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Chemical Analyses of Ancient Anthrosols in Residential Areas at Piedras Negras, Guatemala

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Recent chemical analyses of ancient anthrosols in Mesoamerica and elsewhere demonstrate the explanatory value of these investigative techniques and also point out some of the problems that challenge interpretive capabilities. This paper presents the results of phosphate and heavy metals analyses of soils in residential areas at Piedras Negras, Guatemala, and offers some preliminary interpretations of the patterns obtained. After a brief review of recent studies of soils in archaeological contexts, we discuss some of the merits and problems with using different sampling designs and with obtaining reference samples that help model distributions of chemical concentrations. To aid in interpreting domestic activities, soil analyses are combined with archaeological data produced from both large-scale clearing and smaller test units. In this way, phosphate concentrations implicate refuse disposal areas, and heavy metal signatures and their patterning suggest that urban Maya houses may have been painted with metal-based mineral pigments. Varying, relative proportions of phosphates and heavy metals in midden deposits indicate the probability of classifying such features according to chemical signatures. We argue that this combined approach offers greater clarity in discerning activity patterns in residential environments than investigations that do not incorporate soil chemical analyses.

Keywords: SOIL CHEMISTRY, PHOSPHATES, HEAVY METALS, LAND-USE, HOUSEHOLDS, MAYA.

Introduction

Phosphate and other chemical analyses of anthrosols, soils that have been chemically modified by human activity, have become powerful analytical tools in the study of prehistoric land-use patterns. Recent applications of these techniques in Mesoamerica, to both ancient (e.g. Ball & Kelsay, 1992; Coultas *et al.*, 1993; Dunning, 1994; Jacob, 1995; Manzanilla & Barba, 1990) and modern (e.g. Barba & Bello, 1978; Barba & Ortiz, 1992) activity areas, not only demonstrate the explanatory value of such methods, but also highlight some of the problems that challenge interpretive capabilities. In this paper we present a brief review of soil chemistry studies in Mesoamerica and elsewhere, drawing attention to some of the problems that confront researchers. We also outline our ongoing work in urban residential zones at the ancient Maya city of Piedras Negras, Guatemala. It would be premature to provide a detailed and exhaustive study of Piedras Negras land-use practices in this publication, as several years of field and laboratory study remain. Instead, our objectives are to provide a general overview of our results to date and to discuss why soil chemistry has been a crucial component of our work in residential areas. After two seasons of work, we are now able to confidently identify midden deposits before excavation by using

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soil phosphate analyses to prospect for domestic activity areas. In addition, our techniques permit us to detect complex patterns of heavy metal concentrations in soils near residential buildings, perhaps residual markers of mineral-based paints that once decorated the facades of these structures.

Chemical Analyses of Ancient Anthrosols

It has long been recognized that concentrations of phosphorous at archaeological sites can be linked with soil enhancement in agricultural areas, refuse disposal in habitation zones, and a variety of other cultural activities (e.g. Dauncey, 1952; Griffith, 1981; Proudfoot, 1976; Sánchez *et al.*, 1996; Solecki, 1951; Weston, 1995; for a detailed overview, see Bethell & Máté, 1989; Craddock *et al.*, 1986; Gurney, 1985; Hammond, 1983; Scudder *et al.*, 1996). The underlying premise is that a number of phosphate compounds are associated with human activities, such as food preparation and consumption, and disposal of food products and fecal materials. Since phosphates are rapidly fixed by naturally occurring compounds in the soil, they tend to remain stable in soils for very long periods. Thus, chemical detection of phosphate concentrations serves to inform archaeologists about aspects of past human behaviors. Methodological advancements (Eidt, 1973, 1977, 1984; Mehlich, 1978; Terry *et al.*, 2000; Woods, 1977) have enabled archaeologists to use phosphate analysis readily in the field at low cost and with minimal labour.

The application of phosphate analysis in archaeology was first developed in Europe, where pioneering efforts by Arrhenius (1931) and Lorch (1940) were followed by work of numerous researchers including Dauncey (1952) and Provan (1973). American archaeologists were relatively slow in applying chemical methods to soil analysis until the influential work of Eidt (1973, 1977). Recent studies demonstrate the applicability of this investigative technique in a diversity of environments. Phosphate analysis, for example, allowed Lippi (1988) to reconstruct excavated stratigraphy, ancient landforms, and human activity areas at the subtropical rainforest site of Nambillo in the Ecuadorian highlands. Cavanagh *et al.* (1988) used the technique on soils obtained from alluvial bottomland sites in the Eurotas river drainage in Greece to search for site boundaries. Lillios (1992) applied phosphate fractionation analysis in a study of the evolution of land-use practices on soils at Agroal, Portugal. In Mesoamerica, Dunning and colleagues (Dunning, 1993; Dunning *et al.*, 1997, 1998) have investigated the paleoecology of the Petexbatún region in the Petén jungle lowlands in Guatemala using phosphate fractionation, among other techniques. The correlation between residual soil phosphate levels and intrasite land-use was the focus of a study by Ball & Kelsay (1992) at sites on upper alluvial terraces above the Mopan River in west central Belize. Also in Belize, Coultas *et al.* (1993; cf. Healy *et al.*, 1983) explored the effects of terracing employed to impede soil erosion on the quality of soils, as implicated by phosphate concentrations, near the tropical lowland ancient Maya city of Caracol. The diversity of these studies indicates that phosphate analysis is successfully applicable to soils formed under a wide variety of geological conditions, and subject to a range of erosional and depositional processes. Soil phosphate testing in the Maya region is particularly promising given the highly calcareous nature of soils derived from the limestone parent materials underlying much of the peninsula, as phosphate reacts with calcium to form insoluble minerals in the soil (Sample *et al.* 1980).

Although the detection and interpretation of heavy metals in soils associated with ancient habitations has been far more limited than phosphate analysis, the past decade has witnessed a growing interest in the analysis of these elements, particularly heavy metals such as copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) (e.g. Aston *et al.*, 1998; Bintliff *et al.*, 1990; Entwistle *et al.*, 1998; Lewis *et al.*, 1993; Linderholm & Lundberg, 1994; Lambert *et al.*, 1984). Metals are readily adsorbed or precipitated on the mineral surfaces of calcareous soils. The resultant metallic ions remain stable in alkaline soils for long periods of time in the form of adsorbed and complexed ions on clay surfaces, and as insoluble oxides, sulfides, and carbonates (Lindsay, 1979; Alloway, 1995).

Researchers have utilized a variety of extraction techniques and total metal analysis procedures on soils from archaeological sites. The quantity of trace metal removed from the soil by a total analysis digestion procedure is much greater than the quantity removed by a dilute acid or a chelate extraction procedure designed to removed soluble and easily labile trace elements that were deposited in the soil and adsorbed on particle surfaces. For interpretation of archaeological data it is the spatial patterns of trace elements which are important, rather than the absolute values (Linderholm & Lundberg, 1994; Entwistle & Abrahams 1997). Bintliff *et al.* (1990) analysed trace metal accumulation in soils near ancient Greek settlements (see Davies' (1978) use of EDTA chelate extraction). They concluded that trace metals accumulate at very significant excess levels on and around ancient sites, and that these patterns can be useful for archaeological prospection and site survey, as well as for reconstructions of land-use histories. However, they caution that many close-spaced soil samples need to be taken in order to evaluate the usefulness of trace metal assay for past land-use intensity. This close-spaced sampling is certainly a necessity for soil studies in ancient Mesoamerica where kitchen gardens, midden zones, and craft activity areas crowded the domestic landscape. Samples spaced too far apart would inevitably lead to undetected features or misinterpretation of the patterns of the distribution of elements.

More recently, Entwistle *et al.* (1998) performed a total elemental analysis of anthrosols from Scottish historical sites by digesting soil samples in nitric and perchloric acid. They employed an array of statistical techniques in their analysis to argue that some soils were enriched with the use of phosphate-bearing organics. Their study underscores the need for the establishment of off-site control soils for comparisons. In addition, they report difficulty with interpreting phosphate levels and their distributions, noting that "[s] oil is effectively a palimpsest, with each successive phase of human activity modifying the soil record" (p.63). This is clearly of concern to archaeologists working in Mesoamerica where sites often represent multiple agricultural occupations, which result in a composite picture of numerous settlement systems superimposed over time.

In Mesoamerica, Barba and colleagues have demonstrated in archaeological (Barba, 1986, 1990; Barba & Denise, 1984) as well as ethnographic (Barba & Bello, 1978; Barba & Ortiz, 1992) situations that stucco floors trap chemical compounds derived from specific activities that are repeatedly performed in a given locale. Combined with other lines of evidence, chemical analyses of stuccos and soils in an apartment compound in the Oztoyahualco district of Teotihuacan (Barba *et al.*, 1987; Barba & Manzanilla, 1987; Manzanilla & Barba, 1990; Ortiz & Barba, 1993; see also Manzanilla, 1996) have helped in the identification of areas for food preparation and food consumption, storage places, refuse zones, sleeping quarters, and spaces for ritual and funerary activities. It must be noted, however, that the residential areas under investigation at Teotihuacan probably represent an unusually good context for chemical studies of this kind due to the exceptional nature of preservation at the site. In contrast to the Teotihuacan context, weathering, root action, and other forms of bioturbation at sites in the Maya lowlands tend to destroy most traces of stucco, often leaving the archaeologist with little more than artifact concentrations and residual soils from which to reconstruct domestic activities. With extensive and consistent sampling (i.e. use of a tightly spaced sampling grid) archaeologists may be able to overcome these challenges. It may also be possible to draw comparisons among different archaeological sites and variant soil environments. We note that this can only be achieved if archaeological reports on soil analyses elaborate on the specific methods employed in a much more detailed manner than has been the case so far.

The Study Area

Piedras Negras is a Classic period (c. AD 250–850) Maya centre located in the western reaches of the Petén jungle on the eastern banks of the Usumacinta River in present-day Guatemala. The site lies on a Cretaceous carbonate rock plateau in a region of tropical semi-evergreen rainforest characterized by a tall broadleaf canopy made up of hardwoods, such as mahogany, ceiba, and cedar and an understory primarily composed of a variety of palm species (Breedlove, 1973; Lundell, 1937; see also Beach & Dunning, 1995). Soils of the site are generally well drained and fertile and consist principally of rendolls which formed from the underlying limestone (Aliphat, 1996).

Investigations at the site in the 1930s by Mason and Satterthwaite (e.g. Mason, 1933; Satterthwaite, 1936, 1943) of the University of Pennsylvania Museum revealed a complex construction sequence of civic and ceremonial structures, as well as a rich epigraphic record from which came Proskouriakoff's (1960) breakthroughs in Maya writing. More recent research, that augments our knowledge of ceramics and caching practices (e.g. Coe, 1959; Holley, 1983), has brought these earlier studies into sharper focus. Although they conducted nearly a decade of investigations, Mason and Satterthwaite invested little energy in probing household areas, with the exception of their work in the V-Group (Satterthwaite, 1954), a residential patio cluster in the southeastern portion of the city. This is understandable given the historical circumstances in the 1930s in which archaeological research was largely shaped by the institutional needs of museums, specifically, to secure impressive and interesting monuments and artifacts for exhibition.

Recent investigations in the 1990s by the Piedras Negras Project, led by Houston and Escobedo (e.g. Escobedo and Houston, eds. 1997, 1998; Houston *et al.*, 1998, 1999), have continued work on monumental buildings, such as the Acropolis, Temple O-13, and the sweatbaths, and also have refocused sampling to include residential areas within the city. To date, excavations in these locations have produced data on household size and composition through the excavation of human burials, production activities revealed by artifact distributions, and residential growth documented by the construction stages of domestic buildings. In addition, attention has been given to land-use and human–environment interactions through a vigorous program of soil analysis. The analysis of soils at Piedras Negras will provide additional lines of evidence to support our interpretations based on excavation and artifact analysis, and will hopefully fill some of the gaps in our knowledge that still persist about domestic activities within the city. In future field seasons, these concerns will also be brought to bear on areas surrounding monumental architecture. Additionally, we are interested in comparing the chemical signatures of garden plots and craft activities in urban zones to those in non-urban (i.e. suburban, rural) contexts. These objectives will contribute crucial information to the broader research questions of the Project that

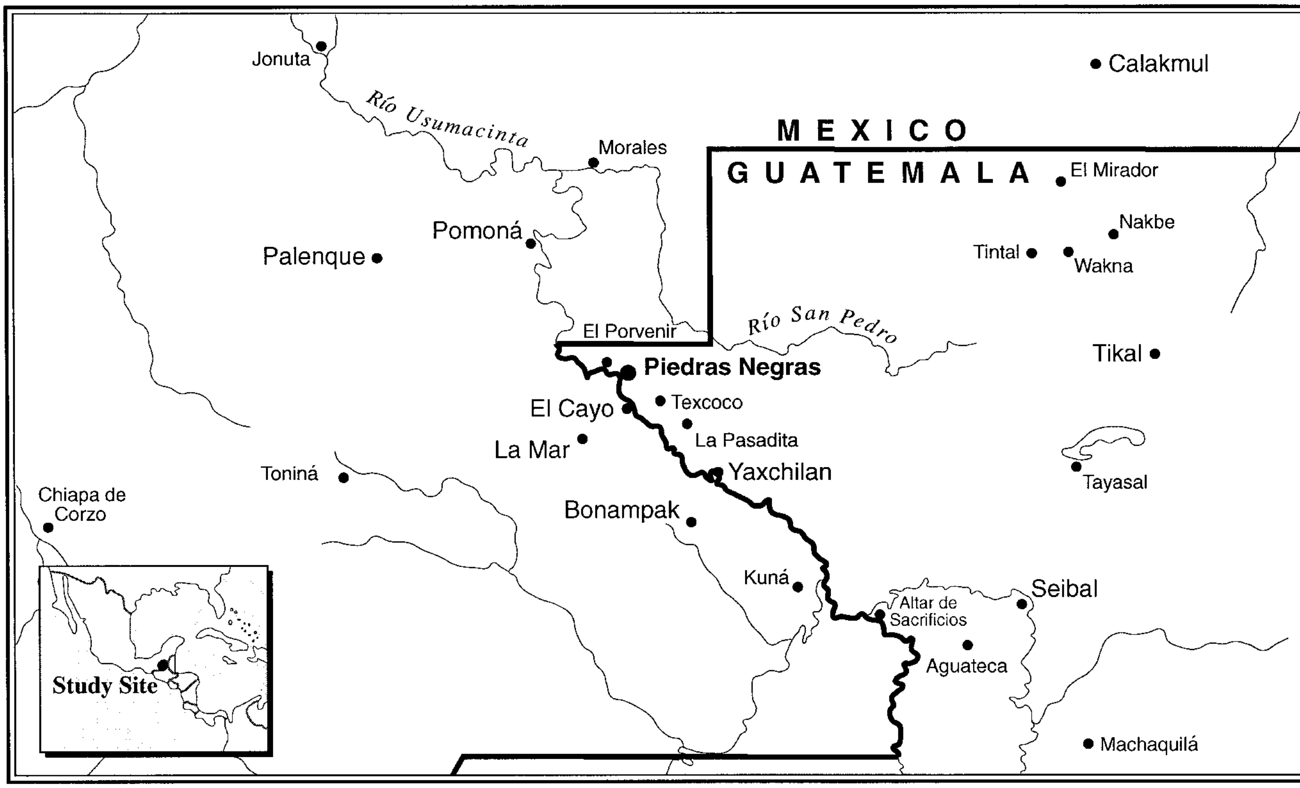

Figure 1. Western Maya Lowlands, showing the location of Piedras Negras.

are concerned with the explosive growth, unusually sustained occupation, and abrupt cessation of urban life at Piedras Negras, all within an area of relative political isolation and geographically broken terrain.

Soil Analysis at Piedras Negras

Our primary objectives in analysing soils from Piedras Negras were: (1) to adapt a simple field test of extractable soil phosphate for use in settlement analysis and in the identification of subsurface features (see Terry *et al.*, 2000; (2) to develop a method of prospection whereby soil phosphate concentration measured in the field before excavation might lead us to alter our excavation sampling strategy; and (3) to use data on the concentrations of phosphates and heavy metals in anthropogenic soil to aid in our interpretations of land-use patterns and domestic activities. To this end, three residential areas in and around the city were selected for study, and over 100 samples were collected and analysed. Operation 10 is located in the O and N sectors of Piedras Negras in the northwestern zone of the city. The residential area is bounded by the great Acropolis on the north, by monumental architecture of the West Group Plaza on the east, and by a steep ravine (see Figure 2). Operation 33 is located in Sector U in the southeastern portion of the city. This residential area is delimited by the South Group Plaza to the west and a steep ravine on all other sides. Operation 38 is located to the north of Piedras Negras, outside the bounds of the dense habitation of the city, in a residential cluster of five structures centrally focused on a shared patio.

Sampling design and analytical procedures

The majority of samples were collected at uniform distances from one another on a regular x/y grid. This sampling was done primarily with the goal of establishing patterns of soil chemical concentrations across patio groups and between house-mounds. For the prospection sampling of Operations 10 and 38 we avoided sampling house-mounds. The sampling grid for the activity areas of Operation 33 conformed to the established excavation grid. The representative sampling included soils collected from pits excavated by archaeologists and suspected midden sites. As the grid samples were collected, we occasionally encountered high concentrations of sherds adjacent to house-mounds. Representative samples were also collected from these suspected middens.

Analysis of Piedras Negras soils was performed in two stages, a preliminary effort in the field and a more tightly controlled analysis in the laboratory. Soil samples were collected prior to and during excavations, and all samples were air-dried and sieved (2 mm). Extractable phosphorus concentrations were determined by the field laboratory procedures described by

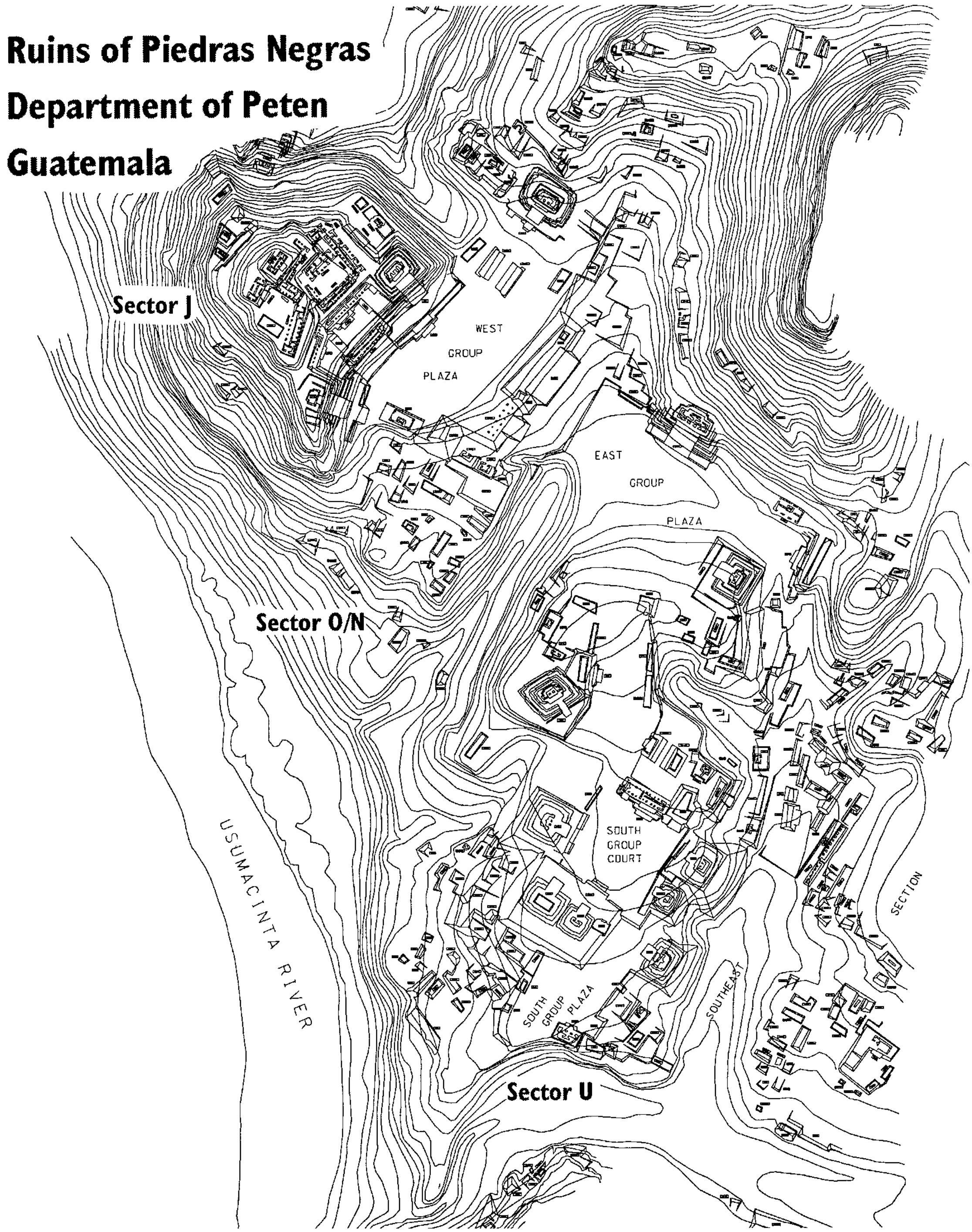

Figure 2. Map of Piedras Negras.

Terry *et al.* (2000), which are derived from the Mehlich II dilute acid extraction technique (Mehlich, 1978). The resultant solution containing the soil was filtered, diluted, and mixed with a PhosVer reagent pillow manufactured by Hach (Loveland, CO). The phosphates in solution reacted with the molybdate and ascorbate chemicals of the PhosVer pillow to develop a blue colour. Using a portable colorimeter, the colour of the solution was then related to the concentration of phosphates in the soil. The percent transmittance was converted to mg/L by standard curve, and appropriate dilution factors were used to convert the concentration values to mg P/kg soil.

Samples were later transported to the Department of Agronomy and Horticulture at Brigham Young University for analysis of heavy metal concentrations

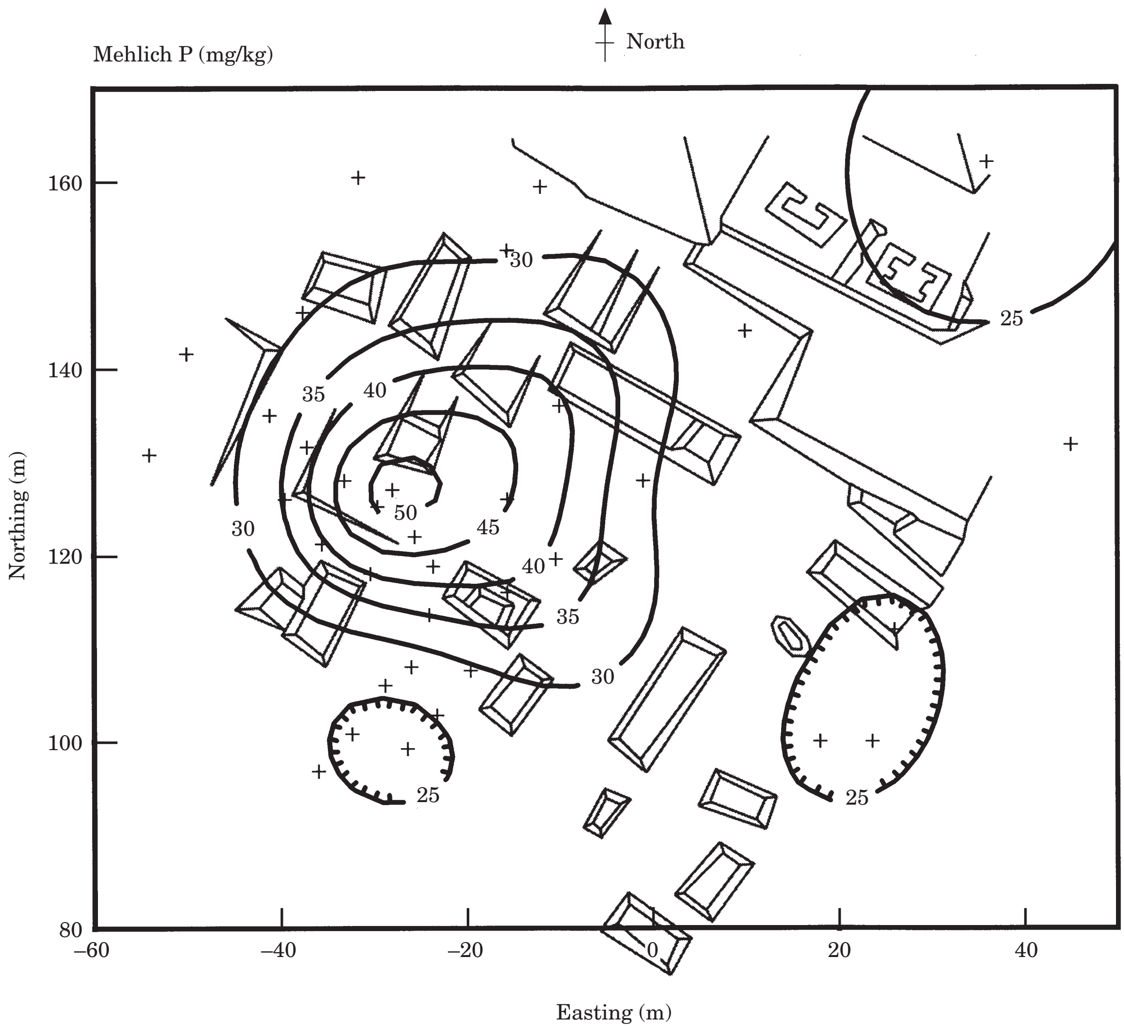

Figure 3. Concentrations and spatial distribution of extractable soil phosphorus (mg/kg) in Operation 10 (O and N sectors) of Piedras Negras.

using the DTPA (diethylenetriaminepentaacetic acid) extraction procedure developed by Lindsay & Norvell (1978). A chelate (DTPA) extraction of the highly calcareous soils and floors of Piedras Negras was appropriate for trace metal analysis because the procedure avoids the complete dissolution of $CaCO_3$, therefore only the trace elements that were deposited in the soil and adsorbed on the surfaces of soil particles were removed. In this procedure, 10 g of soil are mixed with 20 ml of 0·005 M DTPA solution buffered at pH 7·3 to extract the metals from the soil. The samples are then shaken for 2 h, after which the extracting solution is separated from the soil by centrifugation and filtration. For the present analysis, the concentrations of barium (Ba), cadmium (Cd), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), lead (Pb), and zinc (Zn) were determined simultaneously on a Thermo Jarrell Ash ICP spectrometer (see Linderholm & Lundberg, 1994).

Midden characterization

Chemical signatures of middens were characterized by calculating the average extractable element concentrations of replicate surface (0–20 cm) samples from two middens in the N sector (south corner of structure N-6 and the patio of structure N-10) and triplicate samples of a midden in the U sector (narrow terrace of structure U-17). Background levels of extractable elements in the soils of sectors N and U of Piedras Negras were determined by calculating the average of the five lowest elemental concentrations from each sector.

Results: operation 10

Thirty soil samples were collected at evenly spaced locations on platforms, in patios, and in the interspaces between house-mounds of Operation 10 located in the O and N Sectors of Piedras Negras. All samples were collected from the contemporary ground surface to a

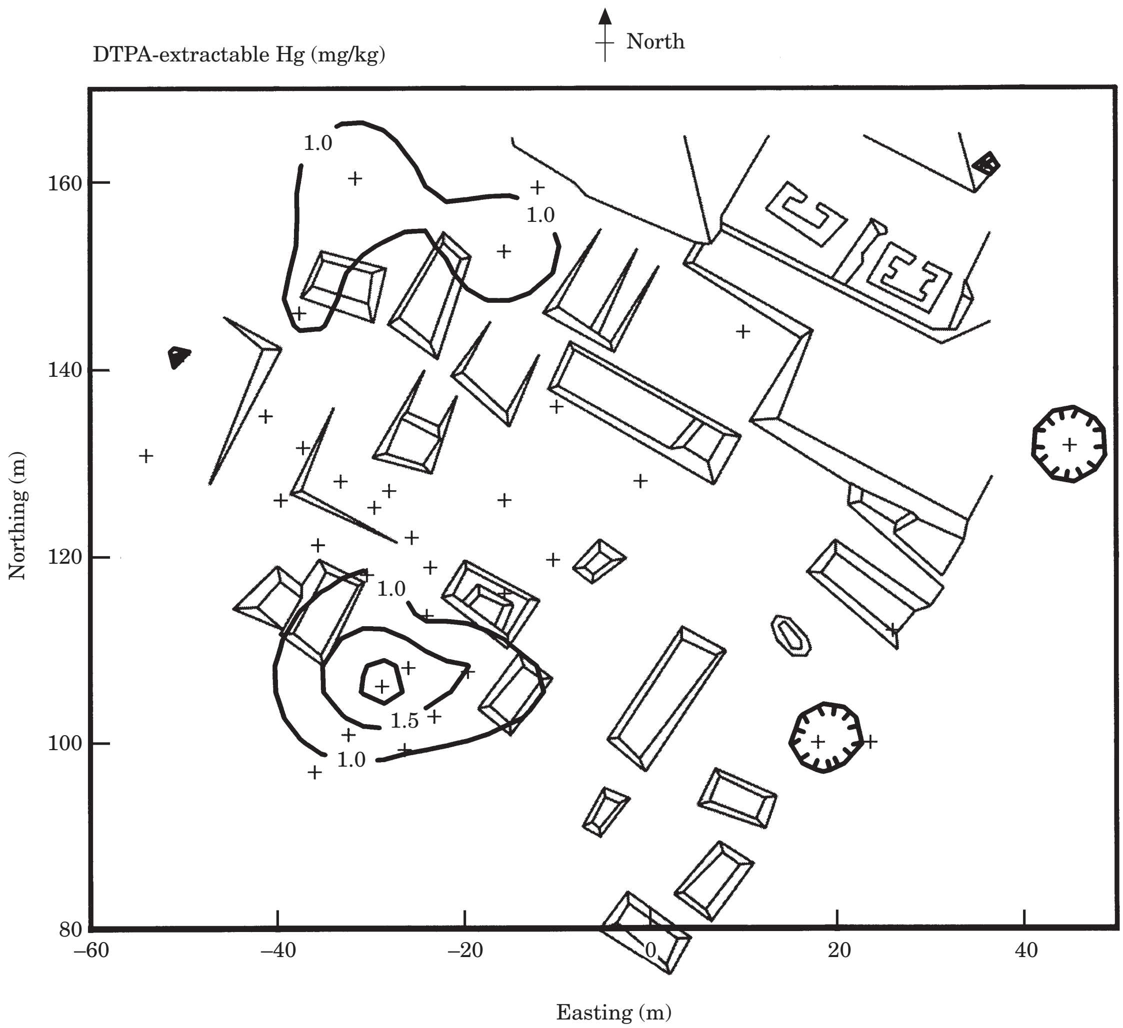

Figure 4. Concentrations and spatial distribution of DTPA extractable Mercury (mg/kg) in Operation 10 of Piedras Negras.

maximum depth of 20 cm. The purpose of this method of sampling was to develop a technique for prospection, that is, to determine areas of high phosphate concentrations that might lead to the identification of middens and areas of food production and consumption.

Chemical analyses of soils in Operation 10 showed two interesting patterns. First, a high phosphate peak (125 mg/kg) was discovered in samples at the southern corner of structure N-6 (Figure 3), relative to background phosphate concentrations in the majority of samples in Operation 10 (20–30 mg/kg). Excavations in this area revealed a sizeable midden, containing nearly 1000 pottery shards from storage jars and serving plates, that probably served as fill for the platform in which it was contained (Urquizú, 1997:82). The high phosphate concentration is an indication of food waste disposal in this midden. The second pattern that we noted was a high mercury peak (2·7 mg/kg compared to 0·4–0·8 mg/kg in the rest of the sector), in the center of the patio dominated by structure N-10 (Figure 4). Phosphorus levels within this same patio were near background levels of 20–30 mg/kg. Excavations within this patio revealed an accumulation of sherds and other debris used as patio fill. The low phosphate level in the midden material suggests that food waste was not disposed at this location. This particular accumulation, a possible royal midden, contained a wide variety of obsidian and chert tool production debris, plainware ceramic jars and bowls, figurines of superb quality that may actually represent kingly portraits, a three-chambered ceramic flute and other musical instruments, and some of the most spectacular polychrome pottery with glyphic inscriptions found at the site. Stephen Houston has translated the glyphs and found that at least two of the vessels record the name, *K'an Ak*, the second ruler of Piedras Negras (accession AD 639, death AD 686). The proximity of house-mounds in the O and N sectors to the Acropolis and the discovery of the royal midden suggest that this area may represent a "service sector" to the king and his court that resided in the palaces (Houston *et al.*, 1998).

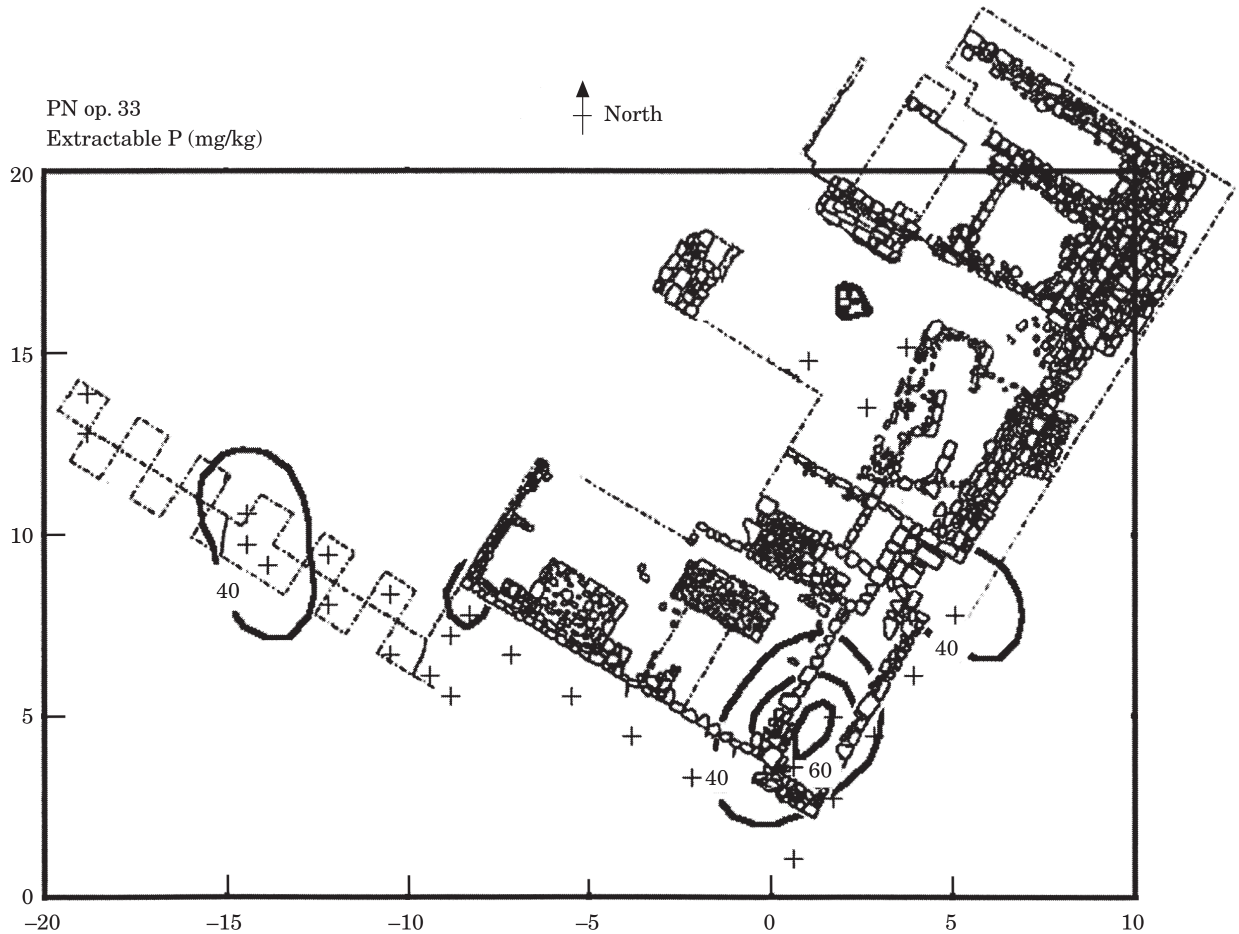

Figure 5. Concentrations and spatial distribution of extractable soil phosphorus (mg/kg) in Operation 33 (U sector) of Piedras Negras.

Chemical analysis of midden materials may prove very useful in identifying the types of debris that accumulated at ancient activity areas. These discoveries underscore the value of soil chemical-based prospection, and will continue to be integrated with our research at Piedras Negras.

Results: Operation 33

Thirty soil samples were collected in Operation 33 (Sector U) for chemical analysis and flotation analysis of macrobotanical specimens. The soil and floor samples were taken from structures, patios, and special deposits (i.e. human burials, dedicatory caches, concentrations of lithic tool manufacturing debris). All samples were collected from the same stratigraphic unit (dated with ceramics to the late facet of the Chacalhaaz Phase, c. AD 780–830), within approximately 10 cm of patio floors and platform surfaces.

Subsequent excavations revealed a group of platforms focused on a central patio and surrounded by open patio space. One of the buildings, structure U-17, supported two benches that are likely to have been in use contemporaneously along with a third bench located on the eastern edge of the central patio. The platform also maintained a narrow terrace on its eastern side where dense concentrations of production debris were encountered (Wells, 1998*a*). Evidence suggests that these activities included the manufacture of obsidian and chert tools, the production of iron pyrite mirrors, maize grinding, and textile working. Phosphate levels from this area (108 mg/kg compared to background levels of 15–30 mg/kg) confirm the presence of an extensive midden filled with the debris of these production activities, unearthed at the southeast corner of the terrace and along its eastern edge (Figure 5).

High concentrations of DTPA extractable heavy metals, particularly Fe (36·0 compared to 5·0 mg/kg; Figure 6), Hg (5·6 compared to 2·0 mg/kg; Figure 7), Mn (27·0 compared to 3·0 mg/kg), and Cu (2·7 compared to 1·0 mg/kg), were found in association with soils at the bases of architecture at the southeast corner of the platform. One possible interpretation is that these patterns represent the residues of paint that once

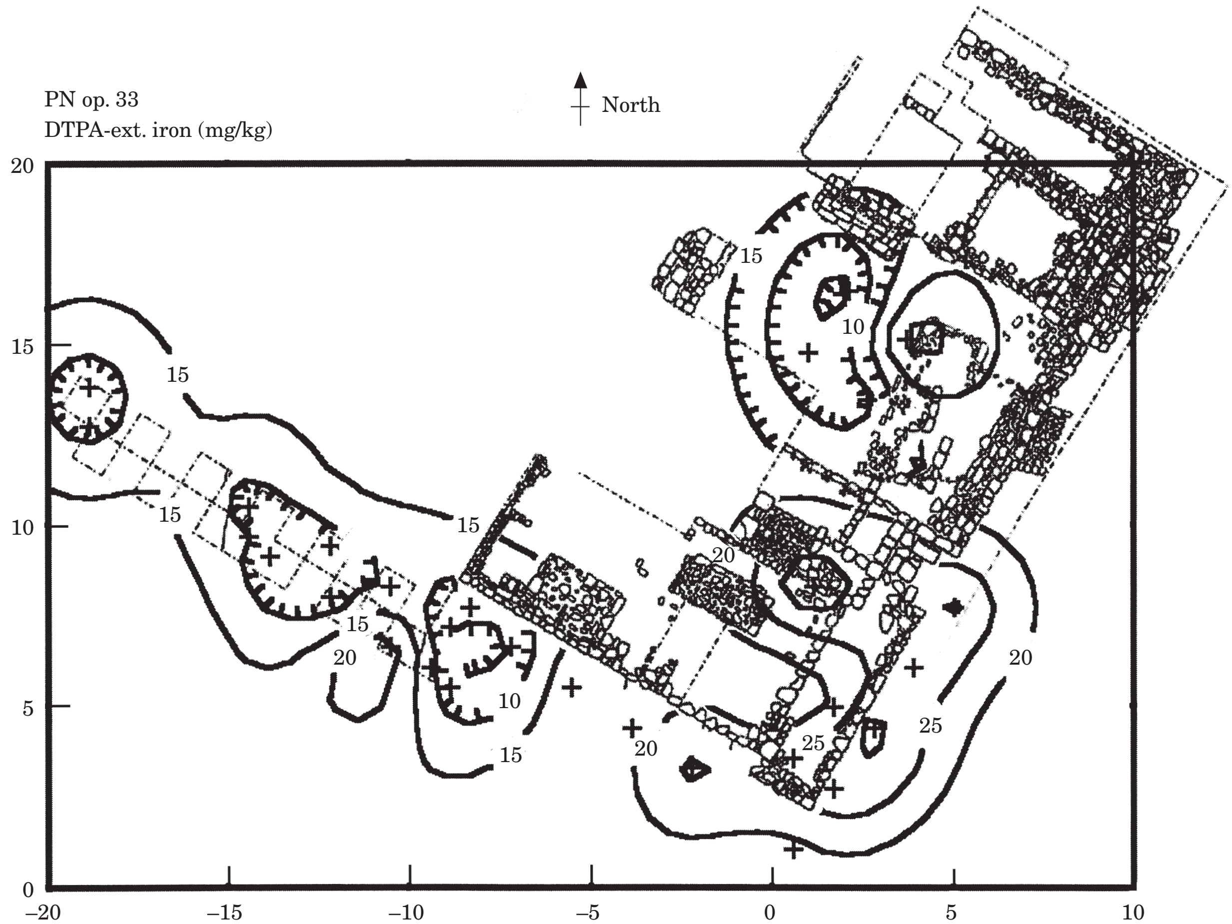

Figure 6. Concentrations and spatial distribution DTPA extractable iron (mg/kg) in Operation 33 of Piedras Negras.

decorated the stucco on these buildings (Wells, 1998*b*), rendering them polychromatic. The inhabitants may have used haematite (iron oxide, Fe_2O_3) and cinnabar (mercuric sulfide, HgS) for reds, pyrolusite (manganese dioxide, MnO_2) for blacks, ochre (hydrated ferric oxide, $Fe_2O_3.H_2O$) for yellows, malachite (copper carbonate, $CuCO_3.Cu(OH)_2$) for greens, and azurite (copper carbonate, $2CuCO_3.Cu(OH)_2$) for blues (see Goffer, 1980:167–173 for a review of pigment chemistry; see also Vásquez and Velázquez, 1996*a*, 1996b for examples). Metal-based pigments may have been preferred over organic-based ones in house painting for their longevity and resistance to climatic conditions (i.e. precipitation, temperature extremes). One way to evaluate this proposition is to compare the compositional data from areas within roughly half a metre of all architecture with data obtained from further away. If the patterns represent paint residuals, then we might expect to find consistent concentrations of heavy metals in soils close to buildings that were painted. Interrupted "patches" of heavy metal concentrations may indicate some other activities, such as the use or manufacture of iron pyrite mirrors, the presence of cached items containing cinnabar, or even the grinding of pigments for use on pottery or other portable media.

Structure U-8 defines the northern edge of the patio group and was most likely a domestic ancestor shrine, attested by the discovery of an adult male interred beneath the building on its central axis (Wells, 1998*a*). A dedicatory cache was unearthed at the base of the structure on its southern side and consisted of three smashed ceramic vessels, one of which was dusted with cinnabar and so probably explains a high peak in our plot of the distribution of Hg (4·8 mg/kg; see Figure 7). As expected, we found low concentrations of phosphorus (22·0 mg/kg; see Figure 5) around this structure, as activities involving the deposition of phosphorus compounds probably would not have taken place in this location. Yet, this does not necessarily accord with the discovery of a number of ceramic sherds from large polychrome serving vessels, perhaps used for holding offerings of food or other organic remains, found on the structure's summit and southern stairway.

The lack of phosphates in this area is a potentially important finding, as it suggests that we may be able to identify "ritual" buildings in domestic contexts by the

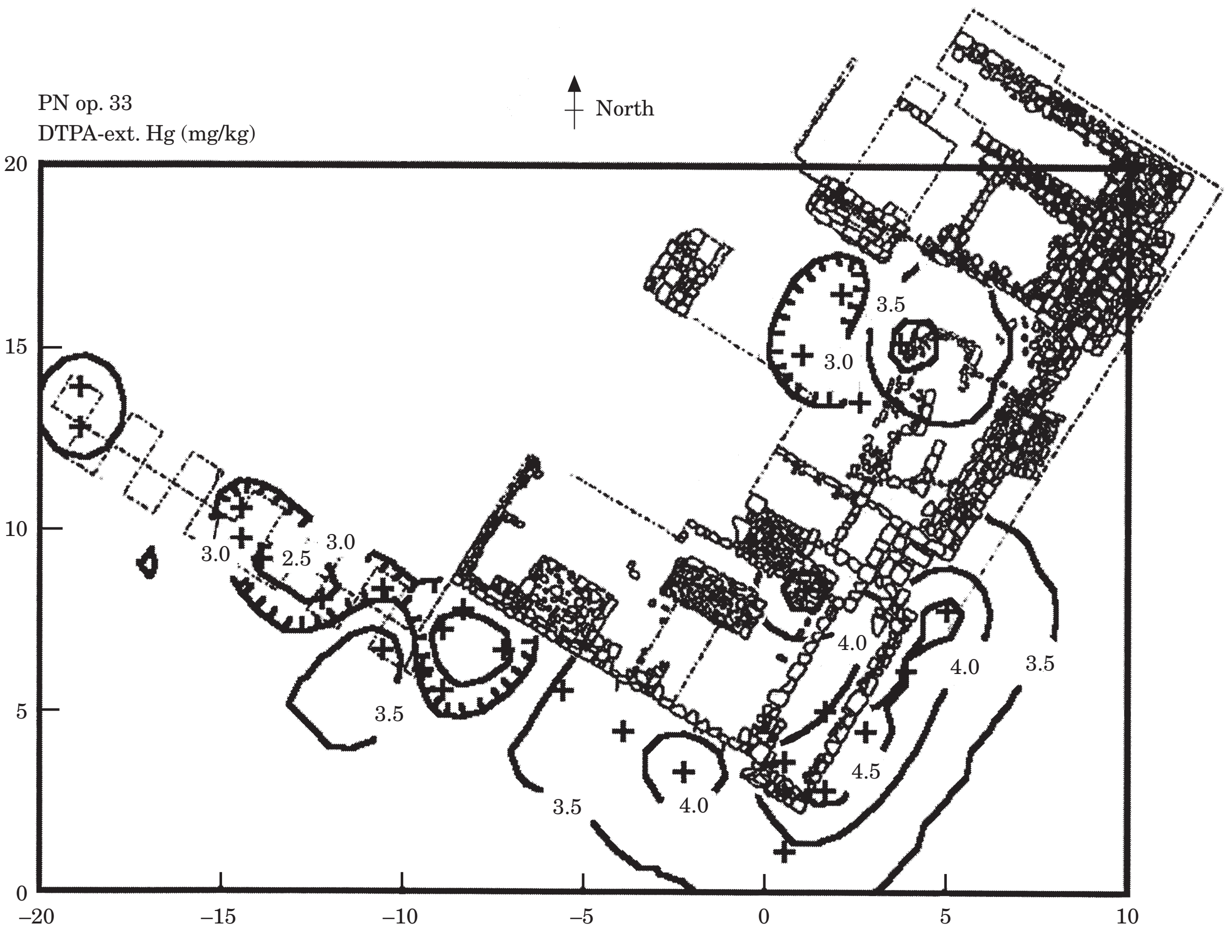

Figure 7. Concentrations and spatial distribution of DTPA extractable mercury (mg/kg) in Operation 33.

absence of phosphates—perhaps a result of repeated sweepings around such buildings. Interestingly, throughout Mesoamerica, sweeping is largely a task done by women (e.g. Vogt, 1970:40–42), with whom this activity has moral undertones. It is possible that women were responsible for maintenance of domestic shrines at Piedras Negras. To be sure, though, sweeping may have been marked in ritual contexts as it is among contemporary Maya groups (Watanabe, 1992:117–126), leading men to perform services normally associated with women.

Results: Operation 38

Fifty soil samples were collected in Operation 38 located north of Piedras Negras for phosphate analysis. The samples were collected at the intersections of a 3-m grid established around the house-mound group. The leaf litter was scraped away and surface soil samples (0–15 cm) were collected.

The prospection revealed two relatively intense peaks of phosphate (4·0 and 5·0 mg/kg compared to background levels of 1·5–2·0 mg/kg) located outside the patio area to the east and to the north (Figure 8). Excavations in these areas confirmed the presence of extensive middens, mostly containing plainware pottery sherds. No further elemental characterizations of the soil were determined. It is interesting to note that the phosphate levels detected in Operation 38 were substantially lower than those detected within the city. The minimum phosphorus concentrations of samples collected within Piedras Negras were in the range of 20–30 mg/kg. The minimum level at Operation 38 was 1·2 mg/kg, and the highest phosphorus peaks in the midden areas were just above 6·0 mg/kg. This demonstrates the effects of hundreds of years of concentrated human activities within the city which increased the levels of phosphate in the soil, compared to outlying residential areas that were likely occupied for shorter periods.

Chemical signatures of middens

The grid-sampling strategy and soil chemical analyses have not only allowed us to prospect for middens, but also have permitted us to begin constructing

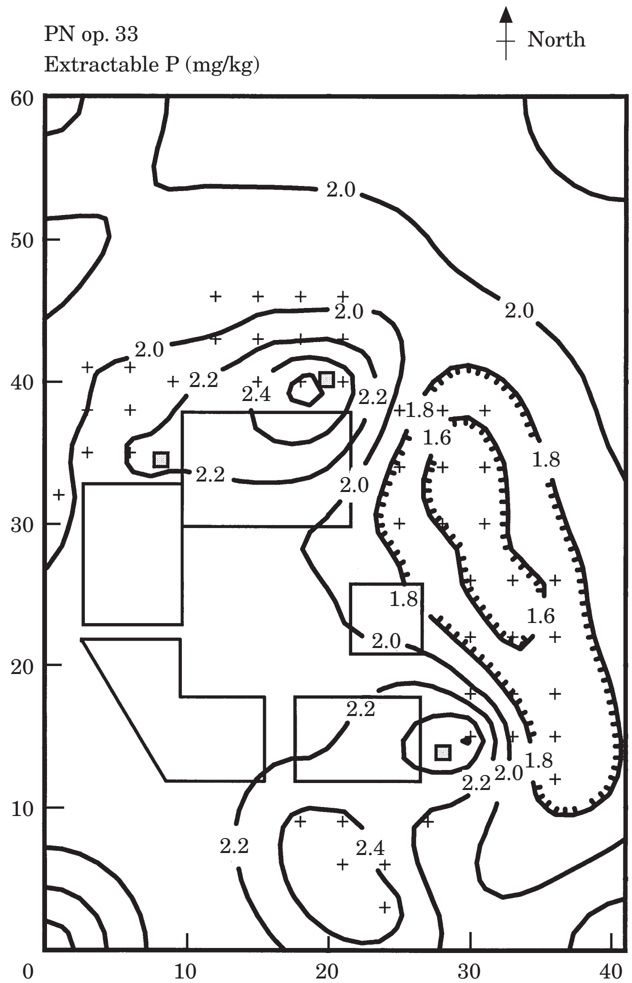

Figure 8. Concentrations and spatial distribution of extractable soil phosphorus (mg/kg) in Operation 38 located outside of Piedras Negras.

ways to characterize different types of middens more accurately and more comprehensively than has ever been done before. The concentration of extractable elements in three middens discovered in our investigations of the N and U sectors, are shown in Table 1. Kitchen waste, high in organic matter, contains significant levels of phosphate. The midden at the corner of structure N-6 is characterized as a kitchen midden with high concentrations of phosphorus and numerous sherds. The royal midden discovered near structure N-10 consisted of trash likely transported from the elite residences of the Acropolis and used as patio fill. The chemical signature of this midden is low in phosphorus and relatively high levels of Mn, Cu, and Hg. The midden at structure U-17 was found on a terrace just below a probable workshop area. This midden is characterized by high concentrations of P, Cu, Fe, Mn, and Hg. The midden likely contains kitchen waste combined with production debris from the work area. Some middens may have been subject to long-term sustained use, versus *ad hoc* casual scatterings. Through additional work in soil analysis and excavation, we envision the development of "midden typologies" that will prove enlightening in our understanding of the residues of domestic, ritual, and civic activities.

Conclusions

The results of our analyses, although preliminary, indicate that soil chemical signatures of midden materials may be very important in decoding the various waste deposits of the ancient Maya. High phosphate concentrations are good indications of kitchen middens, but other types of trash deposits, characterized by relatively high levels of heavy metals, may be indicators of workshop, craft, or ceremonial activities. While phosphate analyses also have been used by archaeologists to measure the degree to which soils in domestic areas were chemically enhanced, leading to the identification of "house-lots" and "kitchen gardens" (e.g. Doolittle, 1992; Killion, 1987; 1992; Santley, 1992), we found no evidence for urban agriculture at the O and N house-mound group (Operation 10). Extractable soil phosphate levels decreased in all directions radiating from the midden at the corner of structure N-6. Elevated phosphorus concentrations near this structure suggest garden sites but the spaces between house-mounds were small.

Heavy metal analyses have informed us that urban Maya domestic structures at Piedras Negras may have been painted, possibly with polychromatic designs and symbols that served as public expressions of local

Table 1. Soil chemical characterization of three middens

Extracted element	Kitchen midden Structure N-6 (mg/kg)	Transport midden Patio N-10 (mg/kg)	Workshop midden Terrace U-17 (mg/kg)	Background (mg/kg)
Phosphorus	80·1	18·5	80·8	19·4
Iron	26	12·5	13·7	12·5
Manganese	24·3	22·9	16·5	9·5
Copper	2·5	4·6	2·3	0·7
Mercury	0·9	2·4	4·5	0·4

identities, such as status, rank, or lineage. This proposition also remains to be tested through a sampling strategy that will focus on soils close to buildings.

It is important to point out that the observations concerning chemical patterning in the soils might have been missed altogether were it not for the excavation methods: broad, horizontal exposures combined with sampling using smaller test units. Our powers of observation, and hence, understanding of domestic activities, in Operations 10 and 38 are hampered by our limited excavations in these areas. Other studies (e.g. Ball and Kelsay, 1992; Lippi, 1988) also have encountered similar difficulties with interpreting chemical signatures based on limited excavation data. Extensive clearing of residential structures coupled with tightly spaced grid-sampling of soils yields a robust database of information on phosphate and heavy metal concentrations necessary for constructing informed interpretations of domestic activities. Also, as previous studies (e.g., Barba & Bello, 1978; Barba & Ortiz, 1992) indicate, additional soil chemistry research in ethnographic settings will undoubtedly prove useful for developing more nuanced sampling strategies, as well as better informed interpretations of chemical patterns. Detailed soil chemical analyses of known activity areas are in progress in our laboratory. These studies include ethnoarchaeological analysis of Maya house lots at Aguateca and Las Pozas in the department of Petén, Guatemala and analysis of known ceremonial and food processing areas preserved beneath volcanic ash at Cerén, El Salvador. We are also processing floor samples from an ancient pyrite mirror workshop at Aguateca (Structure M 8–4).

Clearly we are just beginning to understand the complexity of land use and domestic activity patterning at Piedras Negras. Nevertheless, chemical analyses of anthrosols that combine both organic (i.e. phosphates) and inorganic (i.e. heavy metals) material residues provide a powerful means to reconstruct past human behavior in domestic contexts. Further, interpreting domestic activities and their material patterning in the archaeological record is best addressed by a research design that combines chemical analyses of soils with archaeological data produced from horizontal clearing of residential areas. Additional test-pitting provides a probability sample of the inventory of features not detected in clearing operations. This conjunctive approach offers greater clarity in discerning domestic activity patterns than would be possible with fewer lines of evidence.

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