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Source: *Latin American Antiquity*, Vol. 13, No. 3 (Sep., 2002), pp. 331-342
Published by: Society for American Archaeology
Stable URL: http://www.jstor.org/stable/972114
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SOIL CHEMICAL ANALYSIS OF ANCIENT ACTIVITIES IN CERÉN, EL SALVADOR: A CASE STUDY OF A RAPIDLY ABANDONED SITE

J. Jacob Parnell, Richard E. Terry, and Payson Sheets

Activities performed over long periods of time tend to leave soil chemical residues as evidence of those activities. Some of the questions studied in this paper deal with the interpretive capabilities provided by chemical patterns. Soil samples from Cerén, El Salvador, a well-preserved site, were analyzed for extractable phosphorus and heavy metals. We compared in situ artifacts collected from the site with chemical signatures that indicate activity areas. We found that elevated concentrations of phosphorus were associated with food preparation, consumption, and disposal. Heavy metals were associated with the interior of the structure where pigments and painted gourds were found. In this case, where well-preserved, in situ artifacts were available for analysis, we found that chemical analysis was effective in locating human activity areas. Our findings indicate that chemical analysis can be used to guide interpretation in areas of poor artifact preservation with reasonable accuracy, and in archaeological sites that underwent gradual abandonment.

Actividades realizadas por largos períodos de tiempo tienden a dejar residuos químicos como evidencia de estas actividades. Algunos de los puntos de este estudio se relacionan con la capacidad interpretativa que los patrones químicos proveen. Muestras de suelo de Cerén, El Salvador, un sitio bien preservado, fueron analizadas para obtener fosfatos y metales pesados extraibles en ácido. Comparamos los artefactos recogidos in situ del lugar con los patrones químicos que indican áreas de actividad. Encontramos que las concentraciones elevadas de fosfatos estaban asociadas con preparación, consumo y desecho de alimentos. Los metales pesados estaban asociados con el interior de la estructura donde se encontraron pigmentos y calabazas pintadas. En este caso, cuando bien conservados, los artefactos in situ estaban disponibles para analizar, encontramos que el análisis químico era eficaz para localizar áreas de actividades predetermindas. Nuestros hallazgos indican que el análisis químico puede ser utilizado para guiar la interpretación en áreas donde los artefactos han sido pobremente preservados con una precisión razonable, y en lugares arqueológicos que sufrieron un abandono gradual.

With the development of studies directed toward household groups over the past few decades, the demand for more efficient means of interpreting archaeological evidence and analysis of space-use patterns has grown (Bawden 1982; Bermann 1994; Deetz 1982; Drennan 1988; Manzanilla 1987; Santley and Hirth 1993; Smith 1987; Tringham 1991; Wilk and Ashmore 1988; Wilk and Rathje 1982). There are, however, several difficulties that often hamper the efficient analysis of space-use patterns. Conventional interpretation based exclusively on artifact distribution can often be misleading due to poor preservation or disturbance of artifacts (Manzanilla and Barba 1990). However, unlike traditional artifacts that are easily transported or removed from the actual loci of activity, some chemical signatures are evidence of specific activity and usually become fixed in the soil where the activity took place. Thus, the development of soil chemical analysis provides an essential facet to the analysis of activity areas and space use, particularly in the field of household archaeology (Carr 1984; Kent 1984, 1987, 1990; Kroll and Price 1991). In order to study the role of chemical analysis in Maya household archaeology, we examined the relationship between soil chemical residues and activities through a combination of soil chemical analysis and traditional artifact- and architecture-based research in the well-preserved, rapidly abandoned site of Cerén, El Salvador. Our goal is to gain a more

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Latin American Antiquity, 13(3), 2002, pp. 331–342
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complete understanding of chemical signatures and their association with activity areas.

Theoretical Framework

The underlying premise of soil chemical analyses is that activities performed in the same place over a long period of time leave behind distinct chemical signatures as residues that are trapped in the soil where they remain relatively unaffected over time (Barba and Ortiz 1992; Parnell 2001; Parnell et al. 2002). Unlike moveable artifacts, the spatial pattern of many chemicals fixed in the floor or soil remains relatively intact provided there is minimal disruption of the soil by natural processes or cultural practices.

Past studies involving soil chemical analyses have demonstrated significant interpretive potential in the study of prehistoric land-use and activity patterns (e.g., Ball and Kelsay 1992; Cavanagh et al. 1988; Coultas et al. 1993; Dunning 1993; Lippi 1988; Manzanilla and Barba 1990). Ethnographic studies aimed at the association of specific activities with chemical signatures demonstrate the interpretive value of chemical analysis (Barba and Ortiz 1992; Fernández et al. 2002; Hayden and Cannon 1983; Manzanilla 1996; Smyth 1990). In those studies, chemical data from floor and soil samples collected and analyzed from modern houses were compared with the ethnographic information on space-use and activity patterns. Although soil chemical analysis in archaeology encompasses a wide range of procedures, some of the more promising signatures come from phosphorus and heavy metal analyses (Entwistle et al. 1998; Manzanilla and Barba 1990; Middleton and Price 1996; Parnell 2001; Parnell et al. 2002; Terry et al. 2000; Wells et al. 2000).

Phosphate Analysis

The analysis of soil phosphorus (P) concentrations has a long tradition in archaeological research, and its utility in the study of domestic activities and land use is well established (Dauncey 1952; Proudfoot 1976; Sánchez et al. 1996; Terry et al. 2000; see Bethell and Máté 1989; Craddock et al. 1986; Gurney 1985; Hammond 1983; Scudder et al. 1996 for reviews). The phosphate ion is rapidly fixed by calcium, iron, and aluminum compounds in the soil; therefore, phosphate compounds remain stable in soils for very long periods of time.

The association of phosphate with human activities lies in the organic remains of food waste. Soil phosphate exists in a complex equilibrium of different forms, including inorganic P fixed by aluminum, calcium, and iron compounds; soluble and labile inorganic P; and organic P. Plants obtain their essential phosphate from the soluble and labile inorganic P forms found in the soil. When the plants are harvested and transported, the phosphate is relocated with them in the form of membranes and other cellular structures. As the plants in the form of food waste or fecal materials decompose, the mineralized phosphate is readily fixed on the surface of the soil particles. Eventually the outfield soils, where crops were grown, are depleted of soil phosphorus while the soil phosphorus concentrations of the areas of food preparation, consumption, and waste deposition are augmented. This process of phosphate transport and fixation implies that household gardens fertilized with organic waste would contain increased concentrations of phosphorus while areas of intensive agriculture that did not benefit from the enrichment of decomposing plants or remains would have lower concentrations (Eidt 1984; McManamon 1984; Woods 1977).

Ethnoarchaeological work by Barba and Ortiz (1992) demonstrated that phosphorus levels indeed correlate with known activities. They reported that high concentrations of phosphorus were found in the floors of kitchen and eating areas, while soils of the discard area for maize-soaking water showed moderate levels. Walkway soils exhibited low P concentrations. However, they indicated that further refinement of the methods and interpretation of results was necessary.

Heavy Metals

The past decade has witnessed a growing interest in the detection of trace elements, particularly heavy metals, e.g., copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), lead (Pb), and zinc (Zn) (Bintliff et al. 1990; Entwistle et al. 1998; Lambert et al. 1984; Lewis et al. 1993; Linderholm and Lundberg 1994; Parnell 2001; Parnell et al. 2002; Scudder et al. 1996; Wells et al. 2000). Metals are readily sorbed or precipitated on the mineral surfaces of calcareous soils and stuccos commonly found at Maya archaeological sites.

Activities of the ancient Mesoamericans involved the use of a variety of metal-containing substances. High Fe concentrations in soils could be found in areas associated with ancient *Agave* processing or

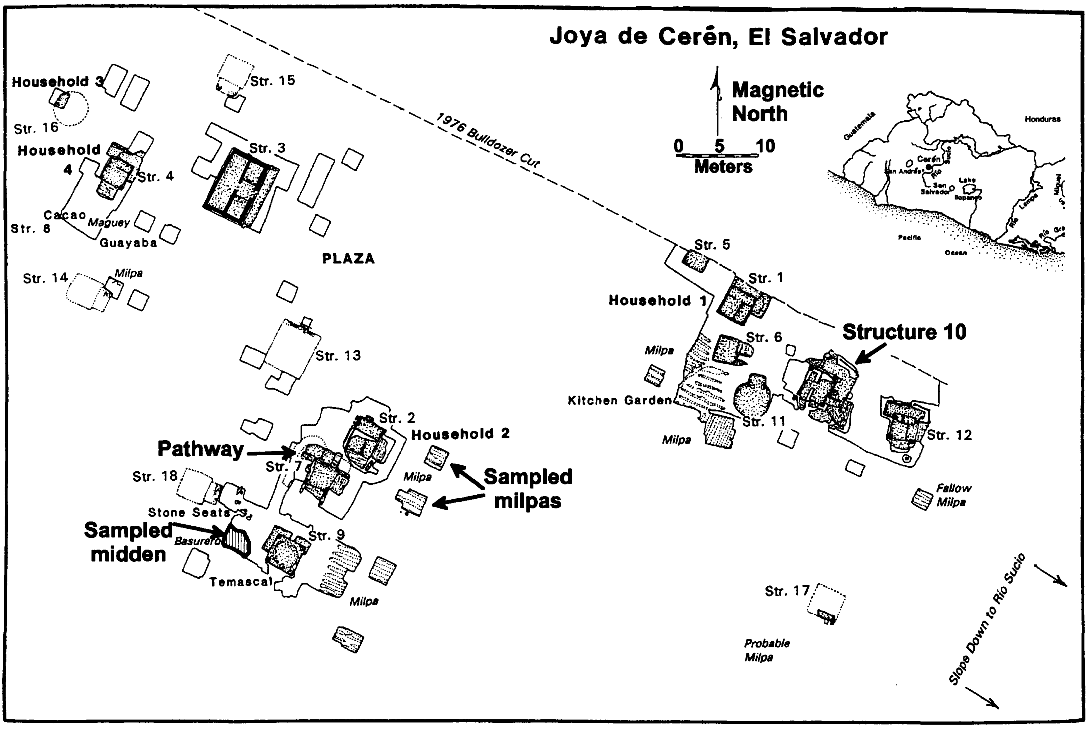

Figure 1. The site of Cerén, El Salvador, and the locations of the midden, pathway, milpas, and Structure 10 sampled for this study.

animal butchering (Manzanilla 1996). Hematite (iron oxide, Fe_2O_3) and iron ochre (hydrated ferric oxide, $Fe_2O_3 \cdot H_2O$) were used in pigments. Cinnabar (mercuric sulfide, HgS) is a bright red mineral that was often used by the Maya as a decorative paint or dye for ritual purposes and is found in ceremonial or sacred areas, such as burials or caches. Additional minerals used as pigments included pyrolusite (manganese dioxide, MnO_2) for blacks, malachite (copper carbonate, $CuCO_3 \cdot Cu[OH]_2$) for greens, and azurite (copper carbonate, $2CuCO_3 \cdot Cu[OH]_2$) for blues (see Goffer 1980:167–173; see also Vázquez and Velázquez 1996a, 1996b for examples). Thus, heavy metal analysis of soils in and around residential and ceremonial architecture will prove useful in identifying areas of pigment processing and ritual activities. The use of heavy metal data in archaeology, however, is still in an incipient stage, and the interpretation of data from the highly calcareous soils and stuccos of lowland Maya sites requires further refinement.

Location

The Precolumbian village of Cerén is located near San Salvador, El Salvador (Figure 1). A deep volcanic ash deposit suddenly entombed the Cerén site in approximately A.D. 600 (Sheets 1979a, 1979b, 1992, 2000; Sheets et al. 1990). Because the ash from the initial eruption of the Laguna Caldera was moist and fine-grained, it preserved even organic materials such as food stored in vessels, thatched roofs, and plants in gardens. The essentially complete preservation of architecture and artifacts in their original loci of storage and use allows for a higher degree of confidence in the reconstruction of activity areas than is usually possible (Brown and Sheets 2001; Sheets 1992, 1994, 2000; Sheets et al. 1990). Chemical residues associated with those activities are also likely to have been well preserved beneath the ash.

Cerén is a United Nations World Heritage Site of great importance because of the degree of artifact and architectural preservation, providing the unusual opportunity to study the behavioral processes that link them (Schiffer 1987; Webster et al. 1997). It is rare that archaeologists have the opportunity to analyze soils associated with known ancient activities. These conditions allowed us to test the efficacy of

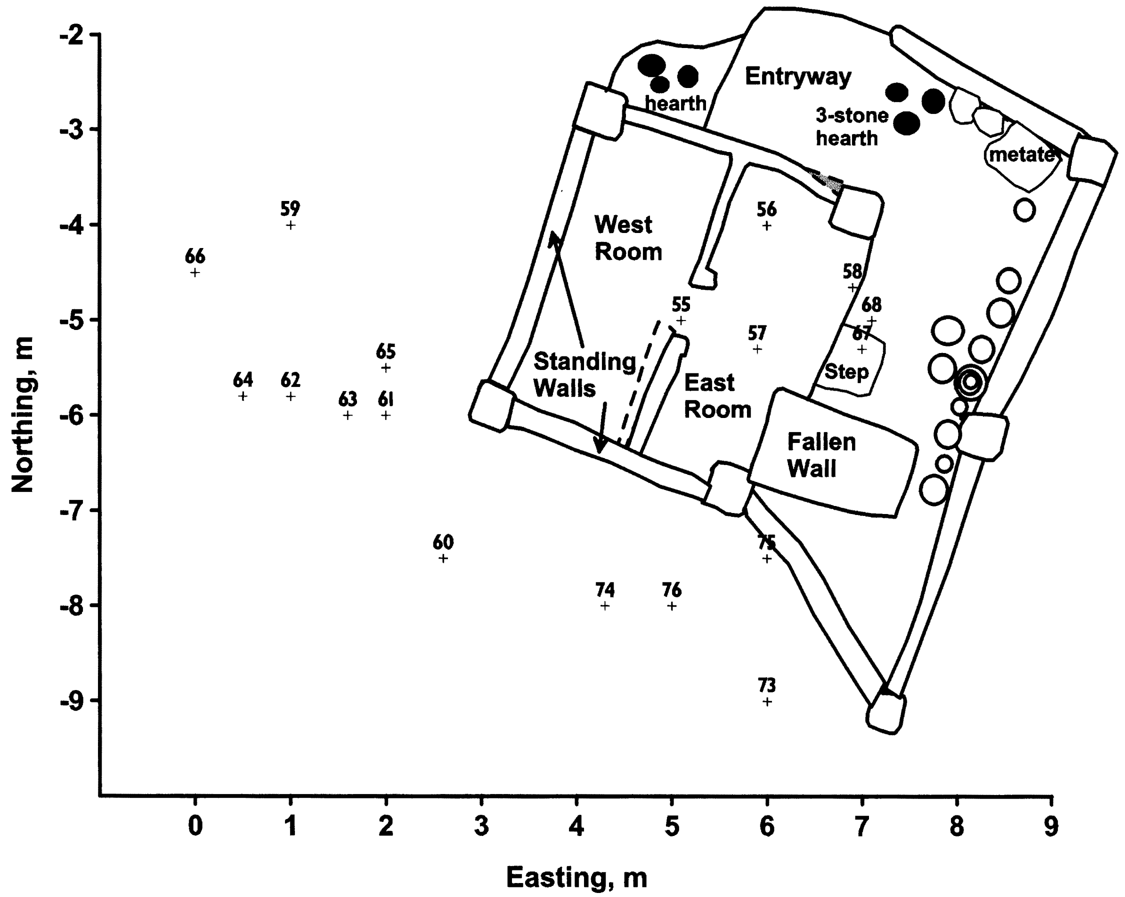

Figure 2. Architecture and floor-contact artifacts of Structure 10 at Cerén. The building consists of two principal rooms (East and West) on an elevated platform, and an entryway and short corridor on the north leading to a large corridor on the east. The corridors were used for temporary food storage, processing, and dispensing to ceremony participants. The sacred artifacts for performances were stored in the East room. Analyzed soil and floor samples are indicated by number.

soil chemical data in the analyses of activity areas and space use.

Sample Collection

At Cerén, the availability of soil samples is limited because of the concern for the preservation of unique earthen structures. Yet, over the past 10 years, soil and floor samples have been collected during excavation for future pollen analysis. The soils of the Cerén site originated from the Tierra Blanca Joven tephra deposit from the great Ilopango eruption that occurred in the early fifth century A.D. (Dull et al. 2001; Sheets 1982; Zier 1992). The sandy soils at Cerén were reported by Olson (1983) to be less than 2.2 percent organic matter and mildly alkaline (pH 7.0 to 7.6). Researchers collected individual surface (0–5 cm) soil samples from areas of confirmed ancient human activity such as milpas (maize fields), pathways between buildings, and from the floor surface (0–.5 cm) of a religious structure used for the production of ceremonials and feasting (Structure 10) in the Precolumbian village (Figure 2). Samples from various depths of a midden near Household 2 were also obtained. The samples were collected during excavations in 1992 and 1993 for future pollen analysis. They represent a limited sample base for soil chemical analysis, but the information that can be gleaned from the samples collected from specific areas of known activities provides a unique view of ancient life.

With the cooperation of the Salvadoran National Museum, 27 soil samples were divided into two portions: one for pollen analysis as originally planned and the other for phosphate and heavy metal analyses. We had hoped to analyze more samples than those that are presented here. However, the earthquake of 1986 damaged the museum sufficiently that collections had to be moved into temporary storage in Santa Tecla, and one unfortunate result was that only a few samples were available to us for analysis. Background soil samples from undisturbed areas were not collected because the extent of human occupation of the ancient land surface is unknown. The average extractable chemical concentrations of the eight samples lowest in phosphate were used to approximate background levels. The eight samples included two each from a milpa and a pathway and four samples outside the west wall of Structure 10.

The soil and floor samples were stored in small paper bags in a clean, dry environment at the museum storage facility until they were subsampled in 1998. The bags remained intact and there was no evidence of water damage or cross-contamination of the samples. All samples were collected with similar metal trowels and stored in paper so that any possible chemical contamination would be the same for all samples.

Chemical Analyses

Extractable Phosphate Procedure

The method of extractable phosphate analysis we used is based on the Mehlich II extraction solution and Hach reagents (Hach Co., Loveland, CO) (Terry et al. 2000). Two grams of air-dried, sieved (<2 mm) floor or soil sample were placed in one of six 50 ml jars attached to a board for facilitation of simultaneous processing of multiple samples. Each soil sample was extracted with 20 ml of the Mehlich II solution for five minutes. The samples were then filtered and the filtrate collected in clean 50 ml jars. One ml of the extract was dispensed to a vial, diluted to 10 ml, and the contents of a PhosVer 3 powder pillow was added to the vial. The sample was shaken by hand for one minute and allowed to stand an additional four minutes for color development. The phosphate in the extract reacts with the contents of the chemical pillow, giving a blue color. More phosphate in the solution results in a darker color. The concentration of phosphorus in the samples is determined on a Hach DR 700 spectrophotometer at a wavelength of 810 nm by comparing the transmittance with a standard curve. A more detailed description of the procedure and justification for its use in archaeological samples can be found in Terry et al. (2000).

Extractable Heavy Metal Analysis

Samples were analyzed for extractable heavy metal concentrations using the DTPA (diethylenetriaminepentaacetic acid) extraction procedure developed by Lindsay and Norvell (1978). In this procedure, 10 g of air-dried, sieved (<2mm) soil is mixed with 20 ml of .005 *M* DTPA solution buffered at pH 7.3 to extract the metals from the soil (Parnell 2001; Parnell et al. 2002). The samples are then shaken for two hours, after which the extracting solution is separated from the soil by centrifugation and filtration. The concentrations of copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), lead (Pb), and zinc (Zn) were determined simultaneously on a Thermo Jarrell Ash inductively coupled plasma atomic emission spectrometer (ICP-AES) (Parnell 2001; Parnell et al. 2002).

Results and Discussion

Phosphorus

The sampled area of highest phosphorus concentration around Cerén Structure 10 probably was associated with refuse disposal (Figure 3). The area to the southeast of the structure may have been used for temporary disposal of refuse and sweepings until the waste could be removed. Feasting and deer-fertility ceremonialism were interrupted by the volcanic eruption that buried the site (Brown and Sheets 2001). Many pottery vessels found in the building still contained food. This structure was used only intermittently for feasting, so we would not expect as great a buildup of phosphorus as a cooking or eating area of a household. The ceramic assemblage at the southeast exterior of the structure was greater in this area than any others tested (Table 1). The samples analyzed from the front of the structure and the floor surfaces inside the rooms were the lowest in phosphorus concentration. These samples were collected from areas that probably would have been well swept of phosphorus-rich organic wastes.

When Structure 10 was being excavated, it was noted that the 30 m^2 to the east and the north of the building were kept clean of artifacts, and the soil surface was particularly flat and well-packed, evidently from a combination of cleaning, surface preparation, and the holding of ceremonial events involving many people (Simmons and Villalobos 1993). In fact, only one large sherd (maximum length over 8 cm) was

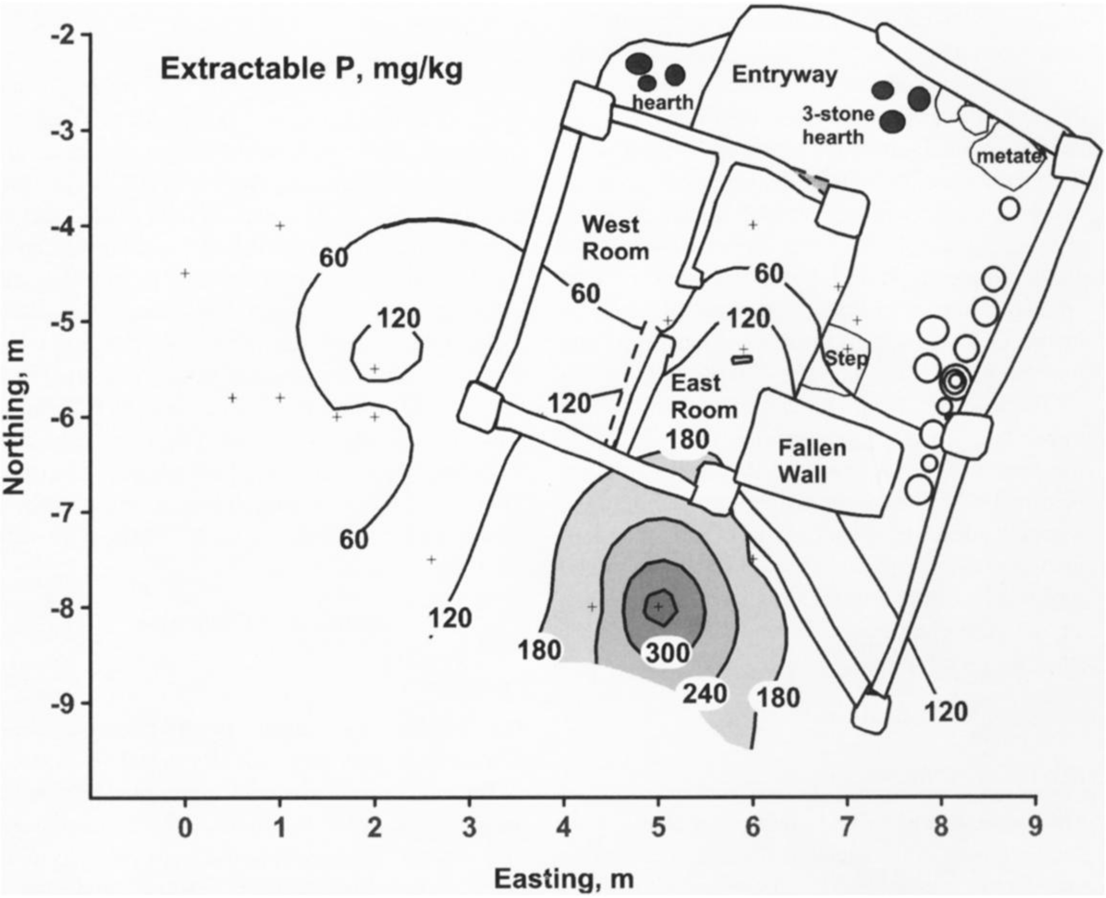

Figure 3. Isopleth lines represent extractable phosphorus (P) concentration (mg/kg) of the floors of Structure 10.

found in that area, in contrast to some 10 large sherds from different vessels found in the 2 m^2 area south of the structure coinciding precisely with the high phosphorus concentration (greater than 300 mg/kg) shown in Figure 3. During the excavations, this area south of Structure 10 was considered to be a provisional discard area for broken pottery, probably thrown over the wall from the east room, or more likely from the food preparation-serving area to the east of that room where most of the pots would have been broken. Much of the area west of the structure was relatively low in phosphorus. Four of the samples (numbers 59, 62, 64, and 66) were less than 24 mg/kg (Table 1). The sherd count of the four excavation units ranged from 0 to 4 per m^2.

Of the milpa, midden, and path samples, we found the highest concentration of extractable phosphorus in the midden, where food and other organic phosphorus-bearing materials would have been disposed (Table 1). The samples from this area contained above 50 mg/kg of extractable phosphorus. We found the lowest concentration of phosphorus in the soil samples from the path (about 5 mg/kg), where constant foot traffic and sweeping of pathways would have prevented an accumulation of phosphorus. Two soil samples taken from the milpa area were also low in extractable phosphorus (about 6 mg/kg). Removal of crops from the milpa would eventually deplete the soil phosphate. The milpa samples were located close to Household 2 but the phosphate data did not provide evidence that the milpa soils were enriched with household wastes. These findings illustrate that the soil is a valuable interpretive resource (Entwistle et al. 1998).

Ethnoarchaeological studies have demonstrated that phosphorus levels indeed correlate with known activities (Barba and Ortiz 1992, Fernández et al. 2002). Study authors reported that high concentrations of phosphorus were found in the floors of kitchen and eating areas, while soils of the discard

Table 1. Artifacts Collected from the Excavation Units and the Concentrations of Extractable Elements from the Soil and Floor Samples.

		Whole				Mehlich mg/kg	DTPA Extractable Elements mg/kg						
Sample	Location	Vessels	Sherds	Obsidian	Organics	P	Ba	Cu	Fe	Hg	Mn	Pb	Zn
55	Doorway between the east and west rooms	3	4	0	fiber, seeds	42	1.27	3.93	8.51	3.72	16.43	2.76	5.37
56	North side of the east room	0	0	0	0	26	.80	5.37	16.98	6.82	107.44	4.44	9.20
57	Center of the east room	3	0	0	1 painted gourd	196	1.03	4.72	9.97	4.11	27.70	2.86	6.51
58	North side of the east room	0	0	0	0	17	2.28	8.83	24.84	10.14	103.20	6.94	4.50
59	Southwest exterior	0	0	0	0	19	.92	2.99	11.33	4.35	30.94	2.91	1.18
60	Southwest exterior	0	1	0	0	98	1.03	3.43	14.63	3.77	17.71	2.99	3.22
61	Southwest exterior	0	4	0	0	21	1.60	2.57	7.40	3.59	14.86	2.86	1.00
62	Southwest exterior	0	3	0	0	15	1.13	2.64	8.46	4.11	27.06	2.92	2.68
63	Southwest exterior	0	6	0	0	57	1.26	3.03	9.13	4.17	34.62	2.86	1.50
64	Southwest exterior	0	4	0	0	24	1.01	3.45	8.87	3.91	26.24	3.49	2.79
65	Southwest exterior	0	2	0	0	159	1.62	3.47	7.02	3.89	19.69	2.88	1.25
66	Southwest exterior	No data	No data	No data	No data	22	.83	2.52	7.77	3.58	23.80	2.55	1.79
67	Step to the east room	2	0	0	0	15	1.57	3.51	9.50	4.52	49.64	2.99	.45
68	East exterior, north of step	2	0	0	0	68	.91	4.49	9.85	3.72	23.82	2.77	.74
73	Southeast exterior	0	16	1	0	181	.95	3.84	14.42	4.13	17.53	3.03	.59
74	Southeast exterior	0	5	0	0	208	1.09	3.85	17.49	4.06	15.79	2.91	.69
75	Southeast exterior	0	5	0	0	171	1.20	3.99	8.98	3.81	16.44	3.02	.61
76	Southeast exterior	0	10	1	0	405	1.03	4.13	13.23	3.91	12.37	3.13	.80
550	Midden 20-25 cm	0	32	0	organic mold, 1	13	1.00	5.83	43.54	5.83	37.78	3.13	1.04
556	Midden 30-35 cm	0	23	1	0	65	.83	3.99	20.76	3.91	15.26	2.40	1.07
559	Midden 35-40 cm	0	9	0	0	54	.91	3.43	15.91	3.19	8.35	2.20	.88
562	Midden 40-45 cm	0	29	0	organic mold, 1	76	.75	4.50	20.40	3.68	11.92	2.83	.92
712	Midden 70-75 cm	0	7	1	organic mold, 4	13	.88	2.27	18.11	3.31	14.02	1.97	.49
2252	Milpa	No data	No data	No data	No data	5	1.26	4.09	11.46	3.79	7.36	2.98	.47
2265	Milpa	No data	No data	No data	No data	6	.81	3.76	9.85	2.70	5.17	2.92	.84
703	Path	0	2	0	organic mold, 3	5	1.52	3.84	18.11	4.76	16.62	3.45	.54
770	Path	0	3	0	0	5	1.86	3.57	13.58	4.22	10.11	2.91	.32
	Average of eight samples[a]					13	1.17	3.36	11.18	3.93	18.41	3.02	1.33

[a] Sample nos. 2252, 2265, 703, 770, 59, 62, 64, and 66.

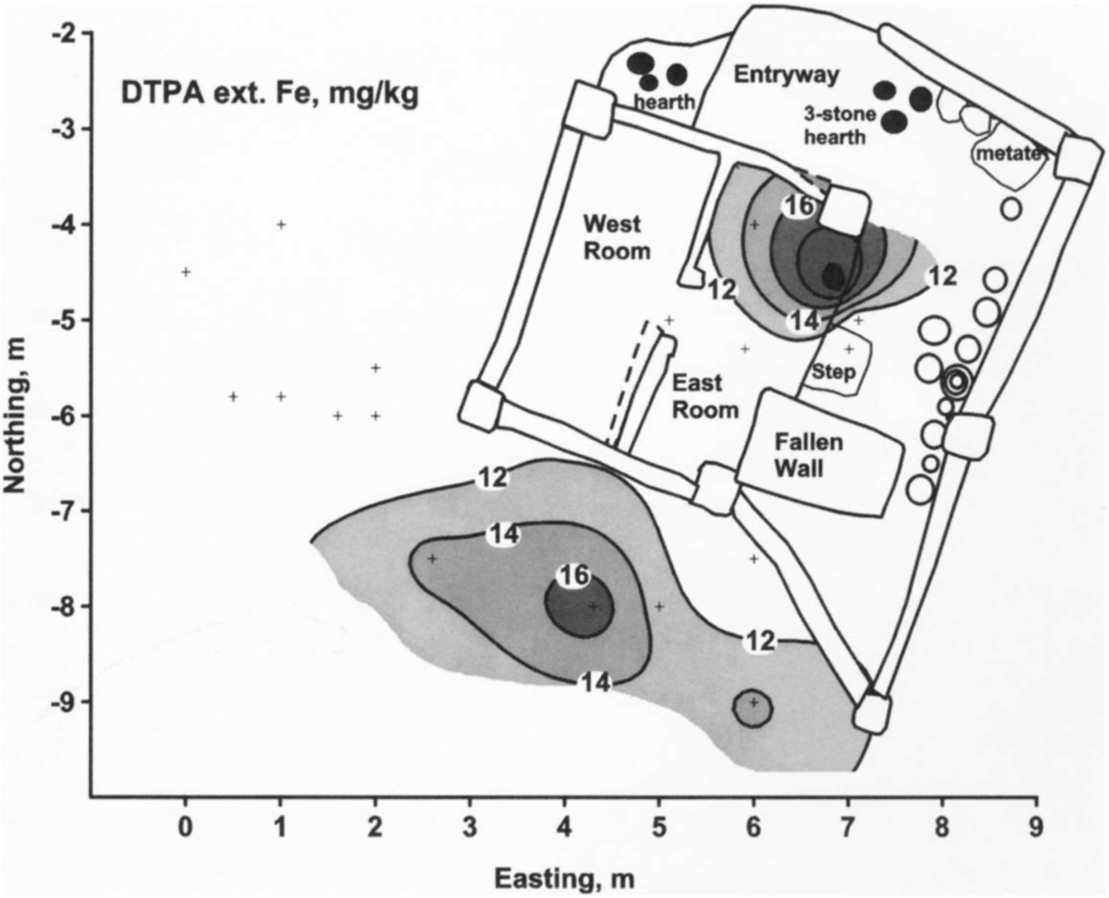

Figure 4. Isopleth lines represent DTPA extractable iron (Fe) concentration (mg/kg) of the floors of Structure 10.

area for maize-soaking water showed moderate levels. Patio and pathway soils exhibited low P concentrations.

Heavy Metals

The highest levels of DTPA extractable iron were found in floor samples from the east room of Structure 10 and from the discard areas just south of the structure (Figure 4). Gerstle (1992) reported that the east face of the internal partition wall between the East and West room was painted red with hematite (iron oxide) paint. In addition, hematite paint was noted on the door jams and the cornices at the top of the partition wall. The abundance of deer bone and antler in the building (Gerstle 1992) indicates that deer must have been butchered somewhere in the site, and iron contained in the discarded blood and tissues may have contributed to iron accumulations. There was also an increased concentration of iron in the provisional discard areas south of the structure.

The iron concentration in the East room of the structure and the approximately equal concentration of iron over the wall to the south of the East room also appear to indicate human activities. Thus, we believe the sources of iron in the soils and floor could have been paints, ceremonial pigments, and wastes from deer butchering and the fashioning of deer artifacts for ceremonial performances in the East room of the building, and provisional discard from that room over the south wall where food and animal butchering wastes were temporarily stored.

The highest concentrations of mercury (Hg) and other heavy metals from the samples collected from Cerén were found in the north end of the East room of Structure 10 (Figure 5) in the same area as the high iron concentration, but more constricted. All three samples from this room had elevated concentrations of copper, mercury, iron, manganese, lead, and zinc. These metals are either associated with pigment compounds or are contaminants in the pigment ores. Arti-

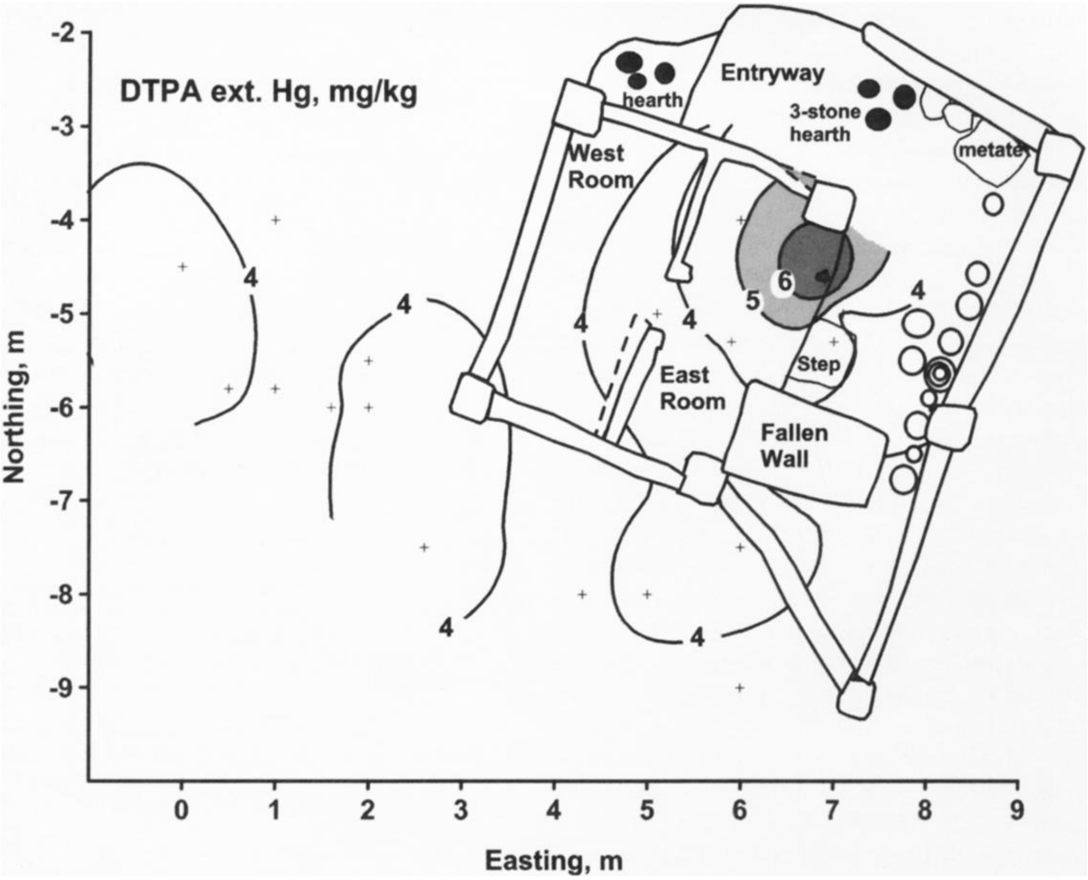

Figure 5. Isopleth lines represent DTPA extractable Mercury (Hg) concentration (mg/kg) of the floors of Structure 10.

facts recovered from this room include a painted deer skull headdress, six pottery vessels including one full of achiote seeds, three painted gourds, and various small bone and stone artifacts (Gerstle 1992). Samples of the painted gourds were examined by X-ray fluorescence at the Smithsonian Center for Materials Research and Education, and the results all indicated hematite (Harriet Beaubien, personal communication 2001). Thus no architectural or artifactual source of the high mercury concentration is clear to us. The mercury probably was introduced as cinnabar (HgS), a red pigment, for painting at that end of the East room. What was being painted is unknown. Clearly, the chemical analysis of samples and the ceremonial artifacts such as elaborately painted vessels, ritual costume accessories, and pigment containers found in the center room indicate the heavy use of pigments (Gerstle 1992).

We compared the heavy metal concentrations of the soil samples from the midden with samples from the milpa and the path. Iron, manganese, and zinc were 1.5 times more concentrated in the midden sample while copper, mercury, and lead levels were about the same or lower (Table 1). This may reflect a heterogeneous disposal of food waste and craft-derived garbage.

Conclusions

Soil chemical analyses of anthropogenic soils and earthen floors served to positively identify areas of ancient activity. Coupled with the analysis of artifacts related to distinct activities, chemical analysis magnifies the interpretive capabilities of household archaeology. Most Maya sites were gradually abandoned and contain few in situ artifacts where they were originally placed. In these situations, soil chemical analyses can provide a powerful tool for archaeologists in the clarification of space use and the types of activity performed. However, the better-known Cerén activity areas have correspondingly diagnostic levels of phosphorus and metals. Particularly striking is the high correspondence of food preparation and serving activities in the eastern corridor of Structure 10 and the high phosphorus just over the southern wall of that enclosure, evidently the provisional discard area for food processing waste and broken pottery. No less striking is the high iron concentration at the northern end of the East room and a corresponding high iron concentration over the south wall of that room. That is interpreted here as ancient storage and use of paints, ceremonial pigments, and wastes from deer butchering or the fashioning of deer artifacts for ceremonial performances. The interpretive potential of ancient activity areas through the use of soil chemical analyses is limited only by our understanding of specific ancient activities. The combination of quantitative soil chemistry data and unusually rich floor assemblages is expected to lead to more detailed views of Classic Maya households than have previously been possible. The development of soil chemical analyses will have significant implications for the future study of households in the Maya area and beyond.

Soil analyses have been widely used in pre-excavation detection of archaeological sites and specific activity areas. We expect that soil chemical residue analysis will also be useful in the study of ceremonial areas, where pigments may have been used and sacrificial blood may have been spilled. In addition, heavy metal analysis can indicate whether some structures, though now eroded, were originally painted, possibly with designs and symbols that served as public expression of local identities, such as status, rank, or lineage (Wells et al. 2000).

Acknowledgments. Funds for this research were graciously provided by the National Science Foundation (# SBR-9974302) and by Brigham Young University. We appreciate the helpful cooperation of CONCULTURA officials in the Salvadoran Ministerio de Educacion, and in particular Arq. Maria Isaura Arauz and Arq. Mercedes Salazar for making accessible the soil samples stored from the Cerén site. We also appreciate the efforts of Andrea Gerstle in taking the samples while she was excavating in and around Structure 10. Brian McKee collected the other samples, and his work is gratefully acknowledged. Thanks go to Eric Jellen and Fabián Fernández for assistance with sample collection and analysis. We also wish to thank Bruce Webb, Director of the Soil and Plant Analysis Laboratory at Brigham Young University. We greatly appreciate the efforts of Harriet Beaubien, Smithsonian Center for Materials Research and Education, in promptly analyzing the three samples from the gourds of Structure 10, in time for us to include her results in this manuscript. Special thanks go to the anonymous reviewers for their help in making this paper better.

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Received June 11, 2001; Accepted March 11, 2002; Revised: April 22, 2002.