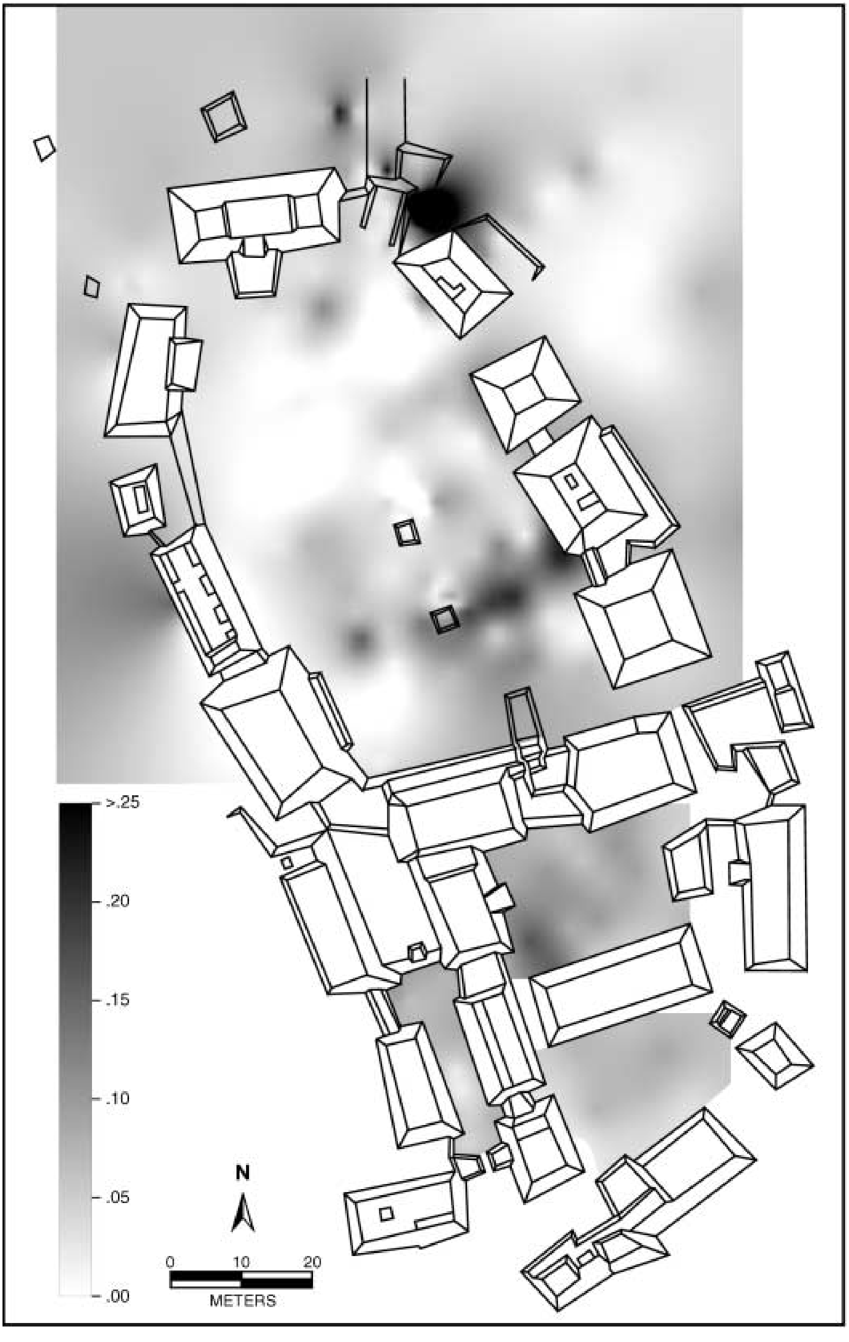

Figure 2 *A kriged image map of extractable soil P from the main plaza at El Coyote (kriging type = point, based on a linear variogram model where slope = 1, anisotropy = 1, 0: see Cressie 1990; Kitanidis 1997). Concentrations are expressed as [$P_{anthrosol}$ (ppm)/$Al_{anthrosol}$ (ppm)] – [$\mu P_{control}$ (ppm)/$\mu Al_{control}$ (ppm)]. The colour white (zero on the scale bar) represents 'natural' levels of P, calculated as $\mu P_{control}$ (ppm)/$\mu Al_{control}$ (ppm), with $n_{control}$ = 13. Darker hues correspond to higher concentrations of P.*

bowls and jars, censers, and grinding and other food processing implements, patterning in elevated levels of P strongly suggests that these buildings were involved in activities related to the preparation and/or consumption of foods and possibly beverages. In contrast, the northern end of the plaza is largely devoid of significant (that is, > 2000 ppm compared to the control mean of 634 ± 486 ppm) P concentrations, suggesting that this area may have been reserved for activities that did not involve organic substances. Alternatively, this pattern could reflect sweeping and cleaning of the northern half of the plaza immediately following consumptive activities, which would have prevented phosphates from fixing to the plaza surface.

The elevated concentrations of P (1320–1823 ppm), compared to adjacent soil P, outside the plaza to the west correspond to midden deposits (numbers 7–12 in Fig. 1). Generally, however, areas outside the plaza appear to lack significantly elevated levels of P, apart from the middens. Such low concentrations stand in sharp contrast to soils inside the plaza, and suggest that areas external to the plaza were not involved significantly with food production and/or consumption, or that these spaces were kept clean of accumulated organic debris. The exceptions are the elite residential patios and the ballcourt to the south of the plaza. Levels of P are generally high among the patios, which is expected given the presumed domestic character of these areas that would have involved food preparation and consumption on a daily basis. That high levels of P also appear in the end zones of the ballcourt, along with a noticeable absence (or very low levels) of P in the central playing alley, is interesting. If the deposition of P in the ballcourt represents evidence for food consumption, then this finding would support prior suggestions that ballcourts in southeastern Mesoamerica served as stages for ritual feasts (e.g., Fox 1996).

In addition to P, the distributions of K and Ca also are useful for locating plaza activities. Based on ethnographic information from studies among the contemporary Lenca who occupy the present-day regions of central and northern Honduras (e.g., Chapman 1985; Castegnaro de Foletti 1989), the presence and distribution, in El Coyote's main plaza, of large jars with lime deposits on their interiors and burning or sooting on their exteriors might constitute evidence for the manufacture of corn-based products, such as *cususa* (a fermented corn drink sweetened with honey or pineapple) and possibly *nixtamal* (corn dough used for making *tortillas*, *tamales* and *atole*). If these products were prepared or consumed in the plaza in significant quantities, as suggested by the elevated levels of P and the high proportions of large jar sherds compared to domestic assemblages at the site, then the patterned distribution of K (contributed to soils by wood ash from cooking) and Ca (contributed by the use of lime in processing corn) in plaza soils should distinguish areas of food preparation from those of consumption, the latter being dominated by high P levels. For example, in their chemical study of contemporary household floors in Oaxaca, Mexico, Middleton and Price (1996, 678) found elevated levels of Ca and a strong positive correlation (Pearson's $r = 0.81$, where $p = 0.05$) between K and P in areas of *nixtamal* production. However, since the plaza floor at El Coyote is composed of crushed limestone and was coated in parts with lime-based plaster, the high concentrations of calcium carbonate ($CaCO_3$) in these surfacings probably mask the distribution of Ca deposited by cooking and food/beverage consumption. Therefore, it is more useful to consider the distribution of K as a proxy for food preparation involving wood burning.

Figure 3 shows the distribution of K standardized by Al, minus the average K/Al ratio of the control samples. High concentrations (generally > 1000 ppm compared to the control mean of 810 ± 507 ppm) appear in black. Similar to the distribution of elevated levels of P, the highest concentrations of K are found in the southern half of the plaza around the central platforms. It is interesting to observe that, in contrast to the distribution of P, there is an absence of elevated

Figure 3 *A kriged image map of extractable soil K from the main plaza at El Coyote (kriging type = point, based on a linear variogram model where slope = 1, anisotropy = 1, 0: see Cressie 1990; Kitanidis 1997). Concentrations are expressed as* $[K_{anthrosol}$ *(ppm)/*$Al_{anthrosol}$ *(ppm)] – [*$\mu K_{control}$ *(ppm)/*$\mu Al_{control}$ *(ppm)]. The colour white (zero on the scale bar) represents 'natural' levels of K, calculated as* $\mu K_{control}$ *(ppm)/*$\mu Al_{control}$ *(ppm), with* $n_{control} = 13$*. Darker hues correspond to higher concentrations of K.*

levels of K immediately encircling the platforms, perhaps indicating that the buildings themselves were reserved for activities other than food preparation, or else they were consistently cleaned of debris. However, this pattern also might be explained by the fact that, since K is more reactive than P in solution, P adsorption may have been inhibited if these spaces were saturated with K. That P and K are not correlated ($r = 0.1$, where $p < 0.05$) supports this idea. Levels of K are also generally high in the residential areas, particularly near the bases of the edges and corners of buildings, which is expected if K marks areas of wood ash deposits (from cooking fires), which would have been allowed to collect in these spaces. Concentrations of K are quite low for the ballcourt, save for the centre of the playing alley, which exhibits an unexpected spike of 780 ppm, perhaps marking the location of incense burning that would have enriched soils with ash deposits.

Chemical characterization of midden anthrosols

Another means of locating activity areas around El Coyote's main plaza is to investigate the possibility that middens containing material residues of certain classes of activities (e.g., craft production, ritual and domestic) have distinct chemical signatures, and that these signatures can be linked to non-midden soils. The basic assumption is that different types of middens form from the deposition of different kinds of materials (only some of which may have survived in the archaeological record) or similar kinds of materials but in different proportions. As a result, these formation processes deposit different combinations of chemical elements in different proportions on to the surfaces of mineral sediments in middens. By extracting the available ions from mineral surfaces and clay interlayers and chemically characterizing them, it may be possible to derive different chemical signatures for each class of midden in areas where soils formed under similar geomorphic conditions. For example, Parnell and colleagues (2001) have demonstrated that extractable soil P in domestic middens at Piedras Negras, Guatemala, has a strong positive correlation ($r = 0.72$, where $p < 0.05$) with ceramic sherd density.

Middens produced from lithic manufacturing activities might be expected to have elevated concentrations of Fe, Ti, Al and K, related to the deposition of phenocrysts and microphenocrysts (i.e., quartz, potassium feldspar, iron oxide, titanium dioxide and ferromagnesian minerals) that compose volcanic glass and some types of cryptocrystalline materials (e.g., Merrick and Brown 1984). Food-production middens should have elevated concentrations of P and Ca, produced from the deposition of faunal bones and other organic remains (e.g., Terry *et al.* 2000), as well as K and Na related to the deposition of wood ash associated with cooking fires (e.g., Middleton and Price 1996). Middens containing ritual paraphernalia might be expected to be the most complex and variable given the variety of potential activities, but may contain elevated concentrations of Fe and Ti (e.g., Wells *et al.* 2000), which reflect the use of hematite (iron oxide, Fe_2O_3) or ilmenite ($FeTiO_3$) and limonite ('ochre' or hydrated ferric oxide, $FeO[OH]$)—mineral-based pigments that witnessed widespread ritual use in prehispanic Mesoamerica (Vázquez N. and Velázquez 1996; Chase and Chase 1998; Fash 2001).

To differentiate chemically among middens surrounding the main plaza with respect to the activities responsible for their formation, I identified two primary compositional groups that derive from soils sampled in the main plaza ($n = 177$) and among the residential patios ($n = 47$) using a principal components analysis conducted on six element concentrations identified for each sample: Ca, Fe, K, Na, P and Ti (the first five principal components account for approximately 97% of the sample variance). These elements were selected for analysis because the deposition of each can be linked, through ethnoarchaeological studies, to specific human activities (e.g., Barba and Bello 1984; Barba and Ortiz Butrón 1992; Barba *et al.* 1995; Middleton and Price 1996; Wells and Urban 2002). While Na has the potential to be a highly mobile ion, especially in contexts of heavy rainfall and good soil drainage (i.e., sandy soils with a high clay percentage), and so may have been leached from the soils that I sampled, the data associated with this element most strongly affect the fifth principal component, which is not utilized in the present analyses. The other element concentrations recorded using ICP–AES (Al, Ba, Mg, Sr, Zn and Mn) have less understood connections to human activities and, as a result, were not included in the present analyses (see Entwistle *et al.* 1998, 2000).

I evaluated the multivariate probabilities that the analysed samples belong to one of the two reference groups using a discriminant analysis, which resolved the data into two primary compositional groups corresponding to their provenance either in the main plaza or among the residential patios. The first two discriminant scores correctly assigned 200 of 224 samples (approximately 90%) according to their provenances. I chose a correlation matrix for the discriminant analysis so as to give equal influence to all variables (element concentrations), as Ca and Fe are major constituents of the sediments' chemistry and potentially could dull the effects of the other elements (K, Na, P and Ti) in the analysis (see Baxter 1994).

Soil samples from all middens and suspected activity areas outside the plaza were characterized chemically. These data, also analysed with principal components analysis, were projected against those of the reference groups to determine whether middens and activity areas could be correlated with plaza or residential spaces. Bivariate plots of some of the principal components (with eigenvectors of the covariance matrix as reference axes) for the sample compositions indicate chemical group distinctions (Fig. 4).

Soils from the midden outside the north-west corner of the plaza ('NW Midden', or number 5 in Fig. 1; $n = 25$), from the middens behind the buildings on the western side of the plaza ('West Middens', or numbers 1–4 in Fig. 1; $n = 13$) and from two adjoining middens from a suspected lithic manufacturing area behind the building on the north-east corner of the plaza ('Lithic Midden', or numbers 7 and 8 in Fig. 1; $n = 4$) all represent the same general class of midden deposit based on their combined soil chemistry ('Group I soils'). Within this group of samples there appears to be some degree of internal differentiation among data sets, however, which may reflect the particular collection of artefacts associated with each midden (see Table 1). The differences among the larger data sets derive, in part, from differences in the concentrations of K and P. Compared to plaza and residential soils, the sampled midden soils have generally lower concentrations of K and P, which suggests that they do not contain the residues of food production (K from wood ash) and consumption (P from organics) in the amounts characteristic of soils from plaza and residential settings. If the sampled middens represent practices that resulted in the deposition of similar kinds of residues, which is suggested by the chemical analysis, then materials unearthed from the NW Midden may be taken to represent the range of activities in the areas encompassed by the sampled middens. Since the NW Midden contains ample evidence for craft production activities, it may have been the case that such activities were performed outside the plaza in these locales. This is an interesting hypothesis that needs to be evaluated further with additional excavation in the area.

Soils from the midden uncovered at the base of a monumental staircase at the north-east corner of the plaza ('NE Midden', or number 6 in Fig. 1; $n = 6$) and from the edges of the ballcourt's alley ($n = 20$) both represent another class of soil ('Group II soils'), which overlaps directly with the main plaza reference group. This pattern is not surprising, since the main plaza and probably the ballcourt were associated with ritual activities. Two important differences are evident between the Group II soils and the main plaza soils. Group II soils contain

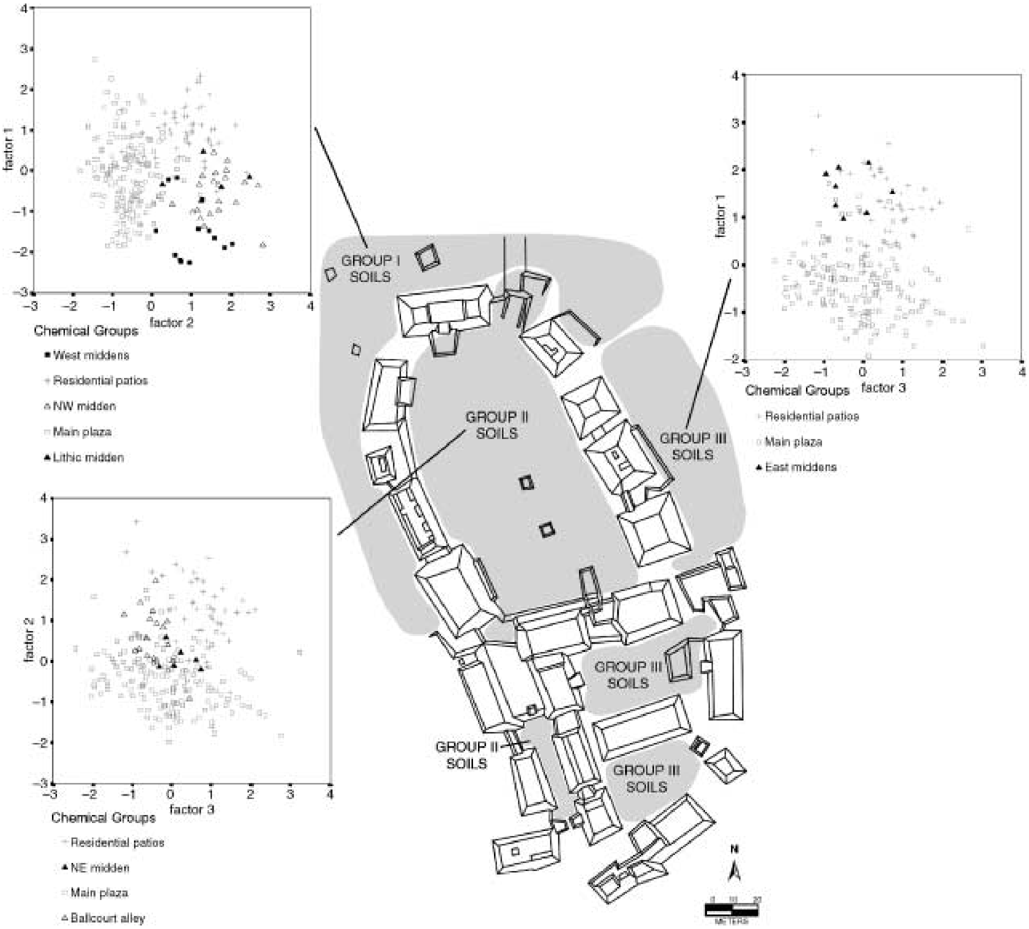

Figure 4 *A map of the distribution of soil chemical groups encompassing the main plaza at El Coyote. The graphs are bivariate plots of the first and third principal components, showing sample data from each soil group projected against the two chemical reference groups (main plaza and residential patios), which indicate chemical group affiliations. Group I soils derive from middens and activity areas associated with craft production. Group II soils are from middens and activity areas created, in part, by ritual behaviour. Group III soils represent middens and activity areas consistent with domestic practices.*

higher concentrations of P, with a mean concentration similar to that of the residential soils, and lower overall concentrations of K. The elevated levels of P are probably related to deposits in the NE Midden, such as high proportions of food waste. The lower levels of K may signal that the NE Midden does not contain significant amounts of wood ash produced from cooking. Nevertheless, since the chemical signature of the NE Midden matches that of the main plaza soils, this midden may contain the remains of activities carried out in the plaza, which include high quantities (compared to other middens investigated near the plaza) of censers and ceramic serving dishes, implicating ritual and feasting. While the same argument cannot be extended confidently to the ballcourt, given its great distance from the NE Midden, the fact that its soils have the same chemical signature suggests at least the possibility that similar activities (incense burning and food consumption) were carried out therein.

Table 3 *Correlation coefficients for artefacts and elemental concentrations in anthrosols*

Material	*Al*	*Ba*	*Ca*	*Fe*	*K*	*Mg*	*Na*	*P*	*Sr*	*Zn*	*Mn*	*Ti*
Ceramic	0.20	0.16	0.44	−0.20	−0.36	0.07	−0.10	**0.62**	0.24	0.33	0.15	−0.37
Obsidian	−0.15	−0.10	−0.52	0.23	0.33	−0.01	−0.28	−0.26	−0.25	0.01	0.07	**0.51**
Chert	−0.14	−0.05	−0.44	0.18	0.08	−0.07	−0.24	−0.25	−0.18	−0.03	0.04	0.38
Groundstone	0.02	−0.09	−0.10	−0.02	**0.69**	0.26	−0.10	0.01	−0.06	0.18	0.20	0.30
Bone	−0.60	−0.27	0.36	−0.57	−0.38	−0.79	**0.61**	−0.23	−0.16	−0.91	−0.80	−0.29
Shell	−0.58	−0.30	0.46	−0.59	−0.43	−0.77	**0.77**	−0.22	−0.15	−0.89	−0.79	−0.34

Note: highlighted values indicate that the correlation is significant at the 0.05 level.

Finally, soils from the middens ('East Middens', or numbers 9–12 in Fig. 1; $n = 8$) on the terraces flanking the buildings on the east side of the plaza map directly on to the reference group representing the residential patios ('Group III soils'). This might be explained by the fact that, on the basis of the artefact assemblages recovered from the middens, numerous activities appear to be represented on the eastern terraces, creating soils in a manner similar to that for residential areas, which also undoubtedly hosted a variety of domestic activities. These practices included at least food preparation and lithic tool manufacture, as suggested by artefact patterning among neighbouring middens and activity areas. Soils from the East Middens have the lowest mean concentration of K among the data sets, perhaps reflecting fewer activities that produced wood ash. Variation in excavation intensity and the small sample size of analysed soils in this area, however, preclude firm conclusions.

Table 3 compares correlation coefficients among chemical elements from soils and densities of artefact classes from the middens studied in this paper. Ceramic density has a strong positive correlation with P ($r = 0.62$) and groundstone density correlates with K ($r = 0.69$), suggesting that P and K are good indicators of food consumption and preparation. Faunal remains (bone and shell) have strong positive correlations with Na ($r = 0.61$ and $r = 0.77$, respectively) and positive, although weaker, correlations with Ca ($r = 0.36$ and $r = 0.46$, respectively), suggesting that elevated levels of Na and Ca in soils may mark locations of food deposition. As discussed previously, however, this signature may be affected strongly by the mobility of Na and the generally high concentrations of Ca in the soil as a result of its creation from limestone parent materials. Finally, obsidian density correlates mildly with Ti ($r = 0.51$), Fe ($r = 0.23$) and K ($r = 0.33$), suggesting that patterning in these elements across space (deposited in soils as constituents of volcanic glass) may reveal areas of lithic tool use and/or lithic manufacture, although the correlations are especially weak for Fe and K.

CONCLUSIONS

Compositional analysis of plaza anthrosols reveals locations of probable activities in El Coyote's main plaza, which include food and/or beverage preparation and consumption as suggested by the artefacts recovered from excavations inside the plaza. Ethnohistoric accounts of plaza events in northern Honduras during the late 16th century by the Spanish historian, Antonio de Herrera y Tordesillas (1944), indicate that feasting was a primary component of chiefly largesse, aimed at attracting labour for agricultural and craft manufacturing work-parties (*composturas*), which continue to serve as effective mechanisms for mobilizing labour among the contemporary Lenca (Chapman 1985). Chemical studies of anthrosols in trash deposits outside the plaza extend the interpretive potential of midden inventories by suggesting behavioural links between the formation of particular middens and specific activity areas. Excavations of middens recovered evidence indicating a variety of craft activities, including lithic tool production (tools and manufacturing debris), animal or hide processing (chert scrapers and large mammal bones, including deer and feline phalanxes), paper-making (bark beaters and ceramic stamps), pigment processing (mortars, pestles, and red and yellow mineral pigments), and possibly ceramic manufacture (a possible workshop and clay extraction pit located nearby).

The combined soil chemical data and midden inventories strongly suggest that the main plaza and its adjacent spaces represent three different suites of behaviour, and that the deposition of refuse generated by those behaviours occurred in close proximity to what may have been their points of origin. Figure 4 shows the distribution of the three primary classes of activity areas around the main plaza. The shaded area encompassing Group I soils and associated trash deposits corresponds to areas that I suspect were used for craft manufacturing activities, given their association with large amounts of lithic tools and debris and soils containing Fe and Ti in higher concentrations than the control samples. The main plaza and the ballcourt, distinguished by Group II soils and adjacent middens, represent areas where ritual activities, including food and beverage consumption, may have been performed. Artefacts unearthed in these spaces include ceramic serving dishes and groundstone implements, along with ceramic braziers and censers (used for burning incense). Compared to the control samples, I found that soils in these spaces have exceptionally high amounts of P, K, Ca and Na—possibly deposited as a result of activities consistent with food preparation and consumption. Finally, Group III soils and artefact concentrations define the region outside the plaza immediately to the east and residential patios to the south of the plaza. These soils appear to have been formed from behaviours associated with domestic activities, such as those evinced by the grinding stones, cooking and serving dishes, and stone tools that I encountered in these spaces.

The study reported here demonstrates that investigation of the soil chemistry of middens and activity areas at archaeological sites, coupled with excavation data on artefact assemblages and their associated formation processes, can yield important information about the intra-site provenance of material culture contained in middens. Exploring the relationship between the chemical signatures of middens and those of activity areas has been particularly useful at El Coyote, because activity residues in the main plaza and adjacent spaces were swept clean in antiquity. Together, the artefact and soil chemical information provide a reservoir of new data that can suggest future research directions for exploring social dynamics at El Coyote. Since soil samples also have been collected from individual midden strata and from stratigraphic layers and resurfacings of the main plaza, it will be possible in future analyses to track temporal, as well as spatial, changes in the organization of plaza activities.

More broadly, the results of this research suggest that, by studying the chemical behaviour of anthrosols, inferences can be made regarding the ranges and locations of activities within archaeological contexts where little or no direct material evidence has survived. While elemental P and K often can be assigned confidently to activities involving food production, consumption and deposition, other major and minor elements and the activities potentially responsible for their deposition need to be explored. Future studies must include ethnoarchaeological investigations (e.g., Barba and Bello 1984; Barba 1990; Barba and Ortiz Butrón 1992; Barba *et al.* 1995; Middleton and Price 1996; Fernández *et al.* 2002; Wells and Urban 2002) with the aim of developing much needed bridging arguments to be able to link observed patterning in the chemical data directly with human behaviour.

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