The Dirt on the Ancient Maya: Soil Chemical Investigations of Ancient Maya Marketplaces

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ABSTRACT

The Dirt on the Ancient Maya: Soil Chemical Investigations of Ancient Maya Marketplaces

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Various criteria or lines of evidence have been used to identify ancient Maya marketplaces, including location near trade routes, artifactual evidence of trade, open space adjacent to transportation routes, proximity to public structures, low platforms and rock alignments to denote market spaces, and regular patterns in soil and floor chemical concentrations. Seibal and Mayapán were important economic Maya polities controlling the trade routes at the apex of their civilizations. The objectives of these studies were to apply geochemical and geospatial analyses of the soils and floors from public plazas and household patios, to discover the anthropogenic chemical residues of phosphorus (P) and heavy metals associated with the trade of foodstuffs and workshop items that may have been marketed there. Public access, causeways, reservoirs and a pattern of high P and metal concentrations are consistent with marketing of organic foodstuffs and workshop items within suspected marketplaces of each site. In contrast, geochemical patterns of the soils and floors of household structures are consistent with ceremonial and household activities.

Keywords: phosphorus, trace metals, geochemical analysis, geoarchaeology
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Chapter 1

ANCIENT MAYA ACTIVITIES AT PUBLIC PLAZAS AND HOUSEHOLD PATIOS AT SEIBAL, GUATEMALA

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Abstract

Various criteria or lines of evidence have been used to identify ancient Maya marketplaces, including location near trade routes, artifactual evidence of trade, open space adjacent to transportation routes, proximity to public structures, low platforms and rock alignments to denote market spaces, and regular patterns in soil and floor chemical concentrations. Seibal was an important economic Maya polity controlling the trade routes along the Rio Pasión. The objectives of the study were to apply geochemical and geospatial analysis of the soils and floors from the Central Plaza in Group A of Seibal, to discover the anthropogenic chemical residues of P and heavy metals associated with the trade of foodstuffs and workshop items that may have been marketed there. Public access, causeways, reservoirs and a pattern of high P and metal concentrations are consistent with marketing of organic foodstuffs and workshop items within the Plaza. In contrast, geochemical patterns of the soils and floors of the East Court and Group C are consistent with ceremonial and household activities.

Keywords: Seibal, Ceibal, Rio Pasión, marketplace, geochemical analysis, activity areas, phosphorus
Introduction

Many ancient Maya sites were slowly abandoned and artifacts were moved or taken from their locus of ancient use either in ancient or modern times. Archaeological interpretation is often difficult when artifacts are displaced or altogether missing. Analysis of ancient human activities at archaeological sites can be facilitated by determination of certain elemental residues that persist in the soils and floors. In the humid tropics, in particular, high decomposition rates result in the complete loss of perishable artifacts, particularly those related to food products (Dahlin et al., 2009). Examination of soil chemical concentrations can elucidate areas where past activities repeated in a given locale would have left byproducts of such activities such as elevated concentrations of phosphorus (P) and other minerals.

Anthropogenic P originates from plant and animal materials gathered for food and brought to settlements for consumption. Phosphorus is a structural component of phospholipids, nucleic acids, nucleotides, coenzymes, and phospho-proteins within living tissues (Sanchez, 2007). As food wastes are disposed, the P constituents released from the organic matter are readily fixed or adsorbed on the surface of soil particles (Barba and Ortiz, 1992; Parnell et al., 2001; Parnell et al., 2002a; Parnell et al., 2002b). These fixed forms of phosphate are highly insoluble and resistant to physical and chemical processes of oxidation, reduction and leaching, remaining stable for centuries (Barba and Ortiz, 1992; Holliday and Gartner, 2007; Parnell et al., 2001; Wells, 2004). As humans concentrate organic matter in specific locations and residues from the organic matter are worked into the soil, P concentrations can increase significantly compared to the natural concentrations of the soil (Holliday and Gartner, 2007; Terry et al., 2004; Wells et al.,
Therefore, P residues in soils are a viable predictor of ancient human activity (Barba et al., 1996; Bethell and Máté, 1989; Middleton and Price, 1996; Terry et al., 2000).

The karst topography of the Maya Lowlands provides an ideal setting for P investigations. Calcium (Ca) is naturally rich in the thin soils surrounding the ancient Maya settlements and is the means for P fixation in these soils. Plaza floors, causeways, and the floors of elite households and buildings were plastered with lime, produced from burned limestone, which is naturally low in P (Barba et al., 1996; Holliday and Gartner, 2007). Activities associated with high soil P concentrations include gardening, food preparation and consumption, waste disposal, animal pens, and sweeping which pushes organic material to the patio peripheries.

Within the last two decades multi-elemental studies of archaeological sites began to emerge as a result of improved analytical methods for the detection of multiple elements using Inductively Coupled Plasma Spectroscopy (ICPAES). Several trace metals were examined in household, workshop, funerary and ritual activities in ethnographic studies and related to similar patterns of these metals found in the soils in ancient archaeological contexts. Elevated concentrations of metals including iron (Fe), copper (Cu), manganese (Mn), mercury (Hg), lead (Pb), and zinc (Zn) were found to originate from various minerals and pigments attributed to ritual, workshop, and painting activities or were present as contaminants of those minerals (Parnell et al., 2002a; Parnell et al., 2002b; Wells et al., 2000). Weathered metallic ions from these minerals and pigments can adsorb or precipitate on clay surfaces, or form insoluble oxides, sulfates, and carbonates that can remain indomitably stable in soils (Lindsay, 1979; Wells et al.,
Examples of metallic bases found in pigments used by the Prehispanic Maya are hematite, ochre, and cinnabar (Goffer, 1980; Smith, 1982; Vázquez Negrete and Velázquez, 1996a; Vázquez Negrete and Velázquez, 1996b). Sheets (2000) reported that each household in the village of Cerén, El Salvador had at least one cylinder of hematite pigment demonstrating the pervasive use of pigments in the ancient Maya culture. Thus, elevated values of trace metals in soils may help to identify areas where pigments were processed or applied and where craft workshops were located.

Geochemical analysis of ancient activity areas in archaeological studies extends back to the early 1930 and 40’s in Europe when Arrhenius (Arrhenius, 1931) and Lorch (Lorch, 1940) reported the relationship between elevated soil phosphate levels and sites of previous human occupation. More recently, Barba, Manzanilla and their colleagues demonstrated that earthen and stucco floors in domestic compounds at the ancient Maya city of Coba in Yucatan and the site of Teotihuacan in Central Mexico trapped chemical compounds derived from specific activities that were repeatedly performed in given locales (Barba and Manzanilla, 1987; Barba et al., 1987; Manzanilla and Barba 1990). Their work along with other geochemical studies have helped identify areas for food preparation and consumption, storage, refuse, sleeping quarters, workshop activities, and for ritual and funerary activities (Barba and Ortiz, 1992; Barba et al., 1995; Fernández et al., 2002; Pierrebourg, 1999; Terry et al., 2000; Wells et al., 2000).

Geochemical analysis of soil phosphate prior to excavation has been used to identify waste middens and other important features (Parnell et al., 2001; Terry et al., 2000). Phosphate and heavy metal analyses of occupational surfaces of both contemporary and ancient households have been successfully used to identify specific
activity areas (Barba et al., 1996; Fernández et al., 2002; Manzanilla and Barba 1990; Parnell et al., 2002a; Parnell et al., 2002b; Terry et al., 2004). Ceremonial, feasting, and marketplace activities in open plazas have recently been identified by chemical analyses of gridded soil samples (Dahlin et al., 2007; Dahlin et al., 2009; Wells, 2004).

**Ancient Market Areas**

The existence of ancient marketplaces have been suggested at several ancient Maya sites, including Tikal, Seibal, and Trinidad de Nosotros in Guatemala and Calakmul, Sayil, and Chunchucmil in Mexico (Coe, 1967; Dahlin et al., 2007; Folan et al., 2001; Jones, 1996; Moriarty, 2004; Ruppert, 1952; Tourtellot, 1988; Wurtzburg, 1991). Various criteria or lines of evidence have been used to identify and classify these marketplaces (Bair and Terry, 2009; Coe, 1967; Dahlin, 2009; Dahlin et al., 2007; Jones, 1996; Tourtellot, 1988; Wurtzburg, 1991). Many of the identifying characteristics are from personal accounts at the time of the conquest by Cortez and other conquistadors (Cortés, 1962; Diaz del Castillo, 1956; Tozzer, 1941), while other attributes are visible in contemporary marketplaces (Cook and Diskin, 1976; Dahlin et al., 2007). Identifiable marketplace attributes include (Dahlin et al., 2007; Dahlin et al., 2009; Wurtzburg, 1991):

1. Location of the urban center along trade routes and artifactual evidence of trade.
2. Designated open space for a marketplace adjacent to transportation arteries.
3. Proximity to public structures (e.g. palace, acropolis, ballcourt or sweatbath structures) and amenities such as water wells or reservoirs.
4. Specific areas for the exchange of different classes of goods and post holes or stone alignments to denote assignment of market spaces or kiosks.

5. Regular patterns in the chemical concentrations of P and metallic ions aligned with pathways (low concentrations), areas of foodstuff distribution (high levels of P), and the marketing of workshop or craft materials (high levels of metal ions).

**Site Description**

Seibal was an important economic and political center for the Petexbatún region controlling the trade routes along the Rio Pасión (Figure 1). The Central Plaza in Group A of Seibal, is about 2.2 ha in size and is bordered on the east by structures, A-53, A-14 (hieroglyphic stairway), A-12, A-9 and temple pyramid A-10, on the north by structures A-52 and a portion of L-shaped structure A-56, on the west by structures A-56, A-57, A-19, A-21 and temple pyramid A-20 and on the south by structures A-7 and A-8 (Figure 2). Tourtellot (1988) reported: “The location of a marketplace has already been suggested for Seibal: the northern part of the Central Plaza in Group A and the North Plaza. Here we find broad open level spaces delimited by long platforms (Bullard and William, 1960) and perhaps filled with market stall platforms, adjacent to a “palace” construction with hieroglyphic stair-wall panels, not far from major temples with an attached ballcourt…This area is probably the most accessible space in its vicinity atop the ridge, with an easy approach up the long and relatively wide ravine… the presence of a marketplace in Group A is explicable by a combination of available space and easier access conjoined with its position as an early demographic and ritual center on an agriculturally productive ridge”.
Several marketplace characteristics, reported by Tourtellot (1988), indicate that the Central Plaza served as an ancient market area. First, Group A is adjacent to transportation arteries with easy access to the river. There are two entry points or gateways from the main transportation pathways to the Central Plaza: one between the west end of structures A-52 and A-56, the other between the north end of structures A-57 and A-56. Second, the Central Plaza contains public ceremonial structures like the temple pyramids A-10 and A-20 and a ballcourt (str. A-19). Third, the northern and eastern ends of the central plaza are enclosed by arcade-like structures (A-52, A-56, and A-57) that may have been used as stalls for the sale of higher prized goods (Tourtellot, 1988). The Central Plaza also contains low platforms like structures A-54 and A-55 and rock alignments that may have marked the location of market stalls or vendor booths (Smith, 1982; Tourtellot, 1988). These rock alignments and other floor platforms were identified during excavations conducted by the Peabody Museum (operations 9A, B and C) and were found in the north, central and south segments of the Central Plaza. Fourth, Seibal had access to both elite and quotidian commodities that could have been traded or sold in the marketplace. Seibal was a tool production or reduction center for obsidian stone tools identified by the high ratio of waste to obsidian tools found within excavations at the site (Tourtellot, 1988). Several manufacturing activities (figurines, textiles, wood and paper, flint-chipping and spindle whorls) in excavated units were also identified based on high frequencies of tools and/or byproducts (Tourtellot, 1988). Agricultural produce would have been available from the suitable farmland surrounding the site while exotic items like jadeite and serpentine were imported from outside the area (Tourtellot, 1988). Last, the Central Plaza had access to water, a frequent amenity to
marketplaces (Dahlin et al., 2007), from several possible nearby reservoirs (Tourtellot, 1988).

Two areas in addition to the Central Plaza in Group A were sampled as control areas in order to differentiate the patterns of extractable chemical concentrations from different plaza types. The East Court Plaza of Group A (Figure 3) is located in front of the royal palace (Str. A-16) and is separated from the Central Plaza by the hieroglyphic stairway (Str. A-14). Its secluded location makes it an improbable location for marketing activities. The palace patio was most likely used for ceremonial and household activities associated with the royal family and therefore serves as a control against the more easily accessed public area of the Central Plaza in Group A.

Samples were also collected from an elite household group at the northern portion of Group C, defined by the south side of Causeway I and the west side of Causeway II (Figure 4). The group includes a palace type structure (C-1) with a cluster of six constructions (C-2 – C-8) that surround a courtyard, a ball court (C-9), a possible viewing structure (C-10), and a large platform at the south end devoid of any superstructures (C-25). The house mounds, patios, platform and ballcourt at the northern end of Group C were of interest as they present a high level of ancient activity due to their central location within the city and easy access from the major causeways.

**Objectives**

Soil geochemical research was performed as part of the 2006 field season at the ancient Maya polity of Seibal to delineate ancient household and plaza activity areas. We looked to gain a better understanding of the ancient Maya activities performed at Seibal
by studying the patterns of soil phosphorus (P) and heavy metals in three areas sampled: the East Court Palace and Central Plaza in Group A, and the house mounds, ballcourt, and platform areas in the northern portion of Group C. The Central Plaza in Group A was of specific interest due to its previous characterization as an ancient marketplace.

The specific objectives were:

1. To apply geochemical analysis of the soils and floors from the Central Plaza in Group A, the suspected marketplace, to discover the anthropogenic chemical residues of P and heavy metals associated with the trade of foodstuffs and workshop items that may have been marketed there.

2. To use the same sampling and geochemical analyses in areas that were not likely to have served as marketplaces. These included the patios surrounding the royal palace East Palace court and an elite household group in the north portion of the Group C.

3. To geospatially analyze chemical residues associated with ancient activities; and

4. To identify elemental concentration patterns by statistical, principal components and regression analysis.

**Methods**

A total of 842 surface samples of plaza floors and soil were collected from three study areas at Seibal. Ten meter grids were set up in the Central Plaza of Group A and in the northern portion of Group C with 362 and 295 samples collected, respectively. Five meter grids were used around the ballcourts in both groups A and C to get a more detailed look at possible feasting activities in association with the ballgame. A two meter
grid was used in the East Court Plaza with 159 samples collected. Leaf litter was removed from the soil surface and surface soil samples (0-15 cm) were collected at each grid intersection. The soil from each location (100-150 grams) was placed in labeled whirl-pak bags. The samples were sent to the Soil and Plant Analysis Laboratory at Brigham Young University, Provo, UT for P and trace metal analysis.

Soil samples were air-dried and sieved (<2 mm) in preparation for extractable P and trace metal analysis. Phosphorus analysis is based on the Mehlich II extraction procedure detailed in Terry et al. (2000). Two grams of each sample were weighed out and placed in one of six 50 ml glass bottles attached to boards allowing for simultaneous analysis of multiple samples. Twenty ml of Mehlich II extraction solution were added to each soil and samples were shaken for 5 min. Solutions were then filtered. One ml or 0.1 ml of filtrate from each sample was extracted and placed each in a glass vial. The extractant was then diluted to 10 ml with distilled water. Contents of a Phosver 3 packet (Hach reagents, Ames, IA) were added to the 10 ml of solution and immediately shaken first for one minute and then left to rest for 4 minutes to allow color development. The Phosver 3 phosphate reagent contains a molybdate complex that binds to phosphate in solution and reduction of the phosphate-molybdate complex by ascorbic acid produces a blue color. The higher the concentration of P the greater the intensity of the blue color produced. Percent transmittance was determined using a DR/850 portable colorimeter at a wavelength of 690 nm. Phosphorus concentrations in the soils and floors (mg/kg) were calculated using a standard curve produced with known P concentrations. A quality control soil was analyzed with each run and the standard deviation of replicate samples was 0.52 mg/kg (n=24).
Samples were analyzed for extractable trace metal concentrations using the DTPA (diethylenetriaminepentaacetic acid) chelate extraction procedure described by Parnell et al. (2002a). Ten grams of soil and 20 ml of DTPA solution (0.005 M, buffered at pH 7.3) were shaken for two hours on a mechanical shaker. Soil solutions were subsequently centrifuged for five min at 5000 rpm and filtered. The concentrations of cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), lead (Pb) and zinc (Zn) were determined from the filtered solutions simultaneously on a Thermo ICPAES (Inductively Coupled Plasma Atomic Emission Spectrometer). A standard solution was used for the calibration of the ICPAES. A quality control soil was analyzed with each run. The highest standard deviation of the elements analyzed of replicate samples was 3.56 mg/kg Fe.

Statistical analysis was performed using NCSS software (Hintze, 2008). Correlation matrices of elemental concentrations were produced to determine similarities among chemical concentrations of different elements within each area sampled. Principal Components Analysis (PCA) was used to group the highly correlated elements into single variables to illustrate the areas of enrichment for multiple chemicals. These highly correlated elements used in the PCA included Cd, Cu, Mn, Pb, and Zn. The elemental concentrations of P, Fe and the factor score of the correlated heavy metals were then geostatistically analyzed with Surfer Software. We used the kriging model and variogram analysis to map concentration isopleths.

The methods used to determine background concentrations have been a question of concern in geochemical studies (King, 2008; Wells, 2004). The ideal would be to have sampled the undisturbed soils or the freshly constructed plaza fill and stucco from which the plaza and patio floors were originally constructed before anthropogenic chemical
enrichments. We did not have access to such samples and natural soil samples are inappropriate controls for constructed fill and stucco; therefore background concentrations of P and metals were determined by averaging the 10% of the lowest in elemental concentrations found among the samples (Dahlin et al., 2007; Fernández et al., 2002; Hutson and Terry, 2006; King, 2008; Parnell et al., 2001; Terry et al., 2004; Wells et al., 2000).

Results and Discussion

Group A - Central Plaza

The elemental concentrations in the Central Plaza separate into three groups covering discrete areas of the plaza indicative of distinct activities. Elevated P levels predominate in the northern portion of the plaza. The average P concentration across Group A including the Central Plaza and the East Palace court were very high (80.7 mg/kg) when compared to the background level for the site (13.7 mg/kg) (Table 1). The P content of the northern portion of the Central plaza reached levels of up to 532 mg/kg, about 39 times the background concentration. The highest readings are found at the most northern portion of the plaza but high levels (average of 100 mg/kg) were present throughout the portion of the plaza north of the ballcourt (Str. A-19) (Figure 5).

Sanchez et al. (1997) reported the elemental analysis of traditional Mesoamerican food stuffs that might have been found in an ancient marketplace. They reported that maize tortillas are ca. 2900 mg P/kg of dry matter and cooked black beans are 4240 mg P/kg. Large amounts of organic matter would have been needed to produce the levels of P found in the Central Plaza floor. For example, the amount of dry corn meal or dry
black beans necessary to increase the P concentration of the plaza floor by 86 mg/kg over
the background levels in the Central Plaza would be 6,500 g of maize/m² or 4,500 g of
beans/m². About 30,400 g of maize/m² or 20,800 g of beans would be required to
produce an increase of 400 mg/kg as seen in northern portions of the Central Plaza.

The P concentrations in the floor of the plaza were exceptionally high and though
the pattern did not appear linear, the entire north end was the apparent center of intense
activity that deposited organic materials. In 2007 several excavation pits dug by
archaeologists to determine construction history confirmed the presence of a Late Classic
plaza floor at a depth of 15 cm but no midden materials were found as a source of the
enriched P (Inomata, personal communication, 2008). This lack of midden material as a
source of P concentrations supports the marketplace hypothesis as the market would have
been swept regularly leaving only chemical residues to identify it. There are no distinct
linear patterns formed by the elevated P concentrations in the plaza floor but the entire
northern portion of the floor is P enriched which might indicate heavy use over a long
lay within the P enriched northern portion of the Central Plaza. The P concentrations and
patterns do not fit ceremonial or feasting activities, sweeping patterns or waste disposal
activities. Phosphorus deposition from ancient trade in foodstuffs is more likely.

A correlation matrix of the extractable element concentrations from the Central
Plaza in Group A is shown in Table 2. The concentrations of Cd, Cu, Mn, Pb, and Zn
were highly correlated and Principal Component Analysis was used to reduce the highly
correlated heavy metals into a single variable, principal component 1 (PC 1). The new
variable, PC 1, of the multiple elements was mapped using Surfer Software over the
Central Plaza highlighting areas of enrichment for the multiple elements (Figure 6). High concentrations of PC 1 were found in the northern portion of the Central Plaza with greater concentrations lining the central area of the plaza just north of the ball court. The highest heavy metal concentrations are located in front of Structure A-57 (Figure 6). Elevated concentrations of these metals have been used to delineate areas where workshop materials and paints were used anciently (Parnell et al., 2002a; Parnell et al., 2002b; Terry et al., 2004; Wells et al., 2000). The patterns of metal concentrations present in the Central Plaza may designate the area where these goods were sold. Excavations from structure A-14 revealed possible storage and processing areas for these goods (Tourtellot, 1988).

In contrast to the enriched P at the north end of the plaza, lower P concentrations and elevated levels of Fe are found at the southern end of the Central Plaza in front of the A-20 and A-10 pyramids (Figure 7). Two possible explanations may account for the enriched soil Fe. The Fe concentrations in the floor of the plaza may have resulted from Fe based paints having eroded from the painted façades of the temple pyramids. All the paint colors (dark red, red, pink, yellow, green, blue and black) used in the decoration of Structure A-3, located just south of Central Plaza, contained some form of Fe oxide (Smith, 1982). It was also noted that red seemed to be by far the most commonly used color on the structure and was produced with anhydrous Fe oxide or hematite (Smith, 1982). It is highly likely that pyramid structures A-20 and A-10 at one time possessed painted façades like structure A-3 and that the Fe concentrations were derived from the weathered paints. The other possibility is that this area was dedicated to ritual ceremonies where the remnants of offerings (i.e. blood) may have increased the soil Fe.
Evidences of offerings are seen in the excavations from the southern half of the Central Plaza where caches of jadeite celts and pottery vessels were recovered with two of the caches containing jadeite “ice-pick-form” bloodletters (Roman et al., 2009; Smith, 1982).

**East Palace Court**

The East Palace Court is located east of the Central Plaza in Group A. We sampled the northern portion of the court, a patio area enclosed by structures A-14, A-15 and A-16 (Figure 2). The area was sampled during the 2006 field season while Takeshi Inomata and colleagues were excavating palace structure A-16. The P concentration isopleths of the exposed excavation are plotted in Figure 8. The highest levels of P (180 mg/kg) in the floors of the East Palace Court complex were behind the Palace structure and are likely the result of waste deposition in a midden off the edge of the platform. Phosphorus levels between 40 and 60 mg/kg were found at the peripheries of the patio in front of structure A-15 and along the larger of the two stairways leading up to the patio. The elevated P concentrations found at the patio edges and low P concentrations at the center of the patios have been attributed to ancient sweeping patterns that transported organic material to plaza or patio peripheries (Parnell et al., 2002a; Terry et al., 2004; Wells, 2004). Deposition of organic residues may have originated from food preparation and consumption. Willey (1990) described the adjacent structure (A-14) as a locus of storage and distribution of mano and metate implements with food preparation and kitchen functions having taken place in or around this complex. Smith (1982) also reports areas of plaster burned in structures A-14a and b that were likely from fires that had been placed on the floor of the building.
Elevated Fe concentrations are found in a quite distinctive pattern from P and the other metals in the East Court. Levels of up to 30 mg/kg are found at the west end of the patio adjacent to structure A-14b (Figure 9). These elevated iron concentrations are likely the result of mineral paints used in ritual ceremonies or in the decoration of structure A-14. Wall stones were recovered from in and around structure A-14a with red stucco. Although no red colored stucco was found in structure A-14b, exposure to weathering may have removed any visible remains leaving chemical byproducts as the only indicator of these paints (Tourtellot, 1988). High concentrations of Fe are also found at the east end of structure A-15 (Figure 9). These concentrations coincide with elevated P levels and may be associated with food processing.

The highest factor scores from the PCA of the heavy metals (Cd, Cu, Mn, Pb, and Zn) are located atop the western stairway and at the southern end of structure A-16 (Figure 10). As opposed to the Central Plaza, there was no significant correlation between P and Zn in the East Palace Court. The elevated metal concentrations are most likely in relation to pigments used in ritual ceremonies (i.e. dedicatory offerings and burials), and the working of craft materials. A cache and burial were discovered in the passageway between structures A-14a and A-14b just to the west of the sampled patio (Smith, 1982). The cache, reported as a dedicatory offering, contained a 3.06 kg jadeite boulder. The burial contained the skeleton of a young adult accompanied by six pottery vessels. Structure A-14 also contained substantial quantities of shell artifacts, and obsidian with Willey suggesting it may have been a place for working obsidian during the late classic (Willey, 1990).
Excavations just east of the edge of the A-16 structure and platform revealed a midden (Inomata personal communication, 2007). The element isopleths of the exposed excavation were plotted (Figures 7, 8, and 9) and demonstrated significantly higher concentrations of P, Fe and metals in the midden than the concentrations from the structures and platform above. These elevated concentrations are likely due to the deposition of waste materials from the activities enacted on the platform.

Regression analysis of the element concentrations of the East Court are shown in Table 3. Phosphorus shows no correlation with Zn, contrary to what is seen in the Central Plaza. The metals of Cd, Cu, Mn, Pb, and Zn show a fairly consistent correlation. Iron is highly negatively correlated with P and shows no correlation with the other metals. The distinct patterns and correlation of elements (P, Fe, and metals) likely reveal specific activities done in the different areas of the plaza.

**Group C**

Relatively high levels of P (up to 197 mg/kg) were found in relation to the patios and household structures of the elite household in Group C that surround the courtyard (Figure 11). These elevated P concentrations can be attributed to household/kitchen waste that is commonly found in areas adjacent to household structures (Fernández et al., 2002; Parnell et al., 2002a; Wells, 2004). Areas of low P concentrations aligned with the two entryways to the courtyard one from the east and the other from the south in between the ballcourt and the open platform. Low P concentrations are also found within the courtyard itself. These P patterns are expected where ancient sweeping activities removed organic matter from pathways and patios and deposited it at the peripheries of
these areas (Parnell et al., 2002a; Terry et al., 2004; Wells, 2004). The playing alley of
the ball court, also low in P, would have been kept free of organic debris in ancient times.
Elevated Fe and metal concentrations are found in the courtyard floor and in association
with a number of buildings (Figures 12 and 13). These areas may have been dedicated to
workshop activities. Although none of the structures surrounding the courtyard have
been excavated, several structures within Group C have been suggested as kitchens and
production areas where wood, paper, obsidian and textile goods may have been
manufactured and processed leaving chemical traces of these past activities (Tourtellot,
1988). Elevated Fe concentrations are also associated with the ballcourt and structure C-
27 which may be due to paints used in the decoration of many of the structures at Seibal.

A large area that includes platform structure C-25 contains very high
centrations of P and Fe, 197 mg/kg and 99 mg/kg respectively, including areas of
elevated metal concentrations (Figures 11, 12, and 13). Several authors have suggested
that elevated P and Fe concentrations may be representative of butchering activities,
although no formal studies of such activities have been conducted. There were no
structures associated with the platform and it is possible that processing of animal meats
was responsible for these elemental concentrations.

Table 4 contains a correlation matrix of the extractable elements from the soils
and floors of Group C. Phosphorus is highly significantly correlated with Cd, Cu, Mn,
and Zn. The relation between P and Zn is possibly related to high levels of food
preparation and consumption associated with the household structures. The metals of Fe,
Mn, Pb, Cu and Zn are significantly correlated. This is likely due to the workshop
activities in the manufacturing and production of goods.
Conclusion

Seibal is located on the Rio Pasión trade route. Several characteristics of Central Plaza in Group A including public access, causeways, reservoirs and a pattern of high P and metal concentrations are consistent with marketing of organic foodstuffs and workshop items. In contrast, the East Court in Group A is a private secluded area that lacks public access. Phosphorus concentrations were low in the patio floor and elevated P concentrations were located behind the palace structure, consistent with household activities. Elevated heavy metals at certain locations in the patio are consistent with ceremonial activities. The soils and floors of Group C exhibited elevated P and metal concentrations at the corners and behind structures. The elemental concentrations within the group are consistent with household and workshop activities. Phosphorus concentrations in the floor of the ballcourts in Central Plaza and Group C were low indicating that the floors were kept free of waste materials. The large public platform (C-25) in Group C has not been excavated and its purpose is unknown but the floor of the platform was very high in P and Fe and may have been involved in marketplace or animal butchering activities.
Acknowledgements

We acknowledge the work of Chris Balzotti, Eric Becker, and Valerie Ward in collecting and analyzing the soil samples. Funding was provided by the Brigham Young University Mentored Environments Program. Thanks go to the Proyecto Arqueologico Ceibal-Petexbatun.
Table 1. The maximum, minimum, and average concentrations of elements extracted from surface soils and plaza floors. The background levels of extractable elements were estimated by averaging the 10 percent of samples lowest in concentration.

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seibal - Group A (Central Plaza and East Court)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>532.6</td>
<td>5.93</td>
<td>66.90</td>
<td>84.18</td>
<td>49.84</td>
</tr>
<tr>
<td>Minimum</td>
<td>5.1</td>
<td>0.64</td>
<td>2.31</td>
<td>3.51</td>
<td>0.80</td>
</tr>
<tr>
<td>Average</td>
<td>80.7</td>
<td>2.14</td>
<td>15.22</td>
<td>28.64</td>
<td>7.37</td>
</tr>
<tr>
<td>Background</td>
<td>13.7</td>
<td>1.08</td>
<td>4.67</td>
<td>10.90</td>
<td>1.65</td>
</tr>
<tr>
<td>Seibal - Group C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
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<td>5.28</td>
<td>99.02</td>
<td>45.08</td>
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<tr>
<td>Minimum</td>
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<tr>
<td>Average</td>
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<td>24.78</td>
<td>19.99</td>
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<td>8.99</td>
<td>9.83</td>
<td>0.84</td>
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Table 2. Pearson correlation (r) matrix of extractable elements from the Central Plaza in Group A of Seibal.

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>-0.033</td>
<td>0.224**</td>
<td>-0.248**</td>
<td>0.038</td>
<td>0.133*</td>
<td>0.187**</td>
</tr>
<tr>
<td>Cd</td>
<td>0.496**</td>
<td>0.234**</td>
<td>0.181**</td>
<td>0.394**</td>
<td>0.136**</td>
<td>0.136**</td>
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<tr>
<td>Cu</td>
<td>0.019</td>
<td>-0.258**</td>
<td>-0.174**</td>
<td>-0.105*</td>
<td>0.561**</td>
<td>0.479**</td>
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<tr>
<td>Fe</td>
<td>0.181**</td>
<td>0.419**</td>
<td>0.594**</td>
<td>0.599**</td>
<td>-0.105*</td>
<td>0.382**</td>
</tr>
<tr>
<td>Mn</td>
<td>0.038</td>
<td>0.133*</td>
<td>0.394**</td>
<td>0.599**</td>
<td>0.479**</td>
<td>0.382**</td>
</tr>
</tbody>
</table>

** Highly significant (<.01)
* Significant (<.05)
n=359

Cronbachs Alpha = -0.019547  Standardized Cronbachs Alpha = 0.640365
Table 3. Pearson correlation (r) matrix of extractable elements from the East Palace Court in Group A of Seibal.

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
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<td>-0.210**</td>
<td>0.126</td>
<td>0.025</td>
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<td>0.211**</td>
<td>0.122</td>
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<tr>
<td>Cu</td>
<td>0.013</td>
<td>0.571**</td>
<td>0.329**</td>
<td>0.604**</td>
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<td></td>
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<tr>
<td>Fe</td>
<td>-0.105</td>
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<tr>
<td>Mn</td>
<td></td>
<td>0.502**</td>
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<tr>
<td>Pb</td>
<td></td>
<td></td>
<td>0.365**</td>
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</table>

** Highly significant (<.01)
* Significant (<.05)
n=159

Cronbachs Alpha = 0.106662  Standardized Cronbachs Alpha = 0.651074
Table 4. Pearson correlation (r) matrix of extractable elements from the northern portion of Group C in Seibal.

<table>
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<th>Fe</th>
<th>Mn</th>
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<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
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<td>0.314**</td>
<td>-0.053</td>
<td>0.236**</td>
<td>-0.068</td>
<td>0.294**</td>
</tr>
<tr>
<td>Cd</td>
<td>0.412**</td>
<td></td>
<td>0.146*</td>
<td>0.287**</td>
<td>0.391**</td>
<td>0.121*</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td>0.276**</td>
<td></td>
<td>0.371**</td>
<td>0.346**</td>
<td>0.428**</td>
</tr>
<tr>
<td>Fe</td>
<td>-0.010</td>
<td></td>
<td></td>
<td>0.126*</td>
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<td>-0.057</td>
</tr>
<tr>
<td>Mn</td>
<td></td>
<td></td>
<td>0.381**</td>
<td></td>
<td>0.385**</td>
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<tr>
<td>Pb</td>
<td></td>
<td></td>
<td></td>
<td>0.326**</td>
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</tr>
</tbody>
</table>

** Highly significant (<.01)
* Significant (<.05)
n=295

Cronbachs Alpha = 0.135131       Standardized Cronbachs Alpha = 0.675102
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Figure 12. The concentration isopleths of extractable Fe in the soils and floors of the northern portion of Group C of Seibal.

Figure 13. Isopleths of the first factor loading from the Principal Components Analysis of extractable metals in the floors of the northern portion of Group C of Seibal.
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Vázquez Negrete J., Velázquez R. (1996b) Caracterización de materiales constitutivos de relieves en estucos, morteros, y pintura mural de la zona arqueológica de Palenque, Chiapas The Pre-Columbian Art Research Institute, San Francisco.


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Chapter 2

GEOCHEMICAL SIGNATURES OF A POSSIBLE POST-CLASSIC MARKETPLACE AT MAYAPÁN, YUCATAN, MEXICO

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Abstract

Recent analyses of the spatial organization of Postclassic Mayapán have drawn attention to a possible marketplace. In Square K, a large rectangular open area contains few domestic structures and could have accommodated large numbers of people or market activities. Soil research and detailed mapping have identified activity areas in the open space in Square K, which is currently in high ground cover. We used geochemical analyses to determine concentrations of phosphorus and heavy metals at this locality. The chemical signatures manifested in the soil from the open space in Square K indicate patterns that would be consistent with the organization of a marketplace, in which different kinds of items are bought and sold in distinct areas of the open space. These data help identify market stalls and walkways and give added support to the hypothesis that this area functioned as the city’s principal marketplace.

Keywords: Maya, Postclassic Mayapán, marketplace, geochemical analysis, activity areas
Introduction

Phosphorus (P) extractions from soil samples have proven to be an effective means in determining ancient activity areas, including food disposal, preparation, and storage (Barba et al., 1996; Bautista, 2001; Dahlin et al., 2007; Fernández et al., 2002; Parnell et al., 2001; Parnell et al., 2002a; Terry et al., 2000). Similarly, heavy metal soil extractions, such as iron (Fe), mercury (Hg), copper (Cu), cadmium (Cd), manganese (Mn), strontium (Sr), and zinc (Zn), have pointed to activity areas involving mineral pigments, paints, and other workshop activities (Dahlin et al., 2007; Parnell et al., 2002a). Soil phosphate (species of P found in natural systems) and heavy metals were measured at domestic mound groups from Piedras Negras, Guatemala, and significant concentration distributions indicated possible areas of food preparation, craft production, and high traffic areas (Parnell et al., 2002a). Similar analysis performed in ancient and modern activity areas at Aguateca, Guatemala, showed high P concentrations associated with food preparation, consumption, and disposal (Terry et al., 2004). An ethnoarchaeological study of chemical residues in the floors of Q’eqchi’ Maya houselots in Las Pozas, Guatemala further confirmed the reliability of geochemical signatures in determining the nature of past activities. High traffic and sweeping areas exhibited low P and heavy metal concentrations while highly concentrated areas were associated with food-related activities (i.e., preparation, consumption, and refuse disposal) and pigment processes, respectively (Fernández et al., 2002).

The Marketplace Hypothesis

Some scholars believe that the Classic Maya lacked well-developed market exchange among all social classes, emphasizing instead that a hierarchal distribution of
goods from the elite down to the lower class was a more likely and pervasive mode of exchange (Smith, 2003). This notion is epitomized by the historian, Nancy Farriss’ comment, “All but a small minority of the Maya, before or after the conquest, were simply outside a market economy with little to sell and little need to buy” (Farriss, 1984). Although many still give greater emphasis to household self-sufficiency and non-market modes of exchange, even in Colonial Period Maya economies, a growing body of evidence points towards a more complex and diversified system of local and regional trade and market distribution of goods and services pervading all social classes throughout the Classic and Postclassic worlds (Dahlin et al., 2007).

Dahlin et al., 2009 summarized lines of evidence for market exchange during the Postclassic and Early Colonial Period (Dahlin et al., 2009). These include ethnohistorical statements at the time of the conquest and Maya vocabulary that infer market exchange. For example Bishop Landa in his Relación states “the occupation to which [the Maya] had the greatest inclination was trade”, and that they traded in low value articles such as salt, fish, cloth and clothing, copal, wax, honey, and flint knives in addition to swords and slaves for cacao, stone beads, feathers, bells, and other objects of metal (Tozzer, 1941). Peter Martyr describes that the canoes seen by Columbus on his first voyage held such household items as utensils, pottery, and wooden objects (Tozzer, 1941). Words from the Maya vocabulary such as k’iwik translate to market, fair, or where one buys or sells while other words like pplom, ah’pplom yoc, ah k’aay, ah chokom konol, ah lotay konol refer to various types of merchants and traders (Barrera Vasquez 1980:405; Wurtzburg 1991:94-97; King and Shaw 2007:6; Roys 1939:31; Tozzer 1941:94). Additional evidences suggest marketplaces in earlier contexts. For example, mural scenes at the
North Plaza at Calakmul, Mexico, dating to the Classic Period contain several images depicting men, women and children, lacking the fine ceremonial dress of royal performance, possibly of a working merchant class, preparing and dispensing foodstuffs and other goods together with those who receive and consume them (Carrasco Vargas et al., 2009). Specific evidences associated with the Postclassic site of Mayapán suggest that common households played a role in the distribution of both utilitarian commodities and market valuables with possible currency systems, production specialists, and marketplaces (Masson et al., 2004; Masson et al., 2007: 213-214). A study of animal use at Postclassic Mayapán suggests that the production and exchange of animal commodities was an integral component of Mayapán’s economy (Masson and Lope, 2008).

Although there are various lines of evidences pointing to Maya market systems, the artifactual evidence for market exchange in perishable goods is lacking (Dahlin et al., 2009). Geochemical analysis has been an important means in determining ancient activity areas in contexts where the artifacts were removed or disturbed in ancient times (Bautista, 2001; Dahlin et al., 2007; Parnell et al., 2001). Soil chemical residues of perishable organic foodstuffs and other goods often remain as mineralized P and trace metals in the soils and floors of ancient areas where they were made, used, and discarded. Soil chemical signatures of ancient activity areas have the advantage that the processes of abandonment normally did not disturb the soil chemical residues of ancient organic and mineral materials (Parnell et al., 2001; Parnell et al., 2002a; Parnell et al., 2002b; Terry et al., 2004). Also advantageous to soil chemical evidence is the knowledge that the data come from that specific activity location, whereas ultimate artifact distributions may be far from their original locations of use (Parnell et al., 2002a). Exotic objects were likely
traded over considerable distances, and it is difficult to determine how many and to what extent these artifacts were traded to or from the locations at which they were found (Hammond, 1982). Thus, assumptions concerning Maya trade are difficult to make when only considering archeological and ethno-historic evidences. However, when coupled with geochemical signatures, Maya trade and economics can be more fully understood. Geochemical evidence from contemporary market plazas has proven an effective means in establishing appropriate comparative geochemical concentrations (Dahlin et al., 2007). This is best demonstrated by high P and Zn concentrations that were measured at food sale and preparation areas of a modern marketplace at Antigua, Guatemala (Dahlin et al., 2007). Virtually the same spatial patterns of low and high soil P concentrations were first replicated in an open plaza with small linear rock alignments reminiscent of market stalls in the center of Chunchucmil, Yucatan, Mexico, which is known to have been an Early Classic specialized trade center (Dahlin and Ardren, 2002; Dahlin et al., 2007). Therefore, it is evident that when soil chemical remains are analyzed within their archaeological contexts - ancient and modern - specific activities can be discriminated.

Regional marketplace characteristics were also found in Sayil, in the western Puuc region: small structural platforms and organized rubble remains located on artificially flattened floors accessible by a long intrasite causeway (Wurtzburg, 1991). Recent studies show that some Postclassic and Classic Period sites contain evidence of ancient Maya market activities, such as the large and formal marketplace structures found in Tikal’s East Plaza (Jones, 1996), Calakmul’s North Plaza (Carrasco Vargas et al., 2009), and Pueblito’s central plaza (Dahlin et al., 2009; Laporte and Chocon, 2008).
Soil geochemistry research was performed as part of the 2003 and 2008 field seasons at Mayapán to delineate ancient activity areas and to gain a better understanding of the extent of household and market activities in the largest and most metropolitan Postclassic Maya city (Peraza Lope et al., 2006). We hypothesized that extractable P and heavy metal concentrations measured from Mayapán soil samples would display distinct distribution patterns that would serve as important lines of evidence in identifying household and workshop activities and ancient marketplace activities at Mayapán. The contrasting patterns of elevated concentrations of these elements in household and open plaza contexts may identify the locations of market stalls and walkways and could give added support to the marketplace hypothesis. The objectives of this study were to apply geochemical techniques to both households groups and to a proposed marketplace in public open space in square K and to contrast the element concentration patterns of middens, ritual shrines, and workshops with concentration patterns found in both the household and public space.

Site Description

Mayapán was the most powerful regional center in Yucatan during the Postclassic period (900-1200 AD), with high population, urbanization, and concentrated political power (Figure 1). The political and domestic economies of Mayapán did not operate solely within the confines of the Maya world, as during this time period, greater external trading ties and interregional economic dependencies have been documented (Masson, 2004). It was one of the most densely occupied sites in ancient Mesoamerica and
Marilyn Masson and her colleagues are examining its urban form, city wall and gates, thoroughfares, open plazas, and network of houses (Hare, 2009).

**Platform Group P-114**

The mound group associated with platform P-114 was investigated by Masson and Peraza in 2001 and 2002. It lies west of the ceremonial center (Figure 2). The group includes houses of varied social status as well as a large platform of unknown function. At first appearance, Group P-114 resembles other domestic structures within Mayapán but excavations revealed some anomalous attributes. Several structures atop the platform do not exhibit regular patterns of interior benches common for the site, leaving open the possibility that these structures may have been used for storage or some other special function, such as commercial exchange (Figure 3) (Masson, 2004). In addition, relatively large quantities of non-local Fine Orange ceramics were found here compared to other areas of the site (Masson, 2004).

**Group Y-45**

Group Y-45 is a high status household (Figure 4) consisting of a large house/meeting hall (Y-45a), a smaller dwelling and hypothesized kitchen room (Y-45b), and an oratory or shrine (Y-45c). The group is located in a remote neighborhood on a high *altillo* (hill or knoll), 135m from the south part of the wall encircling the city (Masson, 2004). The Y-45a residence has two levels of structures. The upper level, atop the *altillo*, is comprised of two long galleries with shorter exterior rooms bordering the ends of the galleries. The lower level, built along the south slope of the *altillo*, consists of four rooms, which were filled with debris upon abandonment. Of the four rooms that
comprise the lower level, rooms 3 and 4 are smaller and squarer than the other two and may have been used for storage (Masson, 2004).

Although, upper status residences like Y-45a are present in many of Mayapán’s neighborhoods, the style and contents of the house are unique in the city and may attest to the affluence of its ancient inhabitants. Excavations at Y-45a yielded an abundant and elaborate group of vessels. Many of the vessels were smashed and appeared to have been destroyed in a ceremonious act of termination when the structure was abandoned (Masson, 2004). Among the unique grouping of vessels was an orange slipped olla vessel with grey paste, unlike any others found at Mayapán. Also of interest, was the significant proportion of projectile points (> 50%) found among the stone tool assemblages at Y-45a suggestive of military and/or hunting activities (Masson, 2004).

The outlying location of the Y-45a elite residence, the abundance and unique collection of ceramics, the high proportion of weapons, and the presence of storage rooms generate questions as to the status and occupation of the residents. Archaeologists have suggested that the residents may have been affluent merchants and/or heads of lineage segments. Could they have held administrative responsibilities such as overseeing production or collecting tribute for barrios, or neighborhoods, of the city? Structure Y-45a has two possible storage rooms that could have been used for the goods traded within the city (Masson, 2004).

Open Space in Square K

A recent survey of the spatial and social organization of Mayapán has drawn attention to Square K, which contains a large open area associated with the site center and the prominent gates of the ancient city (Figure 5). Several evidences suggest that this
open area may have served a significant economic function. First, one of the major avenues of Mayapán passes through the open area of Square K (Figure 5). This avenue runs from Gate D, a principal entrance through the wall encircling the city, to the only interior portal gate to the monumental center. The avenue is lined at its northern end by a low-density of small houses located just east of Temple E-11, one of the major ritual groups of Mayapán. Second, the unpaved open area in Square K, oriented northeast to southwest, is bordered on the east by a concentration of elite/administrative structures. Located just to the south of the open area is Temple R-19b. Pedestrians entering into the city walls through gate D would have turned west toward the portal gate, passing the three most elaborate elite palaces of the city. These eastern palaces are aligned with the portal gate. There is no other such concentration of aligned elite residential and ritual features in any other part of Mayapán. Third, the open space in Square K is the largest and most centrally located public space near the central precinct. Fourth, the open space contains several significant rock alignments oriented either parallel to or perpendicular to the avenues that cross the space. Hare (2009) hypothesized that the open space in Square K may have served as a marketplace and therefore this area was selected for soil sampling and analysis.

Materials and Methods

Two groups, P-114 and Y-45, were selected to study geochemical distributions on floors with the goal of locating domestic or other types of activity areas. Starting at the northeast corner of structure P-116, grids (10 x 10 m) were established over the platforms and household structures and patios associated with platform P-114. The outlying elite
houselot, Group Y-45, was sampled on a 2 x 2 m grid (Figure 4). The public open space within square K was also selected for soil chemical analysis. A 10-meter grid was set up and 282 samples were collected from within the hypothesized marketplace area (Figure 6). Surface (0 to 10 cm) soil samples of 200 to 400 g were collected from the grid intersections. Samples were transported to Brigham Young University for element analysis.

Soil samples were air-dried and sieved (< 2 mm) in preparation for extractable P and extractable trace metal analysis. Phosphorus analysis was based on the Mehlich II extraction procedure (Terry et al., 2000). Soil samples (2 g) were placed in 50 ml jars and treated with 20 ml of Mehlich II solution and shaken for five minutes. Each solution was filtered into clean 50 ml jars. A one-ml aliquot of the solution was diluted to 10 ml with distilled water, a PhosVer 3 powder pillow packet was added and the solution was immediately shaken for one minute. The solutions were allowed to sit for an additional four minutes for color development. The solution forms a blue color with the intensity of the color dependent on the P concentration. Percent transmittance of each solution was determined using a Hach DR 850 colorimeter with the wavelength set at 690 nm. The concentrations were calculated using regression analysis of a standard curve of known P concentrations. A quality control soil was analyzed with each run of 12 samples.

Heavy metal concentrations were extracted, measured, and analyzed using the DTPA (diethylenetriaminepentaacetic acid) chelate extraction procedure detailed in Parnell et al. (2002). Soil samples (10 g) were combined in a 50 ml centrifuge tube with 20 ml of 0.005 M DTPA solution buffered at pH 7.3. The mixture was then shaken for two hours and immediately centrifuged for five minutes. The supernatant was filtered
and analyzed for concentrations of Cd, Cu, Fe, Mn, Pb, Sr and Zn. These concentrations were determined simultaneously on an inductively coupled plasma atomic emission spectrometer (ICP-AES).

Elemental concentration data was geostatistically analyzed and spatially plotted with Surfer Software (Golden, Colorado). We used the Kriging model and variogram analysis to map concentration isopleths. Descriptive statistics and correlation matrices were produced with NCSS software (Kaysville, Utah).

Principal Components Analysis (PCA) was used to identify patterns in the elemental data of P, Cu, Fe, Mn and Zn from each sample point. PCA creates linear combinations of the five elemental variables thereby reducing the data for each sample point to a new relative variable. Areas of increased activity, or high in multiple elements, were grouped using cluster analysis on the new variable produced by PCA. PCA and cluster analysis highlighted areas of moderate and high levels of multiple element enrichment and were compared to the chemical butchering signature obtained from the soils surrounding a butchering post in Telchaquillo, a modern town near Mayapán.

**Results and Discussion**

The background P concentrations of the soils of Mayapán are in the range of 9 to 12 mg/kg. The background level of soil P in Square K was determined by averaging values from 10% of the samples lowest in P concentration. Two additional control soils from ancient pathways through Gate O had similar P concentrations of 9 mg/kg. These background levels of P concentrations are slightly higher than the 7 mg/kg background
reported for the soils of Chunchucmil, Yucatan (Dahlin et al., 2007; Dahlin et al., 2009; Sweetwood et al., 2009).

**Platform Group P-114**

The spatial distribution of Mehlich II extractable P concentrations in the P-114 group is shown in Figure 6. Relative to background P levels, the soil P values of Group P-114 are high across the entire sampled area. The average P concentration in the lowest 10% of the samples in this group is 64 mg/kg. High potsherd density and the presence of dark brown/black midden soils (Masson, personal communication, 2003) throughout this group suggest that cultural activities and the accumulation of trash in ancient times are responsible for elevated P concentrations in these soils. High P levels in excess of 300 mg/kg are found between the south edge of Platform P-114 and the south *albarrada* wall of the lot. High levels of soil P are also found across the adjacent household group east of the platform. These elevated P concentrations indicate high accumulation of organic material possibly from waste disposal, garden or food-processing areas. Note that the densest concentrations of P are located off-structure, and likely identify the richest areas of midden deposition.

Concentrations of DTPA extractable Cu in excess of 4 mg/kg are located just east of the *albarrada* wall separating the household P-114 from the household on the east (Figure 7). These same areas are relatively low in P concentration. Increased concentrations of Fe and Mn in these areas are shown in Figures 8 and 9. High concentrations of these same metals are also seen in the area between the south edge of platform P-114 and the south wall of the houselot. In contrast to the low P concentrations on the west side of the east houselot, the area south of Platform P-114 is also very high in
P. The sources of Cu, Fe and other metal ions in the soils and floors of these two portions of the P-114 group were likely mineral pigments, paints, and other workshop materials that may have been produced, used or disposed at these areas (Parnell et al., 2002a; Wells et al., 2000). The differences in P distribution in these areas suggest different waste disposal behaviors in the adjacent house lots. It is apparent that both workshop and food waste were disposed in the area south of platform P-114. High concentrations of trace metals are located on the west side of the adjacent house lot (Figures 7, 8 and 9) but concentrations of P are relatively low at this same location (Figure 6) suggesting that mostly workshop waste was disposed near the albarrada wall separating the two houselots. These workshop midden zones contain archaeological evidence for craft activities, including higher than average densities of lithic debris and Fine Orange ceramics (Masson, 2004). The combined evidences for special types of debris and chemical signatures in specific zones suggest that economic activities took place at the P-114 group that were different from average domestic production.

Table 1 contains a correlation matrix of the extractable element concentrations from Group P-114. Phosphorus concentrations were significantly correlated with Cu and Fe but the correlation with Zn was highly significant. There was also a highly significant correlation between the metals Cd, Cu, Fe, Mn, and Zn.

**Group Y-45**

Concentrations of extractable P from the household Group Y-45 are shown in Figure 10. Relative differences in P concentrations help us to distinguish possible food processing areas, kitchen middens, or garden areas from other activity areas (Parnell et al., 2001; Terry et al., 2000). Structure Y-45a, shown on the map, was not included in the
sampling because it had already been excavated and consolidated. High P levels were found at the margins of the houselot defined by the albarrada walls indicative of waste disposal at these locations. Elevated P levels in the soil and floor samples associated with structure Y-45b support the hypothesis that the structure served as a kitchen.

Concentrations of P at the Y-45 Group were considerably lower when compared to the P-114 Group described above (Figure 6 and 10). Maximum P concentrations in Group Y-45 are 100 mg/kg while maximum concentrations in the P-114 Group are 300 mg/kg.

Soil concentrations of Cu and Fe in Group Y-45 are shown in Figures 11 and 12, respectively. The elements Mn, Fe, Cu, and Zn were elevated in the samples near or on the ritual structure Y-45c. Elevated heavy metal concentrations at this location suggest ritual use of pigments, paints or workshop activities. Heavy metals were also elevated in samples just east of structure Y-45b suggesting disposal of workshop debris.

Table 2 contains a correlation matrix of the extractable elements from the soils and floors of Group Y-45. Phosphorus is highly correlated with Cu, Fe and Zn. Several of the metals (Cu, Fe, Mn, and Zn) also showed highly significant correlations with each other.

*Open Space in Square K*

Phosphorus concentrations from the open space in Square K at Mayapán range from 20 mg/kg to 230 mg/kg over the entire sample set with the background concentration measuring 12.2 mg/kg P calculated from the lowest 10% of the samples. Previous studies correlated the P concentrations of an ancient site with a modern open-market place, in Chunchucmil, Mexico and Antigua, Guatemala, and showed that the average extractable P concentrations of 63 mg/kg and 77 mg/kg respectively. The
background concentrations were also closely related and ranged between 5 and 7 mg/kg (Dahlin et al., 2007).

Elevated P concentration isopleths are shown in Figure 13. There are roughly parallel linear patterns of very high P concentrations running from northwest to southeast across the square (Figure 13). Another notably high concentrated P area was just southeast of the main structure located near the north entrance. Areas of lower P are found between these alignments. The parallel lines run perpendicular to the two apparent avenues that enter in from the north and are in line with the platforms and other structures surrounding the area. Although the linear patterns of P concentrations intermittent with areas of low concentrations may allude to an ancient market with rows of market stalls and aisles there are a few other factors that need consideration. The shallow soil depths and small depression areas across the open space may have affected the soil P results. We were concerned that the depressions would have accumulated soil P washed from surrounding areas. We found however, that the areas of high P concentration were equally distributed in raised as well as depression areas. The rock alignments observed throughout the site may have actually served as part of marketplace activities. The presence of rock alignments, absence of religious shrines and the distance from ceremonial architecture associated with the central precinct likely rule out P concentrations from feasting activities or metal concentrations from ceremonial worship as was seen in plaza II and plaza III at La Trinidad de Nosotros, Guatemala (Dahlin et al., 2009) and Group II soils at El Coyote, Honduras (Wells, 2004).

The distribution of heavy metal concentrations overlapped in many areas of the open space in square K. Iron was highly concentrated in the lower southwest corner of
the sampled area at 372.4 mg/kg with the next most notable concentration area measuring 148.6 mg/kg, just southeast of the main structure near the upper entrance (Figure 14). The background Fe concentration was measured at 9.4 mg/kg. Most of the central region of the sampled area exhibited very low concentrations of Fe that were consistent with background levels. Similarly, Cu was most concentrated in the lower southwest corner of the plaza measured at 4.5 mg/kg, with another notable area just southeast of the main structure near the upper entrance (2.2 mg/kg) (Figure 15). These high concentrations are at the same location as those of high Fe in Figure 14. The Cu background soil concentration was < 0.5 mg/kg. Copper also had consistently low concentrations throughout the central area of the plaza, which is closely parallel to the Fe concentration data as well. The highest concentration of Mn is located in the lower southwest corner of the plaza (109.9 mg/kg), but more diversified concentrations are found throughout the center of the plaza and the areas surrounding the main structure (Figure 16). The background Mn concentration was 8.5 mg/kg indicating the highest sample concentration almost 13 times greater than the background. All three of these heavy metals exhibited concentration distributions very similar to one another predominantly in two localized areas. The highest concentration of Zn was 16.6 mg/kg at the southern edge, with the background at 1.4 mg/kg (Figure 17).

The correlation matrix of the extractable element concentrations from the open space in square K are found in Table 3. There was a highly significant correlation between P and Zn. This correlation of P with Zn was also found in the soils of a contemporary marketplace in Antigua, Guatemala (Dahlin et al., 2007).
Principal Components Analysis (PCA) was used to reduce the element concentration data of P, Cu, Fe, Mn and Zn from each sample point to identify patterns in the elevated concentrations. Areas of increased ancient activity were high in the multiple elements. Factor 1 of the PCA accounted for 53.7% of the variation in the data. Factor 2 accounted for an additional 25.84% adding to more than 79% of the variation in the dataset. Areas of increased activity, or high in multiple elements, were grouped using cluster analysis on the new variable produced by PCA. Three clusters were produced: areas of high activity (blue square), moderate activity (red squares) and low activity (marked with +) shown in Figures 13-17. One area in the southwest corner of the open space was identified as an area of high activity (blue square, Figures 13-17). The element concentrations of this area were then compared to the chemical butchering signature obtained at Telchaquillo, a modern town near Mayapán. The northwest corner of the central plaza of Telchaquillo contains a butchering post where swine, chickens and other animals are butchered and meat sold. Using discriminant function analysis, the area of high activity from the open space in Square K fell into the same grouping as the butchering signal from the Telchaquillo samples lending to the possibility that this area served the same function.

Conclusions

The chemical analysis of soil samples from Mayapán have indicated activity areas and positive supplemental data in pointing toward Maya markets. The linear P distributions from the upper north east corner to the lower southwest corner of the open space provide evidence of ancient activities. These evidences point to possible rows of
organic goods sold and distributed in a market setting. It is also interesting to note the
greatest patterns of elevated P distribution are located near the edges of the plaza. The
areas that would most likely be high traffic pathways towards the entrance and center of
the sampled region are the areas with the lower P concentrations. Our P and Zn data are
consistent with earlier studies at the marketplace of Antigua, which had a striking
correlation between P and Zn concentration distributions (Dahlin et al., 2007; Fernández
et al., 2002). These studies determined that high P and Zn concentrations correlate with
food preparation, vegetable sale areas, and kitchen areas. Within the open space we can
conclude that food distribution and sales were most concentrated along the southern and
eastern edges of the plaza with possible market rows from the northwest to the south east
corners, perpendicular to the avenues leading into and out of the suspected market area.

The trace metal analysis provided considerable evidence for the localization of Fe,
Cu, and Mn into two predominant locations. Each of these locations, one near the
southwest corner of the marketplace and the other near the entrance at the northeast edge,
indicates two possible sale and distribution locations of pottery, specialized crafts, or
items associated with paints and/or pigments.

The chemical signatures manifested in the soil from the open space in Square K
indicate patterns that would be consistent with the organization of a marketplace, in
which different kinds of items are bought and sold in distinct areas. Although some
evidence suggests merchants and market traders and specialists from all social classes,
many Maya locations have indicated an economic system primarily associated with
strong elite class involvement through gift giving and tribute systems. The geochemical
results from the open space in square K at Mayapán give additional evidence supporting
market exchange of goods among a variety of social classes, which deepen our understanding of a more complex and diversified Maya exchange system. This study when coupled with marketplace studies (Dahlin et al., 2007; Dahlin et al., 2009) from other Maya sites suggests that market exchange was probably characteristic of Maya economies from at least the Early Classic (Chunchucmil) through the Late Classic (Trinidad) to the Postclassic (Mayapán).
Table 1 – Pearson correlation matrix of extractable element concentrations from Group P-114, Mayapán, Yucatan.

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<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Sr</th>
<th>Zn</th>
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<td>0.215*</td>
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<td>0.366**</td>
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<td>Cd</td>
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<td>0.457**</td>
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<tr>
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<td>Fe</td>
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<td>0.295**</td>
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** Highly significant (<.01),

* Significant (<.05)

n=102

Cronbachs Alpha = 0.036839 Standardized Cronbachs Alpha = 0.678176
Table 2 – Pearson correlation matrix of the extractable elements from Group Y-45.

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<th>Sr</th>
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<td>Cu</td>
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<td>Fe</td>
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** Highly significant (<.01)
* Significant (<.05)

n=114

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Table 3 – Pearson correlation matrix of the extractable element concentrations from the open space in square K.

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<th>Mn</th>
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<td>0.386*</td>
<td>0.102</td>
<td>0.021</td>
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** Highly significant (<.01)

* Significant (<.05)

n = 268

Cronbachs Alpha = 0.275964       Standardized Cronbachs Alpha = 0.659438
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